PART IX—PORTLAND CEMENT CONCRETE

Section No. **Page No.**

Section 901
Portland Cement Concrete

901.01 GENERAL. This section specifies requirements for portland cement (PC) concrete, including methods and equipment for handling and storing materials, mixing, transporting, and placing concrete.

Fresh concrete is being in a plastic state that has not achieved initial set.

Structural concrete is designated by "Class" and pavement concrete by "Type."

Portland cement concrete shall conform to the requirements of Table 901-3, "Master Proportion Table for Portland Cement Concrete." Fly ash or ground granulated blast-furnace slag (GGBFS) is permitted as a partial replacement for PC in accordance with 901.08.2. All structural class concrete, except minor structure class concrete, requires permeability testing by surface resistivity in accordance with DOTD TR 233.

Provide portland cement concrete from a Department approved mix design, produced from a Department certified plant, and transported in Department certified trucks.

Provide sufficient plant capacity and transporting equipment to ensure delivery at required rates.

Methods of delivery and handling concrete shall facilitate placing with minimum rehandling.

Provide adequately equipped facilities or means for all quality control testing.

Quality assurance requirements shall be as specified in the latest edition of the Department's publications 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. Provide materials conforming to the following subsections:

Portland Cement	1001.01
Blended Hydraulic Cement	1001.02
Masonry Cement and Mortar Cement	1001.03
Portland Blast-Furnace Slag Cement	1001.02
Aggregates	1003.01 & 1003.08
Admixtures	1011.02

Water	1018.01
Fly Ash	1001.04
Ground Granulated Blast-Furnace Slag	1001.05
Microsilica (Silica Fume)	1001.06

Use cement, fly ash**,** ground granulated blast-furnace slag, and microsilica (silica fume) certified by the manufacturer in accordance with current Department procedures.

Maintain accurate records of cement, fly ash, ground granulated blast-furnace slag, and silica fume deliveries and their use. Furnish copies of these records to the engineer in such form as required.

901.03 TRANSPORTATION AND STORAGE OF CEMENTITIOUS MATERIALS. Transport cementitious materials in watertight conveyances and store in separate dry facilities. Reject material that is contaminated, partially set, or contains lumps of caked material.

Do not mix brands, mills, types, grades, or classes unless authorized by the DOTD Materials Engineer Administrator. The engineer may waive this requirement in case of plant breakdown during production to allow concrete, conforming to the requirements of this Section 901, furnished from another plant to finish a placement in progress.

901.04 HANDLING AND STORAGE OF AGGREGATES. Stockpile aggregates so that no detrimental degradation, contamination or segregation of aggregates results. Do not incorporate any foreign material into the aggregates. Provide a positive separation between natural ground and stockpile. Do not intermingle individual stockpiled materials. Do not add material to working faces of the stockpiles during continuous operations. Maintain drainage of stockpiles to control moisture content. Control aggregates to maintain the required gradation. Do not use aggregates that have become segregated or contaminated.

901.05 SAMPLING AND TESTING. Perform sampling and testing in accordance with the Department's "Materials Sampling Manual and Testing Procedures Manual". Furnish necessary materials for testing at no direct pay.

For pumped concrete, sample at the discharge end of pump.

901.06 QUALITY CONTROL OF CONCRETE. The contractor is responsible for quality control of materials during handling, proportioning, mixing, and placing operations, which includes the following:

1. Initial determination and necessary subsequent adjustments in proportioning of materials used to produce the specified concrete;

2. Providing suitable equipment for determination of aggregate gradation, moisture, air content, slump, unit weight, and temperature;

3. Trial mixes as necessary;

4. Testing and analysis of the mix for quality control purposes;

5. The setting of dials, gauges, scales or meters, adjusting batch weights; and accurate batching.

Furnish a Certified Concrete Technician at the plant or job site to make adjustments in batch weights for moisture content, to perform necessary adjustments in proportioning materials, and to perform tests necessary for control of the concrete mix within specification requirements. Do not begin daily plant operations until the Certified Concrete Technician has determined that gradations and batch weight adjustments are within specification limits. The Certified Concrete Technician or the Authorized Concrete Field Tester shall perform the job-site control tests for slump, air content, mix temperature, and then report the documented results to the contractor. The use of an Authorized Concrete Field Tester 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. Personnel with a current ACI Concrete Field Testing Technician Grade I certification qualify as an Authorized Concrete Field Tester.

901.06.1 Mix Design: The Certified Concrete Technician shall submit a proposed concrete mix design on the form provided by the Department showing details for concrete to be furnished. Do not start work until the concrete mix design has been accepted and signed by the District Laboratory Engineer. 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.

Proportion the volume of coarse aggregates in concrete mixes in accordance with Table 901-1 below. This does not apply to mixes for concrete pipe, Types B and D pavement, and minor structure class concrete. Fine aggregate must have fineness Moduli (FM) between 2.20 and 3.00. For an example of proportioning of coarse aggregate, see 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

Nominal Maximum Size of Aggregate, Inches	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	0.52	0.50	0.48	0.46	0.44
1/2	0.61	0.59	0.57	0.55	0.53
3/4	0.68	0.66	0.64	0.62	0.60
1	0.73	0.71	0.69	0.67	0.65
1 1/2	0.77	0.75	0.73	0.71	0.69
2	0.80	0.78	0.76	0.74	0.72
3	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, these volumes may be increased up to 10 percent. For more workable concrete, as may be required for pumping, these volumes may be reduced up to 10 percent.

Proportion aggregates for pavement Types B and D mixes in accordance with 1003. 08.3.

Perform trial mixes to demonstrate the mix's performance and the compatibility of components.

Submit test results for slump, unit weight, air content, set times, and surface resistivity (i.e., permeability) when required. Develop a curve for compressive strength (flexural strength for pavements if required) at 3, 7, 14, and 28 days. All trial mixes, especially those incorporating ASTM C494 Type S admixtures, shall demonstrate their intended specific use and compliance with this section to the District Lab Engineer. Submit these findings to the DOTD Fabrication Engineer for all precast and prestress elements.

Furnish materials to the Department for verification of trial mixes as requested.

The District Laboratory Engineer may waive trial mixes, in writing, for previously accepted mix designs. Waiver of trial mixes does not release the contractor from the responsibility of producing concrete that meets the minimum requirements of the specifications.

Ensure that slumps are within the ranges shown in Table 901-3 when tested in accordance with DOTD TR 207. The Chief Construction Engineer may authorize an increase in maximum slump, without mix segregation, by use of water reducing admixtures. Formulate mixes to produce concrete that,

when molded and cured in accordance with DOTD TR 226 and tested in accordance with DOTD TR 230, show an average compressive strength not less than shown in Table 901-3.

901.06.2 Quality Control Tests: Conduct tests to confirm the mix complies with the accepted mix design. Determine gradation and moisture content of aggregates used in the concrete mixture. Test the mixture at the job site for slump, unit weight, temperature, and air content. Keep mix variations within specified control limits for individual samples. Plot test results for gradation, slump, unit weight, and air content on control charts for individual samples. Submit these control charts to the engineer.

Monitor the mix components (cementitious materials, chemical admixtures, chemical additives, and aggregates) for variations. As cementitious materials and chemical admixture shipments arrive, verify slump, air content, and initial set time by testing at ambient temperatures. Adjust the mix design to rectify any changes, which would adversely affect constructability, concrete placement, or compliance with the specifications. Document the testing to validate component consistency on the control charts. Note conformance or variation in mix parameters (workability, set times, air content, etc.) on the control charts. Provide a copy of the proposed testing plan to the engineer for record. Acceptance of the plan does not relieve the contractor of the responsibility for satisfying specifications.

Select times to obtain control test samples using random number tables in accordance with DOTD S 605 or by random selection. Conform to gradation control limits of aggregates as shown in 1003.08.

Use the Materials Sampling Manual to determine the minimum number of quality control tests for structural and pavement concrete. Take additional test samples as directed for slump, concrete temperature, and air content.

For minor structure concrete only, a Certified Concrete Technician or Authorized Concrete Field Tester will not be required, but 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, determine gradations daily on each stockpile of aggregates. Base all gradation calculations on percent of dry weight. Upon determination of the gradation of each stockpile, mathematically determine the percent of the total aggregates retained based on the proportions of the combined aggregate blend, and check for conformance with Table 1003-19.

For additional QC requirements for Mass Concrete, see 901.12.

901.06.3 Mix Adjustments: It is permissible to adjust the ratio of fine to coarse aggregates of the approved mix design by no more than 5 percent.

Never adjust to materially affect the volume of concrete. For mixtures incorporating the Type B or D gradation, if the proportions of the aggregate sizes used do not satisfy the gradation requirements of 1003.08.3 due to changes in the gradation, adjust the proportions to bring the combined aggregates back within specification limits. These minor adjustments for gradation will not require a new mix design. Ensure that the mix produced is uniform, workable and within the specification limits of Table 901-3. When plant operations do not produce a uniform and workable mix, cease plant operations and take corrective action prior to restart.

When slump, air content, concrete temperature, or gradation measurements, as plotted on control charts, indicate that the mix is not uniform and may fall outside tolerance limits, immediately make adjustments to keep the mix within specified limits. Failure to make proper adjustments or the mix deviates from specification requirements, or the mix is obviously defective, the Department will reject the mix.

Do not change sources of any materials or percentages of cementitious materials, until a new Mix Design form showing the new material or adjusted proportions hasbeen accepted.

901.06.4 Acceptance and Verification for PCCP Types B and D Concrete: Use the Materials Sampling Manual to determine sampling and testing requirements for acceptance and verification for concrete for Types B and D pavements, except as follows:

1. Gradation testing of individual stockpiles for acceptance will not be required.

2. Verification tests, performed by the District Laboratory to assure conformance to the combined aggregate gradation shown in Table 1003-19, are at the frequency of one sample every five days of production.

3. Upon determination of the gradation of each aggregate size sampled, mathematically determine the percent retained based on the dry weight of the total combined aggregates based on the proportions of the combined aggregate blend, and check for conformance with Table 1003-19.

4. If the results of the verification sample indicate that, the combination of aggregates does not meet the requirements of 1003.08.3, re-sample the aggregates, and test again. If the results of the second verification sample indicate that the combination of aggregates does not meet the requirements of 1003.08.3, adjust operations to produce a mix meeting these specifications. The Department will investigate and compare verification results to quality control results, for the same period, to determine appropriate action.

901.07 SUBSTITUTIONS. In accordance with Table 901-2, these are the allowable mixture substitutions.

Table 901-2
Portland Cement Concrete Mixture Substitutions

Structural Class[1]	Substitute
A1	No Substitutions
A2	No Substitutions
A3	No Substitutions
P1	P2, P3
P2	P3,
P3	No Substitutions
S	No Substitutions
MASS(A1)	No Substitutions
MASS(A2)	No Substitutions
MASS(A3)	No Substitutions
Minor Structure Class[1]	
M	A1, B, D
R	A1, B, D
Pavement Type[1, 2]	
B	D
D	B
E	No Substitutions

[1]The substituting mixture shall meet the requirements of Table 901-3 for its class or type. The substituting mix shall meet the strength requirements of the original mix. .
[2]If approved by the engineer, small irregular areas of paving projects using Types B or D concrete may be substituted with Class A1 concrete.

901.08 COMPOSITION OF CONCRETE. Type of cement and composition of concrete shall be in accordance with the requirements of this Section 901 and Table 901-3. For mix designs not conforming to Section 901 or Table 901-3, the approval of the Chief Construction Engineer is required.

901.08.1 Cement: Allowable types of cement are as follows:

Use	Allowable Cement Types
General Construction (Structural Class Concrete and Minor Structure Class Concrete)	Type I and/or II portland cement; Blended Hydraulic Cement Type IL portland lime cement
Concrete Pavement	Type I and/or II portland cement; Blended Hydraulic Cement Type IL portland lime cement Type III portland cement for high early strength (HES) applications only
Prestressed or Precast Concrete	Type I and/or II, or III portland cement; Blended Hydraulic Cement Type IL portland lime cement

901.08.2 Cementitious Material Substitution: For structural classes of concrete, fly ash conforming to 1001.04 and GGBFS conforming to 1001.05 may be partially substituted for portland cement on a pound for pound basis. For purposes of cement material substitution with fly ash and slag, do not treat Type IL cement as blended.

A binary concrete mix is one that combines portland cement and one additional cementitious replacement, e.g., GGBFS or fly ash (class C or F).

A ternary concrete mix is one that combines portland cement with two additional cementitious replacements, e.g., GGBFS and fly ash (class C or F) or fly ash (both class C and F).

The maximum substitution rate for binary mixtures is 30 percent fly ash or 50 percent GGBFS.

The maximum substitution rate for ternary mixtures containing Type I, II, III, or 1L portland cement is 70 percent of cement. When using Type IP or IS portland cement, the maximum substitution rate for ternary mixtures is 40 percent. Ternary combinations using both class C and F fly ash are allowable. When using fly ash ternary mixtures, replace portland cement with class C and class F fly ash in equal amounts. When using combinations of GGBFS and fly ash, the amount of GGBFS must be equal to or greater than the amount of fly ash.

For pavement types of concrete (Types B and D), the maximum substitution rate for ternary mixtures is limited to 50 percent of cement and for binary mixtures is 30 percent fly ash or 50 percent GGBFS.

The use of Type III portland cement outside of the specified allowances for precast, prestress, and specified HES pavements requires the approval of the Chief Construction Engineer.

901.08.3 Chemical Admixtures: Only use admixtures complying with 1011.02, or listed on the Approved Materials List.

Use an air-entraining admixture in all concrete. Test the total air content of the concrete in accordance with DOTD TR 202, and meet the requirements specified in Table 901-3.

Use set-retarding admixtures in an amount sufficient to produce the necessary retardation. Consider the influence of different materials and job conditions, including local weather on setting characteristics.

Include the amount of water incorporated in admixtures as a part of required mixing water.

Follow manufacturer's recommendations for adding and mixing high range water reducers (HRWR, superplasticizer) to the mix.

When using multiple admixtures, ensure the same company manufactures all the admixtures, and they are all compatible.

901.08.4 Water: Ensure that the total amount of water in the mixture, including admixtures and free water, does not exceed the maximum water- cementitious ratio specified in Table 901-3. Free water includes all water entering the mix with the aggregates, except water absorbed by the aggregate.

901.08.5 Aggregates: Ensure that all aggregates for use in portland cement concrete meet the requirements of 1003.01.

901.08.5.1 Fine Aggregates: Ensure that fine aggregates, except for combined gradations for Types B and D, comply with the requirements of 1003.08.1.

901.08.5.2 Coarse Aggregates: Ensure that coarse aggregates, except for combined gradations for Types B and D, are the grade specified in Table 901-3 and comply with the requirements of 1003.08.2. In concrete for bridge decks, use coarse aggregates with a friction rating of I, II, or III in accordance with 1003.01.2.4.

901.08.5.3 Aggregates for Types B and D Gradations: Ensure that combined aggregate gradations comply with the requirements of 1003.08.3.

901.09 EQUIPMENT. Provide sufficient plant capacity and transporting equipment to ensure delivery at the required rate. Ensure that the rate of delivery provides for proper handling, placing and finishing of concrete and maintains a workable surface. Ensure that methods of delivering and

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

901.09.1 Plant Equipment: Ensure that batch plants include approved storage, weigh hoppers, and measuring devices. Properly seal and vent equipment to minimize contamination, dusting and loss of material. Ensure uniform distribution of the incorporated materials.

Provide adequate water supply and a device for automatically controlling the amount of water used in each batch.

Provide communication between the concrete batcher and loader operator.

901.09.1.1 Direct-Fill Elevating Weigh Hoppers: For plants using direct-fill elevating weigh hoppers, use computer controlled lights as an indicator of aggregate weights, but not as the sole means of control for aggregate proportioning. Provide means of control so that, as approaching the quantity desired in the weigh hopper, material may be added slowly and shut off with precision. Ensure that weigh hoppers eliminate accumulation of materials and discharges completely. Make provisions for removal of overloads.

901.09.1.2 Storage Bins and Silos: For plants with storage bins, ensure that the bins have adequate separate compartments for each size of aggregate. Design each compartment to discharge efficiently and freely. Provide a means of control so that, as approaching the quantity desired in the weigh hopper, material may be added slowly and shut off with precision.

Ensure that silos are weatherproof, sealed, free of holes, and prevent contamination. Ensure complete separation for each cementitious material. Design silos to freely discharge and equip with vibrators and/or aerators to maintain flow of material and prevent accumulation. Provide silos with a positive means of shut off without leaking into the weigh hopper.

901.09.1.3 Measuring Devices: Equip batch plants to proportion materials by approved weighing/metering devices. Moisture probes are allowed to determine the moisture content of aggregates for batch adjustment, provided the accuracy is within 0.5 percent of the results obtained by the Certified Concrete Technician in accordance with DOTD TR 106 and confirmed by the engineer.

Use separate scale systems: one for aggregates, and another for cementitious materials. Weigh each size of aggregate from separate bins either individually or cumulatively. Weighing each cementitious material cumulatively in the same hopper is allowable but measure the weight of the cement first before other cementitious materials.

Ensure that weigh hoppers eliminate accumulation of materials and discharge completely. Make provisions for removal of overloads.

Ensure that scales are 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, ensure that poises are lockable into any position to prevent accidental change of position, and the weigh beam and a telltale device is in view of the operator. Plant measuring devices shall be subject to approval by the Department. They shall be tested, inspected, and certified every 90-calendar days by a qualified independent scale service or the Weights and Measures Division of the Louisiana Department of Agriculture and Forestry at no direct cost to the Department and more frequently when the engineer deems it necessary to assure their accuracy. A qualified independent scale service or the Weights and Measures Division of the Louisiana Department of Agriculture and Forestry shall certify the plant's laboratory-measuring devices annually at no direct cost to the Department.

Batch individual aggregates within 2 percent, and the cumulative total weight of aggregates within 1 percent of the required weight.

Ensure that cementitious materials are within 1 percent of the required weight. For smaller batches of 1 to 3 cubic yards, the quantity of cement and cumulative quantity of cementitious materials shall be neither less than the required amount nor more than 4 percent in excess. Cement in standard bags need not be weighed; however, furnish in full bag increments and adjust the quantities of other materials accordingly. Do not use bagged fly ash or GGBFS.

Measure the mixing water by volume or weight. Ensure that water measuring devices are accurate to 1 percent at 1/2 the maximum allowable water per batch and the maximum graduation is 1 gallon.

Use approved methods and equipment for adding admixtures into the batch. Measure the quantity of admixtures with an accuracy of 3 percent. Provide a separate dispensing device for each admixture.

901.09.1.4 Batch Tickets: Certified concrete plants may be equipped with an approved automatic ticket printer system for recording required batching information. Enter actual weights of material batched each time on the Batch Certification Report or an approved electronic document. When an automatic ticket printer system is not used, determine quantities and batching information by visual observation. The contractor's authorized representative shall record these quantities on the Batch Certification Report.

Ensure that the approved ticket printer system is tamper-proof and prints 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 printer breakdown, determine quantities by visual observation and certify as stated above.

Ensure that all records of batches show batch number, day, month, year, and time of day to the nearest minute for each batch. Record any added water on the Batch Certification Report Provide to the engineer, a legible copy of all batch records identified with lot number and mix design number.

901.09.2 Hauling Equipment: Ensure that hauling equipment is watertight and capable of discharging concrete at a controlled rate without segregation.

901.09.2.1 Truck Mixer: Provide revolving-drum truck mixers, equipped with tanks for carrying any additional portion of the mixing water and capable of dispensing to the nearest gallon. Replace pick-up and throw-over blades in the mixing drum when worn beyond the limit recommended by the manufacturer. Have available a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth.

Equip truck mixers with electrically or mechanically actuated revolution counters. Locate counters to provide safe and convenient inspection.

In a prominent place, attach to each truck mixer a metal plate on which is plainly marked the maximum rated capacity of the drum in terms of concrete volume and rotation speed for both agitating and mixing speeds.

901.09.2.2 Agitator Hauling Equipment: Furnish agitators with blades or paddles to effectively agitate the mix and prevent segregation. Provide covers when directed.

Attach to each agitator in a prominent place, a metal plate on which is plainly marked the designed uses for the equipment, the maximum rated capacity in terms of concrete volume, and agitation speed.

901.09.2.3 Non-Agitator Hauling Equipment: Ensure that the bodies of non-agitating hauling equipment are clean, smooth, metal, and mortar-tight containers. Provide covers when directed.

901.09.3 Portable (Volumetric) Mixers: Provide portable mixers with a minimum capacity of one cubic yard and capable of accurately and uniformly mixing and discharging concrete without segregation.

901.10 BATCHING AND MIXING. Thoroughly mix concrete in a mixer of an approved size and type, which will ensure uniform distribution of materials throughout the mix.

Do not use mixers with worn blades or excessive build-up. Replace pick-up and throw-over blades or mixing paddles in the mixing drum or mixing unit when worn beyond the limit recommended by the manufacturer. Have available a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth.

Begin mixing operations within 15 minutes after addition of cement to the aggregates. When there is an interruption to the mixing operations, thoroughly clean the mixer. Remove the entire contents of the mixer from the drum before placing materials for a succeeding batch. Add a portion of mixing water in advance of cement and aggregates. Do not use a mixer having a rated capacity of less than one cubic yard or charge a mixer in excess of its rated capacity. The minimum size batch shall be one cubic yard.

901.10.1 Central Plant and Site Mixing: Mix concrete until uniformity is achieved but not less than 60 seconds. Mixing time begins after all materials are in the mixer. Mixing time ends when the discharge chute opens. Ensure that the mixer is equipped with an approved timing device, which automatically locks the discharge lever when charging the drum and releases it at the end of the mixing period. During mixing, operate the mixer at its designed drum speed as shown on the manufacturer's nameplate on the mixer.

901.10.2 Truck Mixing: In accordance with 901.09, measure aggregates and cementitious materials for concrete and charge into the drum at the proportioning plant.

Ensure that the size of the batch does not exceed the maximum rated mixing capacity as stated by the manufacturer and stamped on a metal plate on the mixer. When using a truck mixer for complete mixing, mix each batch at designated mixing speed until uniformity is achieved, but not less than 70 revolutions. Ensure that all materials, including mixing water, are in the mixer drum before actuating the revolution counter or taking an initial reading. Ensure that any additional revolutions during transit are at the designated agitating speed.

Add a minimum of 75 percent of the prescribed amount of batch water at the plant. If the slump is low at the jobsite, add up to the “maximum water that can be added at jobsite” as indicated on the Batch Certification form. Ensure that water added at the jobsite does not exceed the maximum allowable water-cementitious material ratio or exceed the maximum allowable slump by more than 1/4 inch. Reject the load if these criteria are exceeded. Add water and/or admixtures at the job site in one or two increments with additional mixing within the range of 20 to 30 revolutions at designated mixer speed for each increment.

When adding to a partial load, add only a proportional amount of water or admixtures. Follow the manufacturer's recommendations when adding and mixing admixtures to the mix.

Perform slump, air, temperature, and unit weight tests, and mold cylinders after the addition of all components into the mix.

901.10.3 Partial Mixing at Central Plant (Shrink Mixing): When partially mixing at a central plant, reduce the mixing time to a minimum of 30 seconds. Complete required mixing in a truck mixer at mixing speed until uniformity is achieved but not less than 10 revolutions.

901.10.4 Time Limitations: Ensure that the maximum time from the addition of cement to the mix to final placement of the concrete is 90 minutes or a maximum of 300 revolutions, whichever occurs first. When transport is by non-agitator truck, ensure that the maximum time from the addition of cement to the mix to final placement of the concrete is 45 minutes. The engineer may reduce the maximum allowable time for any observed conditions contributing to rapid loss of plasticity or uniformity of the concrete.

For special applications, the stated time limitations may be modified based on trial batch results.

901.10.5 Hauling Equipment: Transport fresh concrete in a truck mixer, agitator, or other certified equipment. Non-agitator trucks are only allowed for pavement concrete. Ensure that the volume of mixed concrete transported in an agitator truck at agitation speed is in accordance with the manufacturer's specified rating.

901.10.6 Portable Mixing: Obtain written approval from the Chief Construction Engineer to use portable or volumetric mixers for PCCP patching and minor structure concrete.

901.10.7 Delivery: Provide sufficient plant capacity and transporting equipment to ensure delivery at the required rate. Ensure that methods and rate of delivery and handling of concrete facilitate placement, without damage to the structure or fresh concrete.

901.11 WEATHER AND TEMPERATURE LIMITATIONS. Concrete used in precast/prestress structural elements may be exempt from the following temperature limitations at the determination of the Construction Fabrication Engineer.

Prepare for rain and hot or cold weather concrete placement well in advance of these events.

The contractor is responsible for proper mixing, placing, and curing of all concrete. At no cost to the Department, remove and replace any unacceptable concrete as determined by the Department.

901.11.1 Cold Weather Limitations: Do not place concrete when the internal temperature of the concrete is below 45°F nor on frozen subgrade or into forms that are below 32°F.

901.11.1.1 PC Mixes: Discontinue concreting operations when a descending air temperature at the jobsite, in the shade, and away from artificial heat, reaches 35°F or NOAA forecasts the temperature to be less than 32°F within the 24-hour period following placement. Do not resume PC concreting operations until an ascending air temperature at the jobsite, in the shade, and away from artificial heat, reaches 32°F; provided the high temperature forecasted by NOAA is above 35°F and remains above 32°F for a minimum of 24 hours.

901.11.1.2 Binary Mixes: Discontinue concreting operations when a descending air temperature at the jobsite, in the shade, and away from artificial heat, reaches 40°F or NOAA forecasts the temperature to be less than 35°F within the 36-hour period following placement. Do not resume concreting operations until an ascending air temperature at the jobsite, in the shade, and away from artificial heat, reaches 40°F; provided the high temperature forecasted by NOAA is above 45°F and remains above 40°F for a minimum of 36 hours.

901.11.1.3 Ternary Mixes: Discontinue concreting operations when a descending air temperature at the jobsite, in the shade, and away from artificial heat, reaches 45°F or NOAA forecasts the temperature to be less than 40°F within the 48-hour period following placement. Do not resume concreting operations until an ascending air temperature at the jobsite, in the shade, and away from artificial heat, reaches 45°F; provided the high temperature forecasted by NOAA is above 50°F and remains above 45°F for a minimum of 48 hours.

Written authorization from the Chief Construction Engineer is required for all concrete operations outside these cold weather limitations.

901.11.2 Hot Weather Limitations: During hot weather concreting, it is critical to reduce the evaporation rate from concrete to minimize plastic shrinkage cracking by having an appropriate concrete mix design, placement methods, and curing operations. Furthermore, additional moisture loss precautions may be essential when other environmental conditions (i.e. relative humidity, air temperature, and wind velocity) accelerate water evaporation from the concrete.

Hot weather limitations commence when the internal temperature of the concrete during placement, exceeds 85°F. If these conditions exist, maintain an internal concrete placement temperature less than 90ºF or submit concrete trial-batch test results for the concrete mix designs conforming to the requirements for production during hot weather conditions.

The hot weather trial-batch acceptance criteria shall meet the following requirements:

1. Maintain a minimum internal concrete temperature of 94°F throughout the trial-batching process.

2. After initial mixing, hold the trial batch in the mixer for 90 minutes. During this period, turn the drum intermittently for 30 seconds every five minutes. In between the intermittent turning of the drum, cover the drum opening with an impermeable cover to prevent moisture loss and to maintain heat. At the end of the 90-minute period, remix the trial batch a minimum of one minute and then test for slump and air content.

3. After completion of a 90-minute mixing period, ensure that the trial-batch has the desired workability, with slump and air content within the specified range as shown in Table 901-3. Allow the addition of water if the slump is below the target range but do not exceed the maximum water-to-cementitious material ratio. Remix a minimum of two minutes after addition of second water. Furthermore, ensure that concrete temperature is not less than 94°F at any time during the trial batch testing.

Concrete placed at a temperature exceeding 90ºF that fails to meet the hot weather trial-batch acceptance criteria shall be removed and replaced at no cost to the Department.

The contractor is responsible for proper mixing, placing, and curing of concrete as determined by the Department.

Regardless of any hot weather precaution taken, reject all concrete attaining an internal temperature in excess of 99ºF during placement.

901.11.3 Rain Protection: Prior to any concreting operations, have available at the jobsite sufficient plastic sheeting material to prevent rainwater from marring or leaving indentations in any fresh concrete.

Lap sections of plastic sheeting a minimum of 18 inches and extend coverage beyond edges so that edges are not marred by falling rainwater. Secure plastic sheeting so that it will remain in place to protect the surface. As soon as conditions permit, reapply all curing compound washed away by the rain. Repair all areas of tining or surface finishing marred by rain or plastic sheeting coverage. Repair all rain-damaged areas at no cost to the Department.

901.12 MASS CONCRETE.

901.12.1 Description: Mass concrete is defined as a structural concrete placement having a least dimension of 48 inches or greater, or if designated on the plans or in the project specifications as being mass concrete. Structural Class S concrete is exempt from mass concrete requirements.

901.12.2 General: Submit proposals for the mass concrete mix design, analysis, temperature monitoring, and control, including insulation and methods, to the Department for review and acceptance a minimum of 30 days prior to the placement of any mass concrete.

901.12.3 Materials: The structural class designation for mass concrete is Class MASS (A1, A2, or A3) as shown in Table 901-3.

901.12.3.1 Cement/Cementitious Combination: Use Type II portland cement. Replace portland cement with fly ash at 20 percent to 50 percent by weight or replace with slag cement at 50 percent to 70 percent by weight or a ternary mix meeting specification requirements. Certify that the cementitious combination generates a heat of hydration of not more than 70 calories/gram at 7 days as determined by ASTM C186 or ASTM C1702.

901.12.3.2 Aggregates: Use Type B or D aggregate gradation for mass concrete. See 1003.08.3.

901.12.3.3 Admixtures: Do not use accelerating admixtures in mass concrete.

901.12.4 Construction: Produce a structure free from thermal cracks. Place mass concrete continuously to eliminate cold joints.

Control differential temperatures by appropriate use of insulated forms, curing blankets, or other acceptable methods.

If during the first 48 hours after placement, the temperature differential nears 35ºF, take corrective measures immediately to remain within the limits. Furthermore, revise the plan to maintain the limits on differential temperature on any remaining placements of mass concrete. Obtain the engineer's acceptance of the revised plan prior to implementation.

Strength gain and cooling of the mass concrete placements can take a long time. Take all such time and strength considerations into account when planning construction activities.

901.12.4.1 Analysis and Monitoring: Submit an analysis to the engineer of the projected thermal developments within the mass concrete elements for the anticipated concrete and ambient temperatures, along with the proposed mix design and construction methods. Include a copy of model results, with site and element specific data, and any electronic files. Describe the measures and procedures intended to maintain, monitor, and control the

temperature differential between the interior and exterior of the mass concrete elements. A maximum temperature during curing of 160ºF and a maximum differential temperature of 35°F is allowed. An abbreviated submittal may be allowed for previously approved mass concrete mix designs.

901.12.4.2 Monitoring Devices: Provide temperature-monitoring devices to record temperature development between the interior and the exterior of the element at points acceptable to the engineer. Monitor a minimum of two independent sets of interior and exterior points for each element to provide redundancy. Locate the monitoring points at the geometric center of the element for the interior point and two inches from the surface along the shortest line from the geometric center to the nearest surface of the element for the exterior point.

Monitoring devices shall be automatic sensing and recording instruments that record information at a maximum interval of one hour. Calibrate monitoring devices to the manufacture's recommendations. These devices shall operate within the temperature range of 0 to 180ºF with an accuracy of ± 2ºF. Take readings and record the temperature data at intervals no greater than 6 hours to ensure that the automatic devices are working properly and that the temperatures are within allowable limits. The intervals of one and six hours shall begin immediately after casting is complete and shall continue until the maximum temperature differential is reached and begins to drop. Transmit these readings to the engineer daily.

Prior to the placement of mass concrete, perform a test of the automatic and manual thermal sensing and recording equipment to ensure they are operational.

901.12.5 Payment for Mass Concrete: Materials, labor, equipment, and incidental items associated with mass concrete and controlling the heat of hydration are paid for under Section 805.

901.13 ACCEPTANCE AND PAYMENT SCHEDULES. Acceptance and payment schedules in Table 901-4 and Table 901-6 apply to all cast-in-place structural portland cement concrete. Table 901-6 applies to Classes P1, P2, and P3; whereas, Table 901-4 does not apply. Acceptance and payment schedules in Table 901-5 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.

Table 901-3[12]
Master Proportion Table for Portland Cement Concrete

	Average Compressive Strength, psi at 28 days	Grade of Coarse Aggregate[1]	Surface Resistivity[2] (kΩ-cm)	Maximum Water/Cementitious Ratio, lb/lb	Air Content (Percent by volume)[3]	Slump Range [5], inches		
						Non-Vibrated[4]	Vibrated	Slip Form Paving [6]
Structural Class [7]								
A1	4,500	57M, 67, 89M[9], B,D	22	0.45	2 - 7	2-5	2-4 [4]	N/A
A2	6,500 [11]	57M, 67, 89M[9], B,D	22[11]	0.45	2 - 7	2-5	2-4 [4]	N/A
A3	9,000 [11]	57M, 67, 89M[9], B,D	22[11]	0.36	2 - 7	2-5	2-4 [4]	N/A
P1	6,000 [8]	57M, 67, 89M[9], B,D	22	0.44	2 - 7	N/A	2-6 [10]	N/A
P2	8,500 [8]	57M, 67, 89M[9], B,D	22	0.40	2 - 7	N/A	2-6 [10]	N/A
P3	10,000 [8]	57M, 67, 89M[9], B,D	22	0.40	2 - 7	N/A	2-6 [10]	N/A
S	4,500	B, D	22	0.53	2 - 7	6-8	N/A	N/A
MASS(A1)	4,500	B, D	22	0.53	2 - 7	N/A	2-4 [4]	N/A
MASS(A2)	6,500 [11]	B, D	22[11]	0.46	2 - 7	N/A	2-4 [4]	N/A
MASS(A3)	9,000 [11]	B, D	22[11]	0.36	2 - 7	N/A	2-4 [4]	N/A
Minor Structure Class [7]								
M	3,000	57M, 67, 89M[9], B,D	N/A	0.56	2 - 7	2-5	2-4 [4]	1-2.5
R	1,800	57M, 67, B, D	N/A	0.70	2 - 7	2-5	2-4 [4]	N/A
Pavement Type [7]								
B	4,000	B, D	N/A	0.53	2 - 7	N/A	2-4	1-2.5
D	4,000	B, D	N/A	0.53	2 - 7	N/A	2-4	1-2.5
E	4,000	57M, 67, 89M[9], B,D	N/A	0.40	2 - 7	N/A	2-4	1-2.5

N/A – Not Applicable

[1] Combined aggregate gradation shall comply with the requirements of 1003.08.2.

[2] Value based on a 4-inch X 8-inch cylinder tested at 28 days of age.

[3] See 901.08.3.

[4] Allow an 8-inch maximum slump if water reducers are used.

[5] Additional allowance in slump range to be approved by the Chief Construction Engineer.

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

[7] See 901.08.1 for allowable types of cement.

[8] Values shown represent the minimum compressive strengths allowed for all test cylinders.

[9] Grade 89M coarse aggregate shall be used only when specified or permitted.

[10] No more than 2-inch slump differential for any design placement. Allow 8-inch maximum slump if water reducers are used.

[11] Average Compressive Strength, psi and Resistivity (kΩ-cm) at 56 days.

[12] Dry-cast concrete for concrete pipe is exempt from Table 901-3. See Section 1016 specifications.

Table 901-4
Acceptance and Payment Schedules
Cast-In-Place Structural Concrete

Average Compressive Strength per Lot, psi (28 to 31 days: A1 Mixes) (56 to 59 days: A2 & A3 Mixes)	
Class A1, S & MASS (A1)	**Percent of Contract Unit Price[1]**
4500 & above	100
4301 - 4499	98
4000 - 4300	90
below 4000	50 or remove and replace[2]
Class A2 & MASS (A2)	
6500 & above 6301 - 6499	100
6000 - 6300	98
Below 6000	90 50 or remove and replace[2]
Class A3 & MASS (A3)	
9000 & above	100
8801 - 8999	98
8500 - 8800	90
Below 8500	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 805.11. The value for each cubic yard required will be assessed at $350 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 the specified strength a prompt investigation will be made. If concrete is allowed to remain in place by the Chief Engineer, payment will be based on 50 percent of the contract price unless associated cylinders were improperly molded or tested and investigative core strength results are above design strength (f'c). If concrete is not allowed to remain in place, the identifiable deficient areas shall be removed and replaced at no direct pay.

Table 901-5
Acceptance and Payment Schedules
Cast-In-Place Minor Structure Concrete

Average Compressive Strength, psi (28 to 31 days)		
Class M	Class R	Percent of Contract Price [1]
3000 & Above Below 3000	1800 & Above Below 1800	100 50 or remove and replace [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 of concrete required will be assessed at $350 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 for Class M, and 1,800 psi for Class R, an investigation will be made. If concrete is allowed to remain in place by the Chief Engineer, payment will be based on 50 percent of the contract price.

Any cores obtained in these investigations are for evaluation purposes only. Payment is based on original acceptance samples.

Table 901-6
Acceptance and Payment Schedules
Structural Concrete

Surface Resistivity per Lot, kΩ-cm (28 to 31 days: A1 Mixes) (56 to 59 days: A2 & A3 Mixes)	
Class A1, A2, A3, S, P1, P2, P3, S & MASS(A1,A2,A3)	Percent of Contract Price
22.0 & above	100
20.0 - 21.9	98
18.0 - 19.9	90
below 18.0	50 or remove and replace[1]

[1]When the average surface resistivity is less than 18.0 kΩ - cm, an investigation will be made. If concrete is allowed to remain in place by the Chief Engineer, payment will be based on 50 percent of the contract price. Any cores obtained in these investigations are for evaluation purposes only. Payment will be based on original acceptance samples.