

Concrete Pavement and Flatwork Specification

Part 1. Concrete Quality Control

1.1 Description

This section describes the approval of materials and contractor quality control requirements for class I and class II concrete items.

1.2 Approval of Materials

1.2.1 General

Provide materials conforming to the contract. Use materials the contract specifies unless the engineer authorizes substitutions. Monitor construction operations to identify potential nonconforming materials and prevent their incorporation into the work.

All materials are subject to the engineer's approval before incorporation into the work. The engineer may inspect or test all materials at any time during their preparation, storage, and use. Notify the engineer of the proposed source of materials before delivering those materials to the project site.

Materials or components demonstrated to conform to the contract will be approved. Approval will be based on conformance with the contract as close as it is practical to the point of incorporation into the work. Material approval is based primarily on the engineer's tests, contractor's tests, or tests the manufacturer performs and certifies.

Conform to manufacturer recommended procedures for products incorporated into the work unless the contract specifies otherwise. Provide copies of those procedures if the engineer requests. The contractor may request approval of alternate procedures.

Approval of materials or components does not constitute acceptance of the work incorporating those materials or components.

1.2.2 Approved Products Lists

The WisDOT maintains product acceptability lists and other lists of approved products and approved manufacturers or suppliers. The WisDOT includes products on these lists based on the results of prior testing and a satisfactory performance history on WisDOT projects. The WisDOT approved products list can be viewed at:

<http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm>

Retesting or re-inspection of products located on the WisDOT approved products list may occur after delivery to the project site to verify that they conform to the contract. A product is nonconforming if verification test results indicate the product does not meet the requirements.

1.2.3 Approval by Certification

1.2.3.1 General

For manufactured products or assemblies, approval may be based on a product certification.

1.2.3.2 Product Certifications

For manufactured products or assemblies, the engineer may accept a certified report of test or analysis, or a certificate of compliance instead of performing tests on samples. Provide a copy of the manufacturers certified report of test or analysis to the engineer upon request.

For testing documented by certificate, all sampling and testing procedures and testing facilities are subject to review and approval. Products may be sampled and tested to verify the certified test results.

1.2.4 Approval by Sampling and Testing

Approval of materials will be based on a combination of the results of the following:

1. Contractor quality control testing required under the contract.
2. Optional contractor assurance testing.
3. Engineer verification testing.
4. Inspections of the materials production, storage, handling, and construction processes.
5. Dispute resolution procedures.

1.2.5 Certified Technician

All personnel engaged in sampling and testing of materials to be incorporated into the work must be certified under the WisDOT highway technician certification program, or a national recognized certification agency, for the specific tasks they are performing.

1.2.6 Qualified Laboratory

All laboratory facilities used in sampling and testing of materials to be incorporated into the work must be qualified by the WisDOT laboratory qualification program, AASHTO accreditation program, or other nationally recognized agency, for the specific tests they are performing.

1.2.7 Nonconforming Materials

For nonconforming materials identified before incorporation into the work, the engineer will do one of the following:

1. Reject those materials. Unless the engineer allows otherwise, the contractor shall remove rejected materials from the project site. The engineer may allow the contractor to correct rejected materials. The contractor shall obtain the engineer's approval for previously rejected, but subsequently corrected, materials before incorporating those materials into the work.
2. Approve those materials subject to potential reduced payment. The engineer will determine the circumstances under which those nonconforming materials may be approved and allowed to remain in place. The engineer will document the basis of approval and may execute a contract change order to adjust the contract unit prices for the nonconforming materials.

For materials incorporated in the work and subsequently found to be nonconforming, the engineer will do one of the following:

1. Reject those materials and issue a written order to remove and replace or otherwise correct nonconforming work.
2. Approve those materials and determine the circumstances under which the nonconforming work may be accepted and allowed to remain in place. The engineer will document the basis of acceptance and may execute a contract change order to adjust the contract unit prices for the nonconforming work.

1.2.8 Dispute Prevention

Both the contracting agency and the contractor have a common interest in preventing any misunderstandings or differences that may arise between them from becoming claims against one another. With the intent of avoiding this both parties will make good faith efforts to identify in advance and discuss the potential causes of disputes. The progress of the work will be reviewed on a weekly basis. Any miscommunications or dissatisfactions that may arise will be promptly brought to the attention of the other party to jointly review and resolve the issue.

1.3 Contractor Quality Control

1.3.1 General

Provide and maintain a quality control program, defined as all activities and documentation of the following:

1. Mix design.
2. Control and inspection of production and placement processes.
3. Material sampling, testing, and correction of in-place work.

1.3.2 Quality Control Plan

Submit a comprehensive written quality control plan to the engineer no later than 10 business days before placing material. Update the plan with changes as they become effective. Ensure that the plan provides the following elements:

1. An organizational chart including names, telephone numbers, current certifications and/or titles, and roles and responsibilities of all quality control personnel.
2. Preliminary concrete pavement mix information including anticipated producers, manufacturers, and sources of mix materials, and the name, title, and phone number of the person responsible for developing the mix design.
3. The locations and qualifications of Quality Control laboratories (mix design, aggregate testing, cylinder curing, concrete testing, and compressive strength testing).
4. Anticipated individual and combined aggregate gradations and limits.
5. The initial and routine equipment checks and documentation performed on scales, and water meters.
6. The methods for monitoring and recording the materials used in each batch.
7. Sampling and testing data documentation.
8. Procedures for documenting the locations of yielding foundation layers.

1.3.3 Personnel

Perform the material sampling, testing, and documentation required using a certified technician. Have the technician at the project site, prepared and equipped to perform the required sampling and testing, whenever placing concrete.

1.3.4 Laboratory

Perform the concrete mix design, aggregate testing, cylinder curing, and compressive strength testing at a qualified laboratory.

1.3.5 Equipment

Furnish the necessary equipment and supplies for performing quality control testing. Calibrate all testing equipment and maintain a calibration record at the laboratory.

1.3.6 Concrete Mixes

Determine Class I and Class II concrete mixes for the project conforming to Part 2. Test concrete during mix development at a qualified laboratory.

Submit a concrete mix report at least 3 days before producing concrete in accordance with section 2.3.4 or section 2.3.5. On the mix report clearly indicate the type/classification of aggregates per section 2.3.3.1.

1.3.7 Documentation

Document all observations, inspection records, and process adjustments daily. Submit all test results and records to the engineer upon request. Assure that all properties are within the limits specified.

1.3.8 Testing

1.3.8.1 General

Perform all quality control tests necessary to control the production and construction processes. Use the test methods identified below to perform the following tests:

Aggregate gradations	AASHTO T11 & T27
Aggregate materials finer than the No. 200 sieve	AASHTO T11
Aggregate moisture	AASHTO T255
Sampling freshly mixed concrete	AASHTO R60
Air content	AASHTO T152
Slump	AASHTO T119
Temperature	ASTM C1064
Compressive Strength	AASHTO T22, T23, M201

1.3.8.2 Aggregate Gradation

1.3.8.2.1 Sampling and Testing

The engineer may accept aggregate gradation based upon satisfactory records of previous testing.

Randomly sample and test the individual aggregate gradations according to AASHTO T 11 and AASHTO T 27. Have a certified technician sample and test the aggregate and document the results.

Test aggregates during aggregate production at a minimum frequency of 1 test per 1000 tons of aggregate produced up to a maximum of 3 tests per day. Production tests may be performed during aggregate production or during load out from aggregate source stockpile to plant site stockpile.

If aggregate production test records are not available or not acceptable to the engineer, sample and test aggregates during concrete production at a minimum frequency of 1 test per 500 cubic yards of concrete produced up to a maximum of 3 tests per day.

1.3.8.2.2 Documentation

Maintain control charts or tables at the laboratory for each aggregate stockpile. Maintain a chart or table for each control sieve for each material. Record contractor test results the same day tests are conducted.

Notify the engineer whenever an individual test value exceeds a control limit. Material is nonconforming when an individual test exceeds the control limit. The quantity of nonconforming material includes the

material of the first test exceeding the control limit, continuing to but not including, the material from the first subsequent test that is within the control limits.

1.3.8.3 Aggregate Percent Passing the No. 200 Sieve

1.3.8.3.1 Sampling and Testing

Have a certified technician sample and test the aggregate and document the results.

Measure and record the percent passing the No. 200 sieve of both the fine and coarse aggregates when producing concrete. Conduct tests according to AASHTO T 11 using a washed analysis for both the fine and coarse aggregates.

Sample and test at least one combined aggregate gradation prior to producing concrete for the project. Sample and test aggregates during concrete production at a minimum frequency as follows:

1. One test per 200 CY of cumulative concrete production up to a maximum of one test per day.
2. One test per 5 days of concrete production when the previous 5 consecutive p200 test results are less than or equal to 2.0 percent.

Ensure that the combined aggregate gradation, expressed as weight percentages of the total aggregate, for the percent passing the No. 200 sieve is less than or equal to 2.3 percent.

1.3.8.3.2 Documentation

Document testing using a combined gradation control chart or table for the percent passing the No. 200 sieve.

Notify the engineer whenever an individual test value exceeds a control limit. Material is nonconforming when an individual test exceeds the control limit. The quantity of nonconforming material includes the material of the first test exceeding the control limit, continuing to but not including, the material from the first subsequent test that is within the control limits

1.3.8.4 Concrete Sampling

Sample fresh concrete at the point of placement

1.3.8.5 Slump

Have a certified technician measure slump according to AASHTO T 119.

Test slump for nonslip-formed work whenever an air content test is performed or cylinders are made. Slumps for nonslip-formed work shall be 4-inches or less.

Test slump for slip-formed work whenever the engineer requests

1.3.8.6 Concrete Temperature

Have a certified technician measure concrete temperature according to ASTM C 1064 when concrete temperatures at the point of placement are subject to fall below 60 F. Test concrete taken from the same sample used for strength cylinders. Ensure that all test results are recorded and become part of the project records. Submit concrete temperature results on the compressive strength test reports.

1.3.8.7 Air Content

1.3.8.7.1 Sampling and Testing

On each day of production, test air content at the point of placement at start-up and as frequently as practicable until the concrete meets the specifications and the production process is under control.

For class I concrete items test air content for each compressive strength test.

For class II concrete items test air content at a minimum frequency of one test per 100 CY of concrete.

Have a certified technician test air content according to AASHTO T 152. Test concrete taken from the same sample used for strength cylinders.

The concrete air content control limits after applying the aggregate correction factor is as follows:

- Slip-formed concrete 7.0 percent +/- 1.5 percent
- All other concrete 6.0 percent +/- 1.5 percent

Make every attempt to run at or above the target air content.

1.3.8.7.2 Documentation

Ensure that all test results are recorded and become part of the project records. Submit air content test results to the engineer on the compressive strength test reports.

If an individual air test is outside the control limits, notify the engineer, and perform additional air tests as often as it is practical on subsequent loads until the air content is inside the control limits. The material is nonconforming when an individual test exceeds the control limit. Material from the load with the first test exceeding the control limit, continuing to but not including the load with the first subsequent test within the control limits, is nonconforming.

1.3.8.8 Compressive Strength

Acceptance of concrete will be based on 28 day compressive strength of concrete cylinders.

1.3.8.8.1 Sampling and Curing

Have a certified technician sample, test, and document results during concrete production and placement. Sample according to AASHTO R 60 and cast and initially cure the cylinders according AASHTO T 23.

For class I concrete items randomly select and cast one set of 3 standard 6X12 inch cylinders for each mix grade and placement type at a minimum frequency of one test per 500 CY of concrete, and in any event, not less than one test for each ½ day of placement.

For class II concrete items randomly select and cast one set of 2 standard 6x12 cylinders for each mix grade and placement type at a minimum frequency of one test per 200 CY of concrete.

Do not cast more than one set of cylinders from a single truckload of concrete.

Provide facilities for initial curing. Transport the specimens to a qualified laboratory for standard curing according to AASHTO M 201 for 28 days.

1.3.8.8.2 Compressive Strength Testing

Have a certified technician, in a qualified laboratory, perform compressive strength testing and document the results. For class I concrete randomly select 2 cylinders to test at 28 days. For class II concrete select 2 cylinders to test at 28 days.

Determine the 28-day compressive strength in psi of each cylinder according to AASHTO T 22. Test each cylinder to failure. Use a compression machine that automatically records the date, time, rate of loading, and maximum load of each cylinder. Include a printout of this information with the compressive strength documentation for each cylinder tested.

For Class I concrete compare the strengths of the 2 randomly selected cylinders and determine the 28-day average strength as follows:

- If the lower strength divided by the higher strength is 0.9 or more, average the 2 cylinders.
- If the lower strength divided by the higher strength is less than 0.9, break one additional cylinder and average the 2 higher strength cylinders.

For Class II concrete determine the 28-day average strength by averaging the 2 cylinders.

1.3.8.8.3 Compressive Strength Evaluation

The compressive strength testing laboratory shall furnish the engineer with a copy of all test reports.

For Class I concrete no less than one test for each 500 cubic yards of concrete placed will be required, and in any event, not less than one test for each ½ day of placement.

For Class II concrete no less than one test for each 200 cubic yards of concrete placed will be required.

If the average 28 day compressive strength is less than 3250 psi or if either of the two 28 day cylinders has a compressive strength less than 3000 psi the engineer may direct the contractor to core the subject area to determine its structural adequacy and whether to direct removal. Cut and test cores according to AASHTO T 24 as and where the engineer directs. Have a certified technician perform or observe the coring. Fill all core holes with an approved grout, and provide traffic control during coring at the contractors expense.

The concrete is conforming if the compressive strengths of all cores from the represented area are 3000 psi or greater or the engineer does not require coring.

The concrete is nonconforming if the compressive strength of any core from the represented area is less than 3000 psi.

2 Part 2. Concrete

2.1 Description

This specification includes the requirements for proportioning, mixing, and delivery of portland cement concrete mixtures.

2.2 Materials

2.2.1 Portland Cement

Use cement conforming to ASTM specifications as follows:

- Type I portland cement; ASTM C 150.
- Type II portland cement; ASTM C 150.
- Type III portland cement; ASTM C 150, for high early strength.
- Type IS(X) portland blast-furnace slag cement; ASTM C 595 up to a maximum 20% replacement.
- Type IP(X) portland-pozzolan cement; ASTM C 595 up to a maximum 20% replacement, except maximum loss on ignition is 2.0 percent.
- Type IL portland-limestone cement; ASTM C 595, except maximum nominal limestone content is 10 percent with no individual test result exceeding 12.0 percent.

Use portland cement included in the current WisDOT approved products list, provided they produce the required properties in the concrete.

The engineer will reject cement that is partially set or that contains lumps.

The engineer may reject cement if the temperature at the time of delivery to the mixer exceeds 165 F.

Submit a certified mill test report for all cement shipments used on the project.

2.2.2 Fly Ash

Provide fly ash conforming to ASTM C 618 Class C, except limit the loss on ignition to a maximum of 2 percent.

Use fly ash in portland cement concrete manufactured by facilities and processes known to provide satisfactory material.

Submit a certified mill test report for all fly ash shipments used on the project.

2.2.3 Ground Granulated Blast Furnace Slag

Provide ground granulated blast furnace slag conforming to ASTM C 989, grade 100 or 120.

Use ground granulated blast furnace slag in portland cement concrete manufactured by facilities and processes known to provide satisfactory material.

Submit a certified mill test report for all ground granulated blast furnace slag shipments used on the project.

2.2.4 Pozzolans

The contractor may use pozzolans as a direct and complete replacement for fly ash in concrete mixes. Do not combine pozzolans or use pozzolans with fly ash in the same mix.

Provide pozzolans conforming to the physical, chemical, and performance requirements specified for class C fly ash in ASTM C 618.

Use pozzolans in portland cement concrete manufactured by facilities and processes known to provide satisfactory material. Obtain material from a manufacturer with an in-place quality management program that includes the following daily uniformity tests:

1. Specific gravity
2. Percent retained on the No. 325 sieve
3. Loss on ignition
4. Moisture content
5. Activity index with portland cement.

2.2.5 Admixtures

2.2.5.1 General

Use admixtures included in the current WisDOT approved products list, provided they produce the required properties in the concrete.

The engineer must approve all admixtures not on the WisDOT approved products list before using them.

The engineer will base approval of admixtures on the evaluation of results of tests made in a qualified laboratory. The manufacturer shall furnish test result data. Provide to the engineer a manufacturer's certification that the materials it is furnishing are essentially identical to those used in the performance testing.

Stir, agitate, or circulate admixtures according to manufacturers' recommendations to insure a uniform and homogeneous mixture.

2.2.5.2 Air Entraining Admixture

Conform to AASHTO M 154

2.2.5.3 Retarding Admixtures

Conform to AASHTO M 194, type D.

2.2.5.4 Water Reducing Admixtures

Conform to AASHTO M 194, type A or type D, except if adding a retarding admixture use type D.

2.2.5.5 Non-Chloride Accelerating Admixtures

Conform to AASHTO M 194, type C or type E.

2.2.5.6 Evaporation Reducer

Provide water-born film forming evaporation reducers manufactured for application to fresh concrete.

2.2.6 Water

2.2.6.1 General

Use water with cement in concrete mixing operations conforming to the following:

Water obtained from a municipal supply or approved well to produce concrete may be accepted without testing.

Use water that is not brackish and is clean and free of detrimental amounts of oil, salts, acids, strong alkalis, organic matter, or other deleterious substances detrimental to concrete.

If supply is from a surface water source, enclose the suction pipe intake to keep out silt, mud, grass, and other foreign materials. Position the suction pipe to provide at least 2 feet (600 mm) of water beneath the pipe intake.

2.2.6.2 Testing of Suspected Water Sources

In the event the water supply is suspect the engineer may require the contractor to test the water source.

Test suspected water sources according to AASHTO T 26. Water shall comply with the following:

Acidity, maximum amount of 0.1N NaOH to neutralize 200 mL of water	2 mL
Alkalinity, maximum amount of 0.1N HCL to neutralize 200 mL of water	15 mL
Maximum sulphate (SO ₄)	0.05 percent
Maximum chloride	0.10 percent
Maximum total solids organic	0.04 percent
Maximum total solids inorganic	0.15 percent

Test suspected water sources according to AASHTO T 106 at a qualified laboratory. Use water that causes no indication of unsoundness, no significant change in the time of setting, and varies no more than 10 percent in the strength of standard 2-inch mortar cube from strengths obtained with mixtures containing distilled water and the same cement and sand.

2.2.7 Aggregates

2.2.7.1 General

Supply aggregates from WisDOT approved aggregate sources. The WisDOT maintains a list of current aggregate source test results at:

<http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm>

Testing of aggregates shall conform to the following:

Sampling aggregates.....	AASHTO T 2
Lightweight pieces in aggregate	AASHTO T 113
Material finer than No. 200 (75 µm) sieve.....	AASHTO T 11
Unit weight of aggregate.....	AASHTO T 19
Organic impurities in sands	AASHTO T 21
Sieve analysis of aggregates.....	AASHTO T 27
Effect of organic impurities in fine aggregate.....	AASHTO T 71
Los Angeles abrasion of coarse aggregate	AASHTO T 96
Freeze-thaw soundness of coarse aggregate.....	AASHTO T 103
Sodium sulfate soundness of aggregates.....	AASHTO T 104
Specific gravity and absorption of fine aggregate	AASHTO T 84
Specific gravity and absorption of coarse aggregate	AASHTO T 85

Submit a copy of the aggregate source test results for the current year to the engineer and ensure they meet the durability requirements in section 2.2.7.3.2.

The engineer may prohibit using aggregates from any source, plant, pit, quarry, or deposit if the character of the material or method of operation makes it unlikely to furnish aggregates conforming to specified requirements; or from deposits or formations known to produce unsound materials.

Store aggregates from different sources of supply or with different gradation requirements in separate piles to prevent mixture until proportioned into each batch.

2.2.7.2 Fine Aggregate

Fine aggregate consists of a combination of sand with fine gravel, crushed gravel, or crushed stone consisting of clean, hard, strong, durable inert particles from natural deposits. Fine aggregates entirely pass the 3/8-inch sieve, almost entirely pass the No. 4 sieve and are predominantly retained on the No. 200 sieve.

2.2.7.2.1 Deleterious Substances

Do not exceed the following percentages of deleterious substances:

SUBSTANCE	PERCENT BY WEIGHT
Material passing the No. 200 sieve	3.5
Coal	1.0
Clay lumps	1.0
Shale	1.0
Other deleterious substances like alkali, mica, coated grains, soft and flaky particles	1.0

The total percentage of coal, clay lumps, shale, and other deleterious substances shall not exceed 3.0 percent by weight. There is no requirement to wash fine aggregate for portland cement concrete if produced otherwise to conform to all specified requirements. When used, the fine aggregate shall not contain any of the following: frozen material, and foreign material like wood, hay, burlap, paper, or dirt.

2.2.7.2.2 Organic Impurities

Fine aggregate shall not contain harmful amounts of organic impurities. The engineer will reject aggregates, subjected to the colorimetric test for organic impurities, producing a darker than standard color, unless they pass the mortar strength test.

2.2.7.2.3 Mortar Strength

Fine aggregates, if tested for the effects of organic impurities on strength of mortar, using type I cement, must produce a relative strength at 7 days, calculated according to section 8 of AASHTO T 71, of not less than 95 percent.

2.2.7.2.4 Gradation Requirements

Use well-graded fine aggregate conforming to the following gradation requirements:

FINE AGGREGATE GRADING REQUIREMENTS	
SIEVE SIZE	PERCENT PASSING BY WEIGHT
3/8 Inch	100
No. 4	90 – 100
No. 16	45 – 85
No. 50	5 – 30
No. 100	0 – 10

2.2.7.3 Coarse Aggregates

Coarse aggregate consists of clean, hard, durable gravel, crushed gravel, crushed stone or crushed concrete free of an excess of flat & elongated pieces, frozen lumps, vegetation, deleterious substances or adherent coatings considered injurious. Coarse aggregates are predominantly retained on the No. 4 sieve

2.2.7.3.1 Deleterious Substances

Do not exceed the following percentages of deleterious substances:

SUBSTANCE	PERCENT BY WEIGHT
Coal	1.0
Shale	1.0
Clay Lumps	0.3
Soft fragments	4.0
Any combination of above	4.0
Materials passing the No. 200 sieve	1.5
Unsound chert retained on 3/8 inch sieve with BSG (SSD basis) less than 2.45	3.0
Flat and elongated pieces based on a 3:1 ratio	15.0

If using 2 sizes of coarse aggregates determine the percentages of harmful substances based on the actual percent of size No. 1 and No. 2 used in the work.

The engineer will not require the contractor to wash coarse aggregate produced within specified gradations, free of coatings considered injurious, and conforming to the above limits for harmful substances.

2.2.7.3.2 Aggregate Source Durability Requirements

Aggregate Wear (AASHTO T 96): Loss by abrasion and impact shall not exceed 50 percent by mass.

Aggregate Soundness (AASHTO T 104): The weighted average sodium sulfate loss shall not exceed 12 percent by mass.

Freeze-thaw (AASHTO T 103): The weighted average loss shall not exceed 18 percent by mass.

2.2.7.3.3 Gradation Requirements

Use well graded coarse aggregate conforming to the following gradation requirements:

COARSE AGGREGATE GRADATION REQUIREMENTS		
SIEVE SIZE	PERCENT PASSING BY WEIGHT SIZE No. 1 (AASHTO M 43, Size No. 67)	PERCENT PASSING BY WEIGHT SIZE No. 2 (AASHTO M 43, Size No. 4)
2 inch	---	100
1 1/2 inch	---	90 – 100
1 inch	100	20 – 55
3/4 inch	90 – 100	0 – 15
3/8 inch	20 – 55	0 – 5
No. 4	0 – 10	---
No. 8	0 – 5	---

Proportion the total coarse aggregate quantity between size No. 1 and size No. 2 as necessary to secure suitable workability and ensure that it is within the range of 35 – 65 percent of size No. 1 with the following exceptions:

- Class I concrete may consist entirely of size No. 1 coarse aggregate upon written approval by the engineer.
- Class II concrete may consist entirely of size No. 1 coarse aggregate.

In lieu of providing size No. 1 and size No. 2 coarse aggregates provide a single well graded coarse aggregate with suitable workability conforming to the following gradation requirements for Class I and Class II concrete:

ALTERNATIVE COARSE AGGREGATE GRADATION REQUIREMENT	
SIEVE SIZE	PERCENT PASSING BY WEIGHT
2 inch	100
1 inch	90 – 100
3/4 inch	60 – 80
1/2 inch	35 – 60
3/8 inch	20 – 45
No. 4	0 – 25
No. 8	0 – 15

2.3 Concrete Mix Requirements

2.3.1 General

For all concrete provide air entrainment and a water reducing admixture. Prepare air entrained concrete with sufficient air entrainment admixture to produce concrete with the required air content. Do not use chloride based accelerators in mixes for all new construction.

2.3.2 Concrete Classes

Class I concrete is cast-in-place concrete used in pavement items

Class II concrete is cast-in-place concrete used in curb, curb and gutter, sidewalks, and driveways.

2.3.3 Concrete Grades

For Class I and Class II concrete use grades A, A-FA, A-S, A-T, A-IS, and A-IP air entrained concrete. Prepare air entrained concrete with type I, II, IS(X), IP(X), IL cement except as specified in Special Restrictions 2.3.3.1.

For High Early Strength (HES) concrete use type III cement or one of the following:

- Add at least 95 pounds but no more than 280 pounds of cement per cubic yard to a previously accepted mix along with enough water to maintain workability without raising the w/cm.
- Substitute regular grade C for grade A high early strength concrete.

2.3.3.1 Special Restrictions

If using coarse aggregate composed primarily of igneous or metamorphic materials, provide Grade A, A-FA, A-S, and A-T concrete using type II portland cement, or type IL blended cement where the base cement meets type II chemical requirements or provide Grade A-IS and A-IP concrete using type I/II blended portland cement. Note the type/classification of aggregates on the mix report.

2.3.4 Standard Concrete Mix

2.3.4.1 General

The contractor may elect to use concrete mixes listed under this section. When choosing this alternate, the contractor is responsible for mix performance just as if the contractor provided independent mix designs.

Provide mix documentation ensuring that all materials are conforming unless the engineer waives specific requirements. Ensure that the mix limits, including aggregate gradations in accordance with section 2.2.7.3.3, are within the standard concrete mix master limits. Include documentation for the original mix designs as follows:

1. Mix: quantities per cubic yard expressed as SSD weights and net water, water to cementitious material ratio, and air content.
2. Materials: type, brand, and source.
3. Aggregates: type/classification, absorption, specific gravities, wear, soundness, freeze thaw, air correction factor, and proposed gradation control limits.

2.3.4.2 Standard Concrete Mix Master Limits

The following table specifies the standard concrete mix master limits for several grades of concrete, and designates the quantities of materials and relative proportions for each grade of concrete.

The quantities of aggregates specified in the tabulations are for oven-dry materials with a bulk specific gravity of 2.65. For aggregates with a different specific gravity, adjust the weights in the ratio so that the specific gravity of the material used relates to 2.65. The tabulated design water and maximum water amounts are for total free water in the mix and do not include the water absorbed in the aggregate.

STANDARD CONCRETE MIX MASTER LIMITS QUANTITIES FOR A NOMINAL CUBIC YARD ^[1]							
GRADE	CEMENT (lb)	CLASS C FLY ASH (lb)	SLAG (lb)	WEIGHT TOTAL AGG. (lb)	PERCENT FINE AGG. ^[4] (% Total Agg.)	DESIGN WATER (gals)	MAX. WATER (gals)
A	565	---	---	3120	30 – 40	27	32
A-FA ^[5]	455	110	---	3080	30 – 40	27	32
A-S ^[5]	455	---	110	3100	30 – 40	27	32
A-T ^[6]	455	Fly Ash and Slag = 110		3090	30 – 40	27	32
A-IS ^[2]	565	---	---	3090	30 – 40	27	32
A-IP ^[3]	565	---	---	3100	30 – 40	27	32
C	660	---	---	2980	30 – 40	30	36
C-FA	560	100	---	2960	30 – 40	30	36
C-S	560	---	100	2970	30 – 40	30	36
C-IS ^[2]	660	---	---	2950	30 – 40	30	36
C-IP ^[3]	660	---	---	2970	30 – 40	30	36

^[1] A nominal cubic yard has the tabulated weights of cement and aggregate, design mix water and 6% air.

^[2] For Grades A-IS and C-IS use only IS(X) cement up to a maximum of 20% replacement.

^[3] For Grades A-IP and C-IP use only type IP(X) cement up to a maximum of 20% replacement.

^[4] If using crushed stone the engineer may allow up to 45% fine aggregate.

^[5] If using less than the tabulated maximum quantities of fly ash or slag, calculate the cement content by reducing the base cement content for the grade A mix by the weight of fly ash or slag added.

^[6] For ternary mixes containing cement, fly ash, and slag, if using less than the tabulated maximum combined quantity of fly ash and slag, calculate the cement content by reducing the base cement content for the grade A mix by the combined weight of fly ash and slag added.

The total coarse aggregate quantity equals the difference between the total aggregate and the fine aggregate.

Provide a mix design based on the master limits, adjusted as necessary for the specific gravities of the aggregate furnished, using the lowest quantity or percentage of fine aggregate within the range shown that, without exceeding the maximum quantity of water allowed, yields a mix of the necessary workability.

The difference between the amount of fine aggregate determined above and the total amount of aggregate equals the coarse aggregate proportioned between the 2 sizes within the limits set, except if only one size is required. If the character of the proposed aggregates prohibits producing a workable mix within the maximum fine aggregate and water limits, then reduce the total quantity of aggregates sufficiently and re-proportion the mix to produce a workable mix without exceeding the maximum water allowed. The amount of water allowed includes the free moisture in the aggregates, minus the absorbed moisture determined according to AASHTO T 84 and T 85. Use just the amount of water needed, without exceeding the maximum that produces a mixture of the consistency, plasticity, and workability required for the work.

These requirements do not guarantee yield.

2.3.5 Contractor Concrete Mix

2.3.5.1 General

The contractor may elect to use independent contractor mix designs for concrete. When choosing this alternate, the contractor is responsible for mix performance.

Provide mix design documentation ensuring that all materials are conforming, unless the engineer waives specific requirements. Include documentation for contractor mix designs as follows:

1. Mix development: test dates, the name and location of the laboratory used to develop the mix design.
2. Mix: quantities per cubic yard expressed as SSD weights and net water, water to cementitious material ratio, air content and 28-day or earlier compressive strength.
3. Materials: type, brand, and source.
4. Aggregates: type/classification, absorption, specific gravities, wear, soundness, freeze thaw, air correction factor, and proposed gradation control limits.

2.3.5.2 Physical Requirements

Use at least 5 pairs of cylinders to demonstrate the compressive strength of a mix design. The contractor may report strengths from either laboratory testing or previous field test data for a similar mix design. Ensure that the average compressive strength achieved, in 28-days or less, by the 5 pairs of cylinders is 4200 psi or greater. The contractor need not provide separate laboratory mix designs and compressive strength tests for high early strength concrete.

Provide a minimum cement content of 565 pounds per cubic yard.

The contractor may partially replace portland cement with fly ash, slag, or a combination of fly ash and slag at a replacement ratio in pounds of 1:1 up to a maximum portland cement replacement content of 20% of the total cementitious material.

The target ratio of net water to cementitious material (W/C_m) for the submitted mix design shall not exceed 0.42 by weight. Net water includes free water on the aggregate surface but does not include water absorbed within the aggregate particles.

Provide high early strength concrete, use type III cement or a non-chloride accelerating admixture. Alternatively, the contractor may add a minimum of an additional 95 pounds of portland cement per cubic yard of concrete to a previously accepted mix.

2.3.6 Admixtures

2.3.6.1 General

Dispense admixtures in liquid form only. Incorporate non-liquid admixtures in an aqueous solution according to the manufacturer's instructions before dispensing. Maintain admixtures at uniform concentration. The contractor is responsible for the uniform operation of the admixture and for its compatibility with other mix components and any other admixture used.

2.3.6.2 Air Entrainment

Add an air entraining admixture to all grades of concrete. Use an admixture with non-air entrained portland cement to produce air entrainment.

Perform air content tests on freshly produced concrete according to AASHTO T 152.

2.3.6.3 Set Retarder

If the contractor elects to extend delivery time for ready mixed concrete in accordance with section 2.4.4.4 use admixtures to retard concrete setting as follows:

1. Add to the concrete mix if the air temperature when placing the concrete is 60 F or above.
2. Add according to the manufacturer's instructions to obtain at least a one-hour delay in the initial set, as defined in AASHTO T 197, at the temperature during placement.

2.3.6.4 Water Reducer

Add a water reducing admixture to all grades of concrete. Determine the specific type and rate of use based on the atmospheric conditions, the desired properties of the finished concrete and the manufacturer's recommended rate of use. The actual rate of use shall at least equal the manufacturer's recommended rate.

2.4 Construction

2.4.1 Batching and Mixing Equipment

2.4.1.1 Batch Plant

Use automatic or semi-automatic batching plants conforming to AASHTO M 157

Use either beam, digital or spring less dial-type scales for weighing concrete ingredients.

After erection, test each batch plant before use. Fully load aggregate bins, batchers, and scales with aggregate for not less than 5 hours before testing, in order to allow for settlement and adjustment under working conditions.

Have an authorized testing firm test and certify the weighing and metering equipment. Provide a copy of the certificate to the engineer.

2.4.1.2 Mixers

Use a central-mix plant or truck mixers conforming to AASHTO M 157. Operate all equipment within the manufacturer's recommended capacity to produce concrete of a uniform consistency.

Equip stationary mixers with a timing device that automatically locks the discharge mechanism during the full mixing time and releases it at the end of the mixing period.

2.4.1.3 Admixture Dispensing Equipment

Use accurate, volumetric, mechanical measuring dispensers, capable of presetting to deliver a specified amount of admixture for each admixture. Use a dispensing system with a device that either detects and indicates the presence or absence of flow of the admixture, or provides a convenient means of visually observing the admixture during batching or discharging. Ensure that the dispenser piping is free from leaks and properly valved to prevent back flow or siphoning.

Ensure that the system is capable of dispensing the admixture within +/- 3.0 percent of the required volume or weight of admixture, or the minimum dosage rate per 100 pounds (45.4 kg) of cement, whichever is greater.

2.4.2 Handling Materials

2.4.2.1 Aggregates

Keep all materials required to manufacture concrete clean and free from contamination. Keep the fine aggregate and the coarse aggregates separate until measuring and placing in the batch. Keep aggregates from different supply sources in separate piles.

If using a composite material from 2 or more sources for any aggregate, proportion material from the respective sources separately into the batch by weight.

Store aggregates in stockpiles. After washing, allow aggregates to drain in stockpiles for periods that ensure reasonable uniformity in the moisture content prior to loading in proportioning bins.

Choose reasonably smooth, firm, and well-drained sites for aggregate stockpiles cleared of vegetable matter and foreign material that might contaminate the aggregates. Separate aggregate stockpiles to prevent aggregates from becoming intermixed.

Construct coarse aggregate stockpiles in a manner that minimizes segregation of the coarse and fine fractions.

Utilize proper load out techniques when transporting aggregates from stockpiles to proportioning bins to avoid segregation and contamination of the aggregates.

2.4.2.2 Cement

Handle bulk cement in a manner that precludes contamination and avoids loss.

Store cement of different types, brands, and sources separately. Store bulk cement in suitable bins with smooth inner surfaces.

2.4.2.3 Fly Ash or Slag

Use separate facilities equal to those used for portland cement for handling, storing, transporting, and conveying the fly ash or slag

2.4.3 Proportioning and Batching

Proportion and measure aggregates and cement by weight.

Measure water by volume or weight. Use water-measuring equipment capable of accurately measuring to within one percent of the quantity required for each batch. Ensure that the measurement accuracy is uniform under all construction conditions and that variations in pressure in the water supply line do not affect it.

Proportion and measure admixtures by volume or weight. If using more than one admixture, add each admixture in a manner that prevents intermixing the admixtures before incorporating into the mixture.

2.4.4 Mixing and Delivery

2.4.4.1 General

Use central- mixed or truck-mixed to produce ready-mixed concrete defined as follows:

1. Central-mixed concrete: Concrete completely mixed in a stationary mixer and transported to the point of delivery with or without mechanical agitation in the transporting vehicle.
2. Truck-mixed concrete: Concrete completely mixed in a truck mixer

Use stationary mixers, or truck mixers of the revolving drum type or other types specifically designed for mixing. For agitators, use truck mixers or truck agitators. The manufacturer shall attach in a prominent place, to each stationary mixer, truck mixer, or truck agitator a metal plate plainly marked with the various uses of the equipment, the drum or container capacity in volume of mixed concrete, and the rotation speed of the mixing drum or blades.

Do not incorporate water used to clean mixing equipment and accessories into the mix.

Provide a computer-printed batch ticket which includes load and truck identification, the actual batch weights of all materials in that load, the mixing time for central plant mixed concrete or the start of the batch life for truck mixed concrete, and other pertinent data. Submit batch tickets to the engineer upon arrival at the work site.

The engineer may accept concrete used in pavement and associated bid items based on daily production records, if the concrete is proportioned in a computer-controlled plant erected specifically for this purpose. Submit computer printed batch records for a day's production to the engineer in a single group at the end of the work day.

The engineer may accept minor quantities of ready-mixed concrete used in miscellaneous bid items without batch tickets

2.4.4.2 Central-Mixed

If using a stationary mixer to mix concrete, mix at least one minute, provided that plant operating procedures are reasonably stabilized and controlled, and that it achieves visible blending of materials during charging. Increase mixing time if necessary to achieve proper stabilization, control and blending. Do not exceed a mixing time of two minutes.

Blending implies a uniform volume of flow of all batch ingredients throughout the charging time interval, except for the brief introduction of water and coarse aggregate.

For stationary mixers do not exceed the manufacturer's rated maximum mixing capacity, for the type and volume of mixer used.

2.4.4.3 Truck-Mixed

If mixing concrete in a truck mixer, mix each batch for 70 or more revolutions at the manufacturer designated mixing speed. Do not exceed 300 total revolutions per batch, the sum of the revolutions at mixing and agitating speeds including any re-tempering revolutions. Begin mixer revolutions only after all materials, including mixing water are in the mixer.

Prior to batching ingredients of concrete into truck mixers ensure all wash water has been removed from the drum.

Add the mixing water at the batching plant. Re-tempering is permitted once per load if obtaining the specified slump requires more water. Re-tempering is the process of adding more water and remixing of concrete. When re-tempering, do not exceed the maximum water allowed or maximum water–cementitious ratio allowed for the specific mix.

If re-tempering, perform an additional 30 revolutions of the truck mixer at mixing speed before discharging any concrete. Re-tempering must happen within the following limits, beginning when adding water to the cement, or when adding cement to the aggregates.

1. 45 minutes if the concrete temperature is 60 F or higher at placement, and the contractor does not use an approved retarder.
2. 75 minutes if the concrete temperature is less than 60 F at placement.
3. 75 minutes if the concrete temperature is 60 F or higher at placement, and the contractor uses an approved retarder

Equip truck mixers with an approved revolution counter. Unless equipped to control and count revolutions at mixing speed, perform mixing at the batching plant or job site with the mixer operated at agitating speed while in transit.

For truck mixers do not exceed the manufacturer's rated maximum mixing capacity, for the type and volume of mixer used.

2.4.4.4 Delivery

Deliver ready-mixed concrete at a uniform rate that ensures reasonably continuous progress in the placing and finishing operations with no concrete achieving initial set before placing adjacent concrete. If the time interval between successive loads causes initial set of previously placed concrete provide additional equipment of the kind necessary to preclude these delays. Minimize re-handling of the concrete.

For ready-mixed concrete deliver and completely discharge the concrete within the following limits, beginning when adding water to the cement, or when adding cement to the aggregates.

1. Non-agitating delivery vehicles:
 - 45 minutes if the concrete temperature is 60 F or higher at placement, and the contractor does not use an approved retarder.
 - 1 hour if the concrete temperature is less than 60 F at placement.
 - 1 hour if the concrete temperature is 60 F or higher at placement, and the contractor uses an approved retarder
2. Agitating delivery vehicle:
 - 1 hour if the concrete temperature is 60 F or higher at placement, and the contractor does not use an approved retarder.
 - 1.5 hour if the concrete temperature is less than 60 F at placement.
 - 1.5 hour if the concrete temperature is 60 F or higher at placement, and the contractor uses an approved retarder

Except during the mixing revolutions, operate the drum or agitator of the vehicle at agitating speed until discharging the mix. Ensure the concrete's uniform composition, required consistency, and required air content at time of delivery.

The contractor may deliver central-mixed concrete to the work site by equipment with non-agitating body types. These body types are smooth, mortar-tight, metal containers capable of discharging the concrete at a satisfactorily controlled rate. Do not use aluminum bodies.

Concrete delivered with non-agitating body types should show no appreciable water gain at the surface. The concrete should freely and readily discharge from the vehicle, be free of excessive segregation of the fine and coarse aggregates, and have air content within the required range at the point of discharge.

2.4.5 Consistency

Maintain a uniform consistency in consecutive batches of concrete, with all ingredients uniformly distributed throughout the weight, and so that the mortar clings to the coarse aggregate. Concrete shall not have a consistency sufficiently wet so it flows and segregates, or a mealy, dry consistency.

Use the minimum amount of water that achieves the desired workability and does not exceed the maximum water allowed or maximum water-cementitious ratio allowed for the specific mix.

3 Part 3. Concrete Pavement and Flatwork

3.1 Description

This specification includes the requirements for the construction of portland cement concrete pavement, concrete pavement gaps, approach slabs, alleys, curb, gutter, curb and gutter, driveways, and sidewalks.

This specification includes the following bid items:

Concrete Pavement ___ - Inch	SY
Concrete Pavement Gaps	Each
Concrete Alley	SY
Concrete Pavement Approach Slabs	SY
Concrete Driveway ___ - Inch	SF
Concrete Pavement HES ___ - Inch	SY
Concrete Alley HES	SY
Concrete Pavement Approach Slabs HES	SY
Concrete Driveway ___ - Inch HES	SF
Concrete Curb Type ___	LF
Concrete Gutter 24-Inch	LF
Concrete Curb and Gutter ___ - Inch Type ___	LF
Concrete Sidewalk ___ - Inch	SF
Curb Ramp Detectable Warning Field	SF
Drilled Tie Bars	Each
Drilled Dowel Bars	Each

3.2 Materials

3.2.1 Concrete

Provide quality control for Class I and Class II concrete in accordance with Part 1.

Furnish the required class and grade of air entrained concrete conforming to Part 2.

Furnish High Early Strength (HES) concrete under the HES bid items.

3.2.2 Concrete Pavement Gaps

Use concrete of the same mix design used for contiguous paving. If the engineer allows paving through the gap, use a concrete mix design that will develop 2500 psi opening strength in the required time frame.

3.2.3 Reinforcing Steel

3.2.3.1 Welded Steel Wire Fabric

Use a fabric of the weight and design the plans show and conform to AASHTO M 55.

3.2.3.2 Dowel Bars and Tie Bars

3.2.3.2.1 General

Furnish coated bars conforming to AASHTO M 31, grade 40 or 60. Ensure that the bars are the diameter and length the plans show.

The contractor need not coat or patch exposed ends.

3.2.3.2.2 Dowel Bars

Coat dowel bars with a thermosetting epoxy conforming to AASHTO M 254, type B. The Concrete Reinforcing Steel Institute must certify the coating applicator's plant. Ensure that the bars are straight, round, smooth, and free from burrs or other deformations detrimental to the free movement of the bar in the concrete.

Apply a surface treatment, or furnish manufacturer treated bars, capable of preventing bond between the epoxy-coated bars and the concrete. Apply field surface treatments when loading bars in the dowel bar magazine or after staking the dowel basket to the grade.

3.2.3.2.3 Tie Bars

Coat tie bars conforming to AASHTO M 284. The Concrete Reinforcing Steel Institute must certify the coating applicator's plant.

3.2.3.2.4 Coating Material

Use a powdered epoxy resin located on the WisDOT approved list.

The epoxy resin manufacturer shall supply to the coating applicator, any information on the resin it considers essential to the resins proper use and performance as a coating. The resin manufacturer shall also furnish written certification that the material is the same formulation and quality as the material supplied for prequalification tests.

The epoxy resin manufacturer shall provide patching or repair material, compatible with the coating and inert in concrete. This material shall be suitable for repairing areas of the coating damaged during fabrication or handling in the field

3.2.3.2.5 Certification

Furnish a certificate of compliance for the surface preparation, coating material, and process.

3.2.4 Expansion Joint Filler

Furnish expansion joint filler conforming to AASHTO M 153 or AASHTO M 213.

Furnish the filler in lengths equal to the width of the pavement lanes, and to the thickness and height that the plans show. If dowel bars are required, use filler with clean-cut punched holes, not greater than 1/8 inch larger in diameter than the nominal size of the dowel bar the plans require.

3.2.5 Curing Agents

In areas as noted on the plans or for urban pavements, curb and gutter, and sidewalk provide linseed oil based curing compounds. For all other types of work provide either linseed oil based or poly-alpha-methylstyrene based curing compounds.

Furnish linseed oil based and poly-alpha-methylstyrene (PAM) liquid curing compounds conforming to ASTM C309, type 2, class B as modified below.

Furnish linseed oil emulsion curing compound consisting of, by volume exclusive of the pigment, 50 +/- 4 percent linseed oil and 50 +/- 4 percent water. Ensure that the oil phase is, by weight, 80 percent boiled linseed oil and 20 percent high viscosity (Z-8) linseed oil. Modify ASTM C309 to waive the drying time requirement.

Furnish PAMS curing compound with a resin consisting of 100 percent poly-alpha-methylstyrene and with, by weight, 42 percent or more total solids. Modify ASTM C309 to ensure the following:

Loss of water in 24 hours does not exceed 0.15 kg/m².

Loss of water in 72 hours does not exceed 0.40 kg/m².

Reflectance in 72 hours is greater than or equal to 65 percent.

The volatile organic compound (VOC) content does not exceed 350 g/L.

Furnish polyethylene sheeting conforming to ASTM C171 for clear or white opaque polyethylene film. The contractor may use black polyethylene for cold weather protection.

Furnish burlap conforming to AASHTO M 182, class 3 or 4. The contractor may use 2 layers of class 1 or class 2 instead of one layer of class 3 or class 4.

Furnish polyethylene-coated burlap conforming to AASHTO M 171 for white burlap-polyethylene sheets.

3.2.6 Epoxy for Anchoring

Furnish epoxy consisting of a 2-component epoxy material of contrasting colors and conforming to AASHTO M 235, grade 3 - non-sagging consistency, type IV epoxy, except as modified below:

1. Use class B material for mid-depth slab temperatures between 41 F and 61 F (5 C and 16 C).
2. Use class C material for mid-depth slab temperatures between 61 F (16 C) and the highest temperature allowed by the manufacturer of the product.

Bond strength, tensile strength, and elongation testing is not required.

Achieve minimum compressive yield strength of 5000 pounds per square inch at 3 days for grades A and C concrete. Test according to AASHTO M 235 and ASTM D 695, with the following restrictions:

1. Mold and cure compressive test specimens in cylinders with a one-inch nominal diameter.
2. Machine specimen ends square to produce a final specimen length of 2 inches.

Submit to the engineer a manufacturer's certification showing that the product conforms to all above requirements. Clearly identify the temperature classes and compressive strength cure times for which the product is certified.

3.3 Equipment

3.3.1 Slip-form Concrete Paving Machine

Use a self-propelled slip-form paving machine designed to spread, strike off, consolidate, screed, and float-finish the freshly placed concrete in one complete pass of the machine for the required thickness to produce a dense and homogeneous pavement requiring minimal hand finishing. Slip-form paving machines extrude concrete into a shape using attached molding components consisting of a profile pan and side forms. Equip the slip-form paving machine with the following:

1. Automatic controls to control line and grade from either or both sides of the machine.
2. Vibrators to consolidate the concrete for the full width and depth of the course placed in a single pass, and designed and constructed so no spreading or appreciable slumping of the concrete occurs.
3. A positive interlock system to stop all vibration and tamping elements when forward motion of the machine stops.
4. A mechanical device that accurately spaces and positions the required tie bar reinforcement and that allows satisfactory mechanical or manual tie bar insertion.

Use a concrete spreader, ahead of a slip-form paver that cannot otherwise satisfactorily spread, consolidate, or finish the concrete.

The contractor may use finishing machines that do not conform to these requirements but are specifically designed for finishing concrete pavement to finish minor amounts of concrete pavement with the engineer's written permission. These machines must produce equivalent results including adequate consolidation by internal vibration and an acceptable finish.

3.3.2 Concrete Vibrators

For full width and depth consolidation of slip-formed concrete pavement use internal immersed tube or multiple spud gang vibrators. Operate internal type vibrators at frequencies within 5000-8000 impulses/minute.

To consolidate concrete that is adjacent to forms, joints, or fixtures, and to augment vibrating screeds with internal vibration for placements over 5-inches deep use single spud type internal vibrators. Operate the vibrator at a minimum frequency of 7000 impulses per minute.

3.3.3 Screeds

Use air vibrated, or mechanically vibrated truss screeds designed for striking off manual fixed-form concrete pavement conforming to the proper cross section.

Roller screeds may be used to strike off manual fixed-form concrete pavement upon approval by the engineer. Consolidate concrete using single spud type internal vibrators ahead of roller screeds.

3.3.4 Saws

Furnish concrete saws that are capable of sawing new concrete. Equip all saws with blade guards and guides or devices to control alignment and depth.

3.3.5 Forms

Provide steel edge forms designed and constructed with proper side and base supports to ensure rigidity and capable of supporting the type of equipment used to finish the concrete. Use straight forms free from warping with sufficient strength to resist concrete pressure without bulging. Use forms that are clean and in acceptable condition.

Steel forms are readily available for various pavement thicknesses in even 2 inch increments. Provide steel forms with a vertical face height greater than or equal to the specified pavement edge thickness minus 1 1/2 inches.

Wood or plastic forms may be used for concrete driveways, forming fillets, widening at intersections, curves less than 100-foot radius, and other minor construction.

3.3.6 Finishing Tools

Furnish aluminum, magnesium or wooden hand finishing tools. Avoid the use of steel hand finishing tools on air entrained concrete.

3.4 General Construction of all Concrete

3.4.1 Foundation

Shape the foundation to true cross-section and elevation. Fill all depressions with suitable material, and remove excess material immediately after cutting.

Ensure that the foundation is in a moist condition during concrete placement. Thoroughly dampen the foundation in advance of the placement operation. If the foundation surface dries before concrete is placed sprinkle additional water ahead of the placement operation to dampen the foundation.

Before placing concrete, repair and re-compact rutted or disturbed areas of the foundation. Do not place concrete on frozen subgrade or base.

3.4.2 Setting Forms

Set forms to the required grade and alignment. Firmly support and anchor forms in a manner to prevent movement. All forms shall be thoroughly cleaned and have a form release agent applied prior to placing concrete.

Key-in or firmly support forms to the required grade when using forms with a vertical face height greater than or equal to the specified edge thickness minus 1 1/2 inches. After setting the forms ensure that the interface between the form face and the base is reasonably square and any necessary foundation corrections are compacted.

Check that forms conform to alignment and grade, and make necessary corrections before placing the concrete. If a form has been disturbed, reset and recheck the form.

3.4.3 Placing, Consolidating and Finishing Concrete

Deposit concrete on the foundation across the full placement width in a manner that minimizes required spreading and segregation of the concrete mix.

Adjust and set castings and frames for manholes, catch basins, inlets, and other fixtures to the required alignment and grade while the adjacent concrete is still plastic.

The contractor may set the castings and frames for manholes, catch basins, and inlets, on a full bed of mortar or concrete and adjust to the required alignment and grade before placing concrete. The contractor may also use an engineer-approved non-shrink pressure grout to fill all remaining voids beneath the base of these fixtures before opening to traffic.

Thoroughly and uniformly vibrate and consolidate the concrete during placement without segregating the material. Use handheld internal vibrators along forms and around embedded objects including utility fixtures to prevent voids and to fill openings between the bases of the fixtures and their support structures.

Keep hand finishing efforts on the surface to a minimum to avoid over finishing. Hand-float the surface only as needed to produce a uniform surface. Do not add water to correct surface deficiencies except in emergency cases or with engineer authorization.

If moving or operating paving equipment on concrete bridge decks, asphaltic pavement, or concrete pavements, employ appropriate means to prevent damage to the bridge decks or pavements.

3.4.4 Reinforcement

Reinforce the concrete if and as the plans specify. Keep reinforcement clean and free from rust scale, straight and free from distortion.

3.4.5 Placing Tie Bars in Existing Concrete

Drill holes into the edge of the existing concrete to the dimensions the plans show. Anchor the tie bars into the existing concrete with an epoxy conforming to 3.2.6 and install conforming to 3.4.6 except no bond breaker is required.

3.4.6 Placing Dowel Bars in Existing Concrete

Drill holes into the edge of the existing concrete to the dimensions the plans show. Anchor the dowel bars into the existing concrete with an epoxy conforming to 3.2.6.

Clean drilling dust, debris, and excess moisture from drill holes before inserting the epoxy and dowel bar.

Inject the epoxy into the back of the drill hole. Use an epoxy with a workable viscosity, pumpable, yet thick enough to remain in the hole. Insert a sufficient volume of epoxy into the hole to provide a small quantity of excess material at the face of the concrete after fully inserting the dowel.

Insert dowel bars in the drill holes and rotate 1/2 turn. Do not force drive dowel bars into the drill holes.

Completely fill the annular space between the dowel bar and the concrete with epoxy. Insert a retaining ring over the bar, and push the ring flush against the concrete surface to retain the epoxy.

Coat the protruding portion of each dowel bar with a thin uniform layer of bond breaking lubricant.

3.4.7 Curing

3.4.7.1 General

Maintain adequate temperature and moisture throughout the concrete mass to support hydration until the concrete develops sufficient strength to open it to service. Cure all concrete by the impervious coating or impervious sheeting method or a combination of the two.

3.4.7.2 Impervious Coating Method

After texturing, and immediately after bleed water leaves the surface, coat the exposed surfaces with a liquid membrane-forming curing compound as specified in section 3.2.5. For fixed-form work, coat the sides of the pavement after removing forms.

Apply liquid curing compound in a fine spray to form a continuous, uniform film on the exposed surfaces. Provide sufficient agitation prior to and during spraying to ensure uniform consistency and dispersion of pigment within the curing compound during application.

Protect all liquid curing compounds from freezing.

Apply the curing compound with a self-propelled mechanical power sprayer whenever practical. The contractor may use hand-operated spraying equipment for irregular, narrow, or variable width sections.

For tined surfaces, apply the curing compound uniformly at or exceeding a minimum rate of one gallon per 150 square feet. For all other surface finishes, apply the curing compound uniformly at or exceeding a minimum rate of one gallon per 200 square feet.

If removing forms within 72 hours after placing the concrete, coat newly exposed surfaces within 30 minutes after form removal.

3.4.7.3 Impervious Sheeting Method

After finishing the concrete and allowing it to harden enough to prevent excessive marring, immediately cover all exposed concrete surfaces with one or a combination of the following impervious sheeting materials:

1. Polyethylene sheeting.
2. Polyethylene-coated burlap. Pre-wet the polyethylene-coated burlap and place the uncoated side against the concrete.
3. If the engineer approves, insulated curing blankets with an impervious coating.
4. Alternate impervious sheeting materials as the engineer approves.

For sheet curing materials, extend the sheets beyond the edges of the slab to a distance at least twice the thickness of the pavement.

Provide enough sheeting material to cover all exposed edges, with enough excess to enable use of weights or anchors to hold the material securely in place. Provide 12 inches or more overlap between adjacent pieces of sheeting. Place and maintain the sheets in complete contact with the surface until the concrete conforms to the opening criteria.

If temporary removal is required to remove forms or perform other necessary work, re-cover all exposed concrete as quickly as practical, or as the engineer directs.

3.4.8 Cold Weather Concreting

The contractor is responsible for the quality of the concrete placed in cold weather. Take all precautions necessary to prevent freezing of the concrete until it has developed sufficient strength to open it to service. Remove and replace frozen or frost damaged concrete at the contractor's expense.

Provide a reference high/low thermometer at an engineer approved location to document air temperature during cold weather concreting.

Suspend concreting operations if a descending air temperature falls below 35 F. Do not resume concreting operations until an ascending air temperature in the shade and away from artificial heat reaches 30 F.

Maintain the temperature of the concrete at or above 50 F at the point of placement. If necessary to maintain placement temperature, the contractor may heat the water, aggregates, or both.

When the national weather service forecast for the construction area predicts freezing temperatures within the next 24 hours, or when freezing temperatures actually occur, provide the minimum level of thermal protection specified below for concrete that has yet to conform to the opening criteria.

1. Predicted or actual air temperature 22 to <28 F: single layer of polyethylene
2. Predicted or actual air temperature 17 to <22 F: double layer of polyethylene
3. Predicted or actual air temperature <17 F: 6" of loose, dry straw or hay between 2 layers of polyethylene

Place protective material as soon as the concrete is finished and sets sufficiently to prevent excessive surface marring. If necessary to remove the coverings to saw joints or perform other required work the contractor may remove the covering for the minimum time required to complete that work.

In the event the contractor incurs cold weather concrete expenses due to project delays unforeseen at the time of bidding and outside the contractors control the engineer and contractor shall negotiate a price for cold weather protection.

3.4.9 Protection of Concrete

Erect, maintain, and occupy, if necessary, suitable barricades, warning lights, and signs to keep pedestrian or vehicular traffic off the newly constructed pavement until it is opened for service.

Provide a safe and adequate alternative for pedestrian traffic as deemed necessary.

Protect the unhardened concrete against rain damage. If rain is imminent, cover the unhardened concrete immediately with polyethylene sheeting or other suitable material. Restore pavement texture damaged by rain by re-dragging the concrete while still plastic.

Concrete pavements shall be maintained in a clean condition by the contractor until the project is accepted by the owner and open to public traffic. Regular sweeping is required, including removal of sawing debris prior to opening to traffic, when completing remaining work, immediately prior to joint sealing, immediately prior to pavement marking, and as required by the engineer.

3.4.10 Opening to Service

3.4.10.1 General

Maintain moisture and physical protection for concrete until it develops sufficient strength to open it to service.

Open to construction and public traffic when the concrete attains a compressive strength of 3000 pounds per square inch. The contractor may use opening strength cylinders or the maturity method to determine the concrete opening strength. In the absence of opening strength information the engineer may allow the contractor to open to service based on Equivalent Curing Days.

The contractor may operate concrete saws and profilers on concrete that does not conform to opening criteria. Clean the surface of the pavement by sweeping before allowing traffic of any kind on the pavement.

3.4.10.2 Opening Strength

When using opening strength to determine opening to service provide opening strength data based on compressive strength testing of field cured cylinders. Compute the opening strength as the average of compressive strength test results for 2 cylinders. Fabricate cylinders according to AASHTO T 23 and test the cylinders according to AASHTO T 22.

3.4.10.3 Maturity

When using maturity to determine opening to service develop a calibration curve representing the strength/maturity relationship for each concrete mix design. Develop a new calibration curve every time the mix changes or if compressive strength verification testing varies more than 10 percent from the opening strength value determined from the current calibration curve.

Develop a calibration curve for each mix design by casting at least 15 standard 6x12 inch cylinders. Embed maturity sensors at the center of at least two cylinders. Cure concrete cylinders in conditions similar to which the field concrete will be exposed. Protect the cylinders from moisture loss. Perform compression tests at 1, 2, 3, 5, and 7 days, or other intervals as determined appropriate for the mix design. Develop data points for the strength/maturity relationship up to at least 120 percent of the required opening strength. Test two specimens at each age and compute the average strength. If the strength of the lower strength cylinder is less than 90 percent of the higher strength cylinder, also break a third cylinder. Discard the lowest of the three cylinder strengths, and calculate the strength as the average of the two higher strength cylinders. At each test age, record the average maturity index for the instrumented cylinders.

Calculate the maturity index using the temperature-time factor maturity function as defined in ASTM C 1074. Use a default datum temperature of 32 F (0 C) or use a mix-specific datum temperature per Annex A1 of ASTM C 1074.

Each work week cast a set of 3 verification cylinders for each strength/maturity calibration curve currently in use on the project. Provide 2 cylinders for compressive strength testing and one with a data encrypted sensor embedded in its center for maturity evaluation. Cast and cure these cylinders on-site conforming to the requirements of ASTM C31 for field curing. When the instrumented cylinder reaches the opening maturity perform compressive strength verification testing on the 2 cylinders as closely as possible to that opening maturity level.

Place at least one sensor near the end of the pour to determine opening criteria for concrete placed on or before the time the test location was placed. Embed the sensor in fresh concrete and activate the recording device as soon as possible. Estimate the compressive strength at the sensor location by using the strength/maturity calibration curve for that mix design and the measured maturity index from the embedded sensor.

3.4.10.4 Equivalent Curing Days

When using Equivalent Curing Days to determine opening to service open pavement after the following minimum times, as adjusted for changes in the ambient air temperature on the project:

Concrete Grade	Equivalent Curing Days
High early strength concrete	3
Grade A	4
Grade A-FA	5
Grade A-S, A-IS, A-IP and A-T	7

The equivalent curing day is based on a daily average ambient temperature of 60 F. The daily average ambient temperature is the average of the high and low engineer recorded temperatures on the project site for each day. Accumulate equivalent curing days based on the daily average ambient temperature as follows:

1. 60 F or more; accumulate one equivalent curing day per calendar day.
2. 40 to less than 60 F (4 to <16 C); accumulate 0.6 equivalent curing day per calendar day.
3. Less than 40 F (4 C); accumulate 0.3 equivalent curing day per calendar day.

3.5 Pavement Construction

3.5.1 Foundation

3.5.1.1 General

Trim and shape the foundation for a width equal to the width of the pavement plus at least one foot on each side to approximately the required lines, grade, and cross-section. After trimming and shaping the foundation uniformly re-compact to not less than the required density for standard compaction of earth subgrade, subbase, or base. Perform compaction with suitable rolling or other types of consolidating equipment.

For areas of the foundation that are impractical to prepare by machine methods, prepare these areas by hand methods satisfactory to the engineer.

For alley pavements shape the foundation to the required cross section and width as detailed on the plans.

3.5.1.2 Slip-formed Pavement

If using slip-form methods, after satisfactorily compacting the base, bring the areas that support the slip-form paver to the required grade and the areas where the pavement will be placed to the required grade and cross-section by using a machine designed specifically for trimming foundations. Equip the machine with automatic sensors to trim the foundation to the required grade and cross-section when practical.

3.5.1.3 Manual Fixed-Form Pavement

After preparing the foundation set the forms according to the requirements specified for this work. Bring the foundation to true cross-section and elevation. Fill all depressions with suitable material, and remove excess material immediately after cutting.

Check foundation stability under forms which were placed prior to a rain event.

3.5.2 Placing, Consolidating and Finishing Concrete

3.5.2.1 General

The use of a self-propelled slip-form paving machine is required for the placement of all mainline pavements that are 300 feet or more in length, a minimum of 10 feet in width, and a constant width. In areas inaccessible to self-propelled slip-form paving equipment, paving gaps, small pours, and irregular shaped areas construct the pavement using fixed form methods as approved by the engineer.

Continuously place concrete on the base course in a manner that minimizes segregation. Place to a depth sufficiently above grade so, after consolidating and finishing, the required slab thickness is obtained and the surface conforms to the specified grade and slope.

Deposit concrete at joint installations so as not to displace or disarrange the installations. Completely fill joint assemblies with concrete. Simultaneously place concrete on both sides of expansion joints. Deposit the concrete at and in advance of contraction joint assemblies to prevent the formation of segregated concrete in the assembly.

Strike off and screed the concrete to the required grade, and cross section the plans show, as soon as placed.

If a temporary shutdown occurs, cover the concrete at the unfinished end of the placement to maintain moisture. Install a construction joint if an interruption is long enough for concrete to develop initial set.

Check the surface of the fresh concrete with a long-handled straightedge that is 10 ft. or longer. Remove high areas indicated by the straightedge. Overlap each successive pass of the straightedge by about 1/2 the length of the straightedge. Fill any depressions immediately with freshly mixed concrete, and strike off, consolidate, and refinish the concrete. Also, strike off and refinish all projections.

3.5.2.2 Slip-Formed Pavement

Operate slip-form paving equipment with a continuous forward movement, as practicable, and coordinate mixing, delivering, and spreading concrete to provide uniform progress. Check and adjust string lines, sensors, and other paver guidance equipment during paving to assure uninterrupted placement to the plan alignment and grade.

Carry a sufficient amount of concrete forward ahead of the paver. Minimize starting and stopping the paver. If it is necessary to stop the forward movement of the paver, stop vibrating and tamping immediately, and restart when forward motion resumes.

Uniformly consolidate the concrete throughout its entire width and depth.

Vibrate concrete adjacent to transverse construction joints with hand vibrators.

When placing concrete adjacent to previously constructed pavement, provide that part of the equipment supported on the previously constructed pavement with protective pads, crawler tracks, or rubber-tire wheels and operate a sufficient distance from the edge of the pavement to avoid breaking the pavement edge. Do not operate this equipment on the pavement surface until opening to service requirements have been met.

Maintain a maximum edge slump tolerance of 3/8 inch at free edges and 1/8 inch at locations with adjacent concrete construction. Correct edge slump in excess of these requirements before the concrete sets.

3.5.2.3 Manual Fixed-Formed Pavement

Deposit concrete as near as possible to its final location to minimize segregation.

Use single spud hand vibrators to consolidate the concrete along the full length of all transverse joint assemblies. Vibrate to a depth that consolidates the concrete above and below the dowel bars and assembly.

Use single spud hand vibrators on concrete adjacent to all transverse construction joints, forms, and fixtures to prevent voids.

Supplemental vibration with hand held spud vibrators is required when placing concrete thicker than 5-inches when using a vibratory screed and is always required when using a roller screed. Insert vibrators using vertical plunges leaving the vibrator head inserted for 5 – 15 seconds to properly consolidate the concrete. Do not drag spud vibrators through the concrete nor attempt to move the concrete laterally.

Use surface type vibratory screeds for hand strike-off and to supplement internal vibration. Do not over vibrate if using the internal spud vibrator and the vibratory screed. Maintain a sufficient amount of concrete, during operations, in front of the screed to fill all voids or low areas. Do not allow excessive amounts of concrete to accumulate in front of the screed, causing the concrete to surge under the screed, or produce ridges or waves in the surface. Do not make more than 2 passes of the vibratory screed on a given area of concrete. Regulate the speed of the forward movement of the screed, and the speed of the vibrator, to produce the best results. Do not vibrate the concrete with the screed in a stationary position.

3.5.2.4 Alley Pavement

Concrete alley pavements greater than 15 feet wide and up to 26 feet wide shall be constructed in two passes with a longitudinal construction joint located 2 feet from the centerline. Alleys greater than 26 feet wide shall be constructed in three passes with a longitudinal construction joint located 5 feet to the right and left of the centerline. Alleys less than 15 wide, or where obstructions prevent the use of concrete placing equipment, may be constructed in one pass with the approval of the Engineer.

3.5.3 Reinforcement

When dowel bars are required align dowels vertically and horizontally within the following tolerances:

1. Locate the dowel bars within one inch of the planned transverse location and depth.
2. Locate the dowel bars within 2 inches of the planned longitudinal location.
3. Place dowel bars parallel to the pavement surface and centerline within a tolerance of 1/2 inch in 18 inches.
4. Provide a minimum embedment length of 6 inches on either side of the joint.

If using a mechanical device to install dowel bars when required, conform to the following:

1. Place and consolidate the pavement to full depth before inserting the dowel bars.
2. Insert the dowel bars into the plastic concrete in front of the finishing beam or screed.
3. Ensure that the installing device consolidates the concrete with no voids around the dowel bars.
4. Do not interrupt the forward movement of the finishing beam or screed while inserting the dowel bars.
5. Provide a positive method of marking the locations of the transverse joints.

Place dowel bars for contraction joints if required at the location, depth and spacing shown on the plans. Fasten the dowels to rigid baskets or insert them while the concrete is plastic.

When dowel bar baskets are used to hold dowel bars in the correct position and alignment use an engineer approved rigid basket. The contractor need not cut dowel basket tie wires. Fasten dowel baskets securely to the foundation using stakes or nails.

Place dowel bars for transverse construction joints at the location, depth and spacing shown on the plans. Drill holes and epoxy dowels into position in a sawed joint face, or insert them through holes in a header form taking care to maintain proper alignment.

Place dowel bars in transverse isolation joints at the location, depth and spacing shown on the plans. Fasten the dowels to an expansion basket that remains in the pavement, provides joint closure space and holds each dowel parallel to the surface and center line of the slab. Attach expansion caps to each dowel bar.

Place tie bars reasonably perpendicular to the longitudinal joints with mechanical or manual insertion equipment or rigidly secured chairs without damaging or disrupting the concrete. Do not bend and straighten tie bars into correct position by more than 90°. Repair or replace broken or badly damaged tie bars.

3.5.4 Jointing

3.5.4.1 General

Construct transverse and longitudinal joints to the details, dimensions and spacing shown on the plans. Make joints perpendicular to the pavement surface. Use construction-style joints at any longitudinal joint necessary to facilitate construction staging.

Saw the joints, in a single cut, to the width and depth the plans show. Begin sawing as soon as the concrete hardens sufficiently to prevent excessive raveling along the saw cut and finish before conditions induce uncontrolled cracking, regardless of the time or weather. Provide artificial light if joint sawing after daylight hours. The contractor may saw the joints by the skip method, wherein every third joint is sawed as soon as possible. Following this skip sawing, make the cuts of the remaining intermediate joints.

Edge formed joints, construction joints, and fixed forms with a 1/4-inch radius.

If covering the pavement for cold weather protection, the contractor may delay sawing to avoid early exposure to freezing conditions.

3.5.4.2 Longitudinal Joints

Do not deviate more than 1/2 inch in 10 feet from the required line. Longitudinal joints may consist of construction joints where new work joins existing work. Saw all other longitudinal joints.

Tie new work to existing concrete pavement using tie bars epoxied into the existing concrete. Use only cast-in-place tie bars in construction joints of pavement placed under the contract.

3.5.4.3 Transverse Joints

Extend all transverse joints the entire width of paving. When constructing curbs or medians integral with the pavement, construct transverse joints continuous through the curb or median. When the pavement abuts an existing pavement or curb and gutter, construct transverse joints in the pavement at locations matching transverse joints or cracks in the existing pavement.

Form a construction joint by setting a header board securely in place at the end of each day's run or when an interruption in the concreting operation of 30 minutes or more occurs. Design and set the header board to accommodate proper placement of the tie bars or dowel bars. If a header board is not used the contractor may construct a header by sawing completely through the concrete and remove excess material to expose solid concrete.

Use only production quality concrete in the header. Protect the steel projecting beyond the header from spilled concrete and all loadings or forces that might displace or bend the steel or weaken the bond with the concrete. Use hand vibrators to consolidate the concrete against the header or concrete face.

3.5.4.4 Expansion Joints

Place expansion joints in concrete pavement at locations the plans show.

Install a preformed joint filler extending from the foundation to 1/2 inch below the finished pavement surface, with its respective edges conforming to the contour of the subgrade and the pavement surface. Ensure finished expansion joints are installed straight and perpendicular to the pavement centerline.

For doweled expansion joints install a preformed joint filler with factory-punched holes for and at the exact location of the dowel bars.

3.5.5 Final Surface Texture

3.5.5.1 General

Perform the final finish after straight edging, and after all excess moisture disappears, and while it is still possible to produce a uniform striated surface texture. Texture all concrete surfaces that will be used by traffic.

3.5.5.2 Posted Speed Less Than 45 MPH

Unless otherwise specified, provide an artificial turf drag final finish. Use a seamless strip of artificial turf approximately full pavement width and of sufficient length to provide approximately 2 feet of turf in contact with the pavement surface. Pull the drag with a device that allows control of the time and rate of texturing. Operate the drag in a longitudinal direction parallel with the centerline to produce a straight and acceptable finish. Weight the drag as necessary to maintain contact with the pavement. Keep the drag clean and free of particles of hardened concrete.

Apply a broom finish to small areas of urban pavement and to concrete driveways and other miscellaneous areas.

3.5.5.3 Posted Speed 45 MPH and Higher

3.5.5.3.1 General

Texture the pavement surface with an artificial turf drag prior to tining.

Tine the pavement with a self-propelled tining machine. Where using a tining machine is not practical, tine by hand. Produce uniformly deep grooves approximately 1/8 to 3/16 inch deep. Provide a finished surface free of tining defects. Complete before tining tears or unduly roughens the concrete.

For machine work, use longitudinal tining. For hand work, use transverse tining.

3.5.5.3.2 Transverse Tining

For hand work, use a rake with individual 1/8 inch tines spaced uniformly 5/8 of an inch on center.

3.5.5.3.3 Longitudinal Tining

Use a tining machine with an automated alignment control system to ensure that all tining runs straight and parallel to the longitudinal axis of the pavement. Use a rake with individual 1/8 inch tines spaced uniformly 3/4 of an inch on center. Within 2-inches of longitudinal sawed joints, turf drag but do not tine surface.

3.5.6 Surface Testing and Correction

3.5.6.1 Ten-Foot Straightedge

The engineer will ride the pavement surface to identify locations of any rough areas. Test the pavement surface at engineer-selected locations with a 10-foot straightedge. The engineer may direct the contractor to mark and grind down those areas showing high spots greater than 1/8 inch but not exceeding 1/2 inch in 10 feet until the area or spot's elevation no longer shows surface deviations greater than 1/8 inch when retested with the straightedge. If the departure from correct cross section or profile exceeds 1/2 inch in 10 feet, the engineer may direct the contractor to remove and replace the pavement at the contractor's expense.

3.5.6.2 Pavement Grinding

Perform grinding with a device specifically designed for pavement grinding having diamond blades uniformly spaced with at least 50 blades per linear foot. Perform additional light grinding as necessary to provide a neat rectangular area of uniform appearance. Perform the grinding parallel with the centerline.

3.5.7 Pavement Thickness

Construct pavement to the plan thickness. Measure pavement thickness by probing or other acceptable methods.

3.5.7.1 Pavement Units

Divide the pavement into basic units 250 feet long, measured along the pavement centerline. Treat fractional units less than 250 feet but greater than or equal to 100 feet long as a whole basic unit. Include fractional units less than 100 feet long as a part of a contiguous basic unit.

The basic unit is one lane wide, measured from the pavement edge to the adjacent longitudinal joint; from one longitudinal joint to the next; or between pavement edges if there is no longitudinal joint.

Establish special units for areas of fillets, intersections, gaps, ramps, and other special areas not included in basic units.

3.5.7.2 Measured Thickness

Make 2 measurements for each basic unit. Perform both measurements at a single longitudinal location selected at random. Perform individual measurements at transverse locations near wheel paths or as agreed upon by the engineer.

Determine the measured thickness of a pavement unit by averaging the 2 measurements made within that unit. If an individual measurement exceeds plan thickness by more than $\frac{1}{4}$ inch compute the measured thickness using the plan thickness plus $\frac{1}{4}$ inch for that individual measurement.

Measure the thickness of a special unit at a minimum of 2 locations as the engineer approves.

The contractor may provide coring thickness results to resolve disputed probing results. Perform coring according to AASHTO T 24 and evaluate cores according to AASHTO T 148.

3.5.7.3 Tolerances

Interpret the following terms used to describe measured thickness as follows:

1. **Conforming:** Greater than or equal to plan thickness minus $\frac{3}{8}$ inch.
2. **Nonconforming:** Greater than or equal to the plan thickness minus 1 inch but less than the plan thickness minus $\frac{3}{8}$ inch.
3. **Unacceptable:** Less than plan thickness minus 1 inch.

3.5.7.3.1 Conforming Areas

If the measured thickness of a pavement unit is conforming, the engineer will not require more measurements or adjust pay. If the measured thickness is consistently less than the plan thickness, adjust the operation to construct the plan thickness.

3.5.7.3.2 Nonconforming Areas

If the measured thickness of a pavement unit is nonconforming, the pay adjustment for that unit will be contingent upon the final thickness of the next unit in that lane. If the location for the next required random probing series is within 125 feet of the first test location, the contractor may select and document a new random location to provide space for corrective action.

If the measured thickness of the next unit is conforming, the engineer will not assess any pay adjustments for either unit. If the measured thickness of the next unit is nonconforming or unacceptable, the engineer will adjust the pay for both units. The engineer will continue pay adjustment for each succeeding unit until the contractor produces a unit with conforming measured thickness.

3.5.7.3.3 Unacceptable Areas

The pavement is unacceptable if one or more of the following is true:

1. An individual required contractor probe measurement is unacceptable.
2. A dispute resolution core is unacceptable.

Core the hardened concrete to determine the extent of the unacceptable area. Take cores at points approximately 20 feet in each direction of the unacceptable measurement on a line parallel to the centerline or longitudinal axis of the unit. Continue coring in each direction until locating a core that is not unacceptable. The engineer will determine the limits of the unacceptable area, at each end, by drawing lines across the unit of pavement midway between the locations of the last 2 cores.

Perform coring according to AASHTO T 24. The engineer will evaluate the results according to AASHTO T 148.

3.6 Curb and Gutter Construction

3.6.1 Foundation

Prepare the foundation by excavating or filling to the lines, grades, and cross section the plans show and required for placing concrete. Remove and replace all soft or unsuitable material with suitable material. Compact the foundation to ensure stability

If the plans show, place granular subbase or aggregate base to the thickness and section the plans show.

3.6.2 Placing, Consolidating and Finishing Concrete

Construct curb, gutter, and curb and gutter to the lines, grades, cross section, and dimensions as shown on the plans.

Use a slip-form curb machine to place, form, and consolidate concrete for curb, gutter, and curb and gutter. Use fix-formed placement methods in areas inaccessible to slip-form methods.

Unless constructed integrally with concrete pavement, securely anchor concrete curb, gutter, or curb & gutter, to adjoining concrete pavement by placing specified tie bars if and as the plans show.

Tie new work to existing concrete pavement using tie bars epoxied into the existing concrete. Use only cast-in-place tie bars in construction joints between pavement and curb, gutter, or curb & gutter placed under the contract.

Construct depressions in or revisions of the curb head, in curb, or curb & gutter to accommodate curb ramps and driveways at locations and as the plans show.

Unless specified otherwise, round the back edge of curbs, the edge of the gutter next to the pavement, with a 1/4 inch radius edger.

Unless specified otherwise in the contract, the contractor may construct curb, gutter, or curb & gutter by slip-forming integrally with the pavement. Concrete curb, and or gutter constructed as Integral Curb shall be constructed such that it and the concrete pavement are monolithic. Extend the joints in the pavement through the integral curb, gutter, or curb & gutter. Space these joints to match the joints in the adjacent pavement.

The engineer will not require load transfer dowels within the limits of the integral curb, gutter, or curb & gutter as the plans show. Tie bars at the limits or flange line of the curb, gutter, or curb and gutter are not required unless the plans require that a sawed longitudinal joint be constructed at the flange line. Construct integral curb, gutter, or curb & gutter to the section the plans show.

Check the finished flow line, face of curb, and top of curb with a level and straight edge to ensure positive drainage in the flow line and a straight curb head. Deviations from the straight edge shall be corrected immediately.

3.6.3 Jointing

Install contraction joints by sawing or forming an induced plane of weakness at least 2 inches deep.

Place contraction joints in the curb, gutter, or curb & gutter directly opposite all construction or contraction joints in adjoining concrete pavement and at the required spacing in curb, gutter, or curb & gutter adjoining asphaltic pavement.

Edge formed joints, construction joints, and fixed forms with a 1/4-inch radius.

3.6.4 Expansion Joints

Place expansion joints in curb, gutter, or curb & gutter constructed next to asphaltic pavement located everywhere that tangent and radial curb, or curb & gutter meet; and on tangent sections spaced between 6 feet and 300 feet.

Place expansion joints in curb, gutter, or curb and gutter constructed next to concrete pavement with expansion joints, then place expansion joints to match the expansion joint locations in the pavement.

Set joints at right angles to the face and top of the curb, and at right angles to the flow line and surface of gutters. Use 3/4-inch wide joint filler.

3.6.5 Final Surface Texture

Surface finish with a fine concrete finishing broom in the transverse direction and approximately 3-inches wide longitudinally in the flow line

3.7 Sidewalk Construction

3.7.1 Foundation

Prepare the foundation by excavating or filling to the lines, grades, and cross section the plans show and required for placing concrete. Remove and replace all soft or unsuitable material with suitable material.

In cuts, make the foundation wide enough to allow placing forms and performing concrete placement and finishing. On embankments, construct the foundation at least 2 feet wider than the proposed sidewalk and extend it at least one foot beyond each end of the sidewalk.

Unless specified otherwise, fill depressions in the foundation with materials similar to those in the existing foundation. The contractor may use granular subbase or aggregate base. Compact the foundation to ensure stability.

If the plans show, place granular subbase or aggregate base to the thickness and section the plans show.

3.7.2 Placing, Consolidating and Finishing Concrete

Construct sidewalk to the lines, grades, cross section, and dimensions as shown on the plans. The maximum cross slope is 2.0% with a target value of 1.5%.

The contractor may use a machine to place, form, and consolidate concrete for sidewalk. The resulting slip-formed product shall equal or exceed that produced by fixed-form placement methods.

Strike-off and finish to a true and even surface. Before the mortar sets, brush or lightly broom the surface. Before performing the final surface finish, check the sidewalk surface with a 10-foot straightedge, and correct all areas that vary 1/4 inch from the testing edge by adding or removing concrete while the concrete is still plastic.

Construct curb ramps at the locations and conforming to the details and dimensions the plans show. Install detectable warning fields for curb ramps conforming to manufacturer-recommended procedures.

3.7.3 Jointing

For sidewalks of uniform width, construct transverse joints at right angles to the sidewalk centerline, and construct longitudinal joints parallel to the centerline, unless specified otherwise. For sidewalks of variable or tapering widths, make the transverse and longitudinal joints at right angles to each other, if possible.

Ensure that all joint axis do not deviate more than 1/2 inch from a straight line, or from the designated alignment at any point.

If constructing the sidewalk in partial width slabs, place transverse joints so they match the like joints in adjacent slabs. If widening existing sidewalks, place transverse joints in line with like joints in the existing sidewalk.

If possible, do not divide sidewalks into sections less than 3 feet, or greater than 10 feet in any dimension.

The contractor may form or saw contraction joints, unless otherwise noted on the plans.

Form joints by scoring the finished surface not less than 1/4 of the depth with an appropriate tool.

Saw joints not less than 1/4 of the depth and approximately 1/8 inch wide. Perform the sawing as soon as possible after the concrete sets sufficiently to prevent raveling during sawing and before shrinkage cracking occurs.

Edge formed joints, construction joints, sidewalk edges and fixed forms with a 1/2-inch radius.

3.7.4 Expansion Joints

Place 1/2-inch wide transverse expansion joint filler through the sidewalk at uniform intervals not greater than 96 feet apart.

Place 1/2-inch wide expansion joint filler between the sidewalk and back of abutting parallel curb or gutter; and place one-inch wide expansion joint filler between sidewalk and buildings or other rigid structures.

Place 1/2-inch wide expansion joint filler between sidewalk approaches and the back of curb or gutter or edge of pavement

Extend the expansion joint filler to the concrete's full depth and make the top slightly below the finished surface of the sidewalk.

3.7.5 Final Surface Texture

Surface finish with a fine concrete finishing broom in the transverse direction.

3.7.6 Curb Ramp Detectable Warning Field

Install curb ramp detectable warning field meeting the requirements of the Americans for Disabilities Act in accordance with the plan details.

Assemble modular plates to achieve the required size of the warning field. Verify the layout of Detectable warning field plates and jointing of the curb ramp with the engineer prior to placement.

3.8 Measurement

Measure Concrete Pavement, and Concrete Alley bid items by the square yard acceptably completed, measured using the centerline length and the width from outside to outside of completed pavement

including integral curb and gutter when required by the contract, but limited to the width the plans show or the engineer directs. The engineer will include fillets for widened sections, or at drain basins and similar locations, placed monolithic with the pavement. Integral curb when installed as a contractor option will be measured under the respective curb and gutter bid items and will not be included in the measurement of the adjacent concrete pavement.

Measure Concrete Driveway bid items by the square foot acceptably completed, measured using the length and width from outside to outside of completed driveways and outside the specified limits for the pavement, curbs, gutters, curb & gutter or other structures.

Measure Concrete Pavement Approach Slab bid items by the square yard acceptably completed, based on the width and length the plans show or the engineer directs.

Measure Concrete Pavement Gaps as each individual gap acceptably completed including eliminated gaps the engineer allows the contractor to pave through, measured separately for each roadway. Measure multiple gaps at one roadway location as required to conform to contract staging provisions, but not solely to accommodate the contractor's means and methods.

Measure Drilled Tie Bars and Drilled Dowel Bars as each individual bar acceptable completed.

Measure all the curb, gutter, and curb & gutter bid items by the linear foot acceptably completed including integral curb constructed as a contractor option. The length measured equals the distance along the base of the curb face, or along the flow line of the gutter. Measure continuously along a line extended across driveway and alley entrance returns or ramps. When integral curb along concrete pavement is required by the contract the integral curb shall be included in the bid item of concrete pavement. Measure all excavation required for and performed during this work, if covered by a bid item in the contract, as specified in the specifications. However, if the contract does not provide a bid item for excavation, it is incidental to the work.

Measure Concrete Sidewalk bid items by the square foot acceptably completed. Measurement includes the area of the curb ramp and warning field.

3.9 Payment

3.9.1 General

Payment for the Concrete Pavement, Concrete Pavement HES, Concrete Alleys, Concrete Alley HES, and Concrete Driveway bid items is full compensation for preparing the foundation, unless provided otherwise; for furnishing, hauling, preparing, placing, curing, and protecting the concrete; for measuring opening strength including fabricating and testing cylinders, and obtaining and testing cores; for measuring pavement thickness, and for filling all core holes. Payment includes jointing and providing tie bars and dowel bars in unhardened concrete.

Payment for the Concrete Pavement Approach Slab bid items is full compensation for providing the approach slab; and for bar steel reinforcement, dowel and tie bars, and jointing materials.

Payment for Concrete Pavement Gaps is full compensation for providing pavement gaps. If the engineer allows paving through a gap, pay the full contract price for each gap eliminated. Payment for furnishing and placing concrete material is included under Concrete Pavement.

Payment for Drilled Tie Bars or Drilled Dowel Bars is full compensation for providing and installing tie bars or dowel bars, including coating; for drilling holes in concrete not placed under the contract; and for epoxying.

Payment for all the curb, gutter, and curb & gutter bid items is full compensation for all foundation excavation and preparation; all special construction required at driveway and alley entrances, or curb

ramps; for providing all materials, including concrete, expansion joints; for placing, finishing, protecting, and curing; for sawing joints; and for disposing of surplus excavation material, and restoring the work site. However, if the contract provides a bid item for excavation, pay for excavation required for this work as specified in the contract. Payment also includes providing and installing tie bars in unhardened concrete.

Payment for the Concrete Sidewalk bid items, including the area of curb ramp and warning field, is full compensation for providing all materials, including concrete, reinforcement, and expansion joints; for excavating and preparing the foundation; backfilling and disposing of surplus material; for placing, finishing, protecting, and curing; and restoring the work site. However, if the contract provides a bid item for excavation, then pay for work required and performed in constructing concrete sidewalks as specified in the contract. Payment also includes providing and installing tie bars and dowel bars in unhardened concrete.

Payment for the Curb Ramp Detectable Warning Field bid items is full compensation for providing and installing the warning field of the specified color.

3.9.2 Adjusting Pay for Concrete Pavement Thickness

For nonconforming pavement thinner than plan thickness minus 3/8 inch and subject to pay adjustment, payment will be adjusted as follows:

For Pavement with a Measured Thickness	Percent of the Contract Unit Price
> 3/8 inch but <= 1/2 inch	80
> 1/2 inch but <= 3/4 inch	70
> 3/4 inch but <= 1 inch	50

If areas of pavement have unacceptable measured thickness the engineer will direct the contractor to remove and replace with concrete pavement of conforming thickness. Payment for unacceptable areas removed and replaced with concrete pavement of conforming thickness will be at the full contract price.

Optional Special Provisions

Contracting Agency Testing:

The following "Contracting Agency Testing" special provision may be used to incorporate contracting agency quality control testing in lieu of contractor quality control testing. This special provision requires the contracting agency to perform acceptance tests for compressive strength, air content, and temperature. The contractor will determine the concrete mix design, provide aggregate quality testing and perform all contractor process control testing.

This special provision modifies the Portland Cement Concrete Pavement and Flatwork Specification requiring contracting agency quality control testing for acceptance of compressive strength, air content, slump, and temperature. The contractor will determine the concrete mix design, provide aggregate quality testing and perform all contractor process control testing.

Replace section 1.2.4 with the following:

1.2.4 Approval by Sampling and Testing

Approval of materials will be based on a combination of the results of the following:

1. Contracting agency testing.
2. Optional contractor assurance testing.
3. Inspections of the materials production, storage, handling, and construction processes.
4. Dispute resolution procedures.

Replace section 1.3 with the following:

1.3 Contracting Agency and Contractor Testing

1.3.1 General

Concrete acceptance tests for compressive strength, air content, slump, and temperature will be performed by the contracting agency. The contractor will be responsible for the concrete mix design, aggregate quality testing and optional process control testing.

1.3.2 Personnel

Perform the material sampling, testing, and documentation required using a certified technician.

1.3.3 Laboratory

Perform the concrete mix design and aggregate testing at a qualified laboratory.

1.3.4 Equipment

Furnish the necessary equipment and supplies for performing quality control testing. Calibrate all testing equipment and maintain a calibration record at the laboratory.

1.3.5 Concrete Mixes

Determine Class I and Class II Concrete mixes for the project conforming to Part 2. Test concrete during mix development at a qualified laboratory.

Submit a concrete pavement mix report at least 3 days before producing concrete in accordance with section 2.3.4 or section 2.3.5. On the mix report clearly indicate the type/classification of aggregates per section 2.3.3.1.

1.3.6 Documentation

Submit test results to the engineer and contractor upon request.

1.3.7 Testing

1.3.7.1 General

Perform all quality control tests necessary to control the production and construction processes. Use the test methods identified below to perform the following tests:

Aggregate gradations	AASHTO T 11 & T 27
Aggregate materials finer than the No. 200 sieve	AASHTO T 11
Aggregate moisture	AASHTO T 255
Sampling Freshly mixed concrete	AASHTO R60
Air content	AASHTO T 152
Slump	AASHTO T 119
Temperature	ASTM C1064
Compressive Strength	AASHTO T 22, T 23, M 201

1.3.7.2 Aggregate Gradation

1.3.7.2.1 Sampling and Testing

The engineer may accept aggregate gradation based upon satisfactory records of previous testing.

Randomly sample and test the individual aggregate gradations according to AASHTO T 11 and AASHTO T 27. Have a certified technician sample and test the aggregate and document the results.

Test aggregates during production at a minimum frequency of 1 test per 1000 tons of aggregate produced up to a maximum of 3 tests per day. Production tests may be performed during aggregate production or during load out from aggregate source stockpile to plant site stockpile.

If aggregate production test records are not available or not acceptable to the engineer, sample and test aggregates during concrete production at a minimum frequency of 1 test per 500 cubic yards of concrete produced up to a maximum of 3 tests per day.

1.3.7.2.2 Documentation

Maintain control charts or tables at the laboratory for each aggregate stockpile. Maintain a chart or table for each control sieve for each material. Record contractor test results the same day tests are conducted.

Notify the engineer whenever an individual test value exceeds a control limit. Material is nonconforming when an individual test exceeds the control limit. The quantity of nonconforming material includes the material of the first test exceeding the control limit, continuing to but not including, the material from the first subsequent test that is within the control limits.

1.3.7.3 Aggregate Percent Passing the No. 200 Sieve

1.3.7.3.1 Sampling and Testing

Have a certified technician sample and test the aggregate and document the results.

Measure and record the percent passing the No. 200 sieve of both the fine and coarse aggregates when producing concrete pavement. Conduct tests according to AASHTO T 11.

Sample and test at least one combined aggregate gradation prior to producing concrete for the project. Sample and test aggregates during concrete production at a minimum frequency as follows:

1. One test per 200 CY of concrete production up to a maximum of one test per day.
2. One test per 5 days of concrete production when the previous 5 consecutive p200 test results are less than or equal to 2.0 percent.

Ensure that the combined aggregate gradation, expressed as weight percentages of the total aggregate, for the percent passing the No. 200 sieve is less than or equal to 2.3 percent.

1.3.7.3.2 Documentation

Document testing using a combined gradation control chart or table for the percent passing the No. 200 sieve.

Notify the engineer whenever an individual test value exceeds a control limit. Material is nonconforming when an individual test exceeds the control limit. The quantity of nonconforming material includes the material of the first test exceeding the control limit, continuing to but not including, the material from the first subsequent test that is within the control limits

1.3.7.4 Concrete Sampling

Sample fresh concrete at the point of placement

1.3.7.5 Slump

The contracting agency shall have a certified technician measure slump according to AASHTO T 119.

Slumps for nonslip-formed work shall be 4-inches or less.

1.3.7.6 Concrete Temperature

The contracting agency shall have a certified technician measure concrete temperature according to ASTM C 1064 when concrete temperatures at the point of placement are subject to fall below 60 F.

1.3.7.7 Air Content

1.3.7.7.1 Sampling and Testing

On each day of production the contractor shall test air content at the point of placement at start-up and as frequently as practicable until the concrete meets the specifications and the production process is under control.

The contracting agency shall test air content as follows:

For class I concrete items test air content for each compressive strength test.

For class II concrete items test air content at a minimum frequency of one test per 100 CY of concrete.

The contracting agency shall have a certified technician test air content according to AASHTO T 152. Test concrete taken from the same sample used for strength cylinders.

The concrete air content control limits after applying the aggregate correction factor is as follows:

- Slip-formed concrete 7.0 percent +/- 1.5 percent
- All other concrete 6.0 percent +/- 1.5 percent

Make every attempt to run at or above the target air content.

1.3.7.7.2 Documentation

Ensure that all test results are recorded and become part of the project records. Submit air content test results to the contractor on the compressive strength test reports.

If an individual air test is outside the control limits, notify the contractor, and perform additional air tests as often as it is practical on subsequent loads until the air content is inside the control limits. The material is nonconforming when an individual test exceeds the control limit. Material from the load with the first test exceeding the control limit, continuing to but not including the load with the first subsequent test within the control limits, is nonconforming.

1.3.7.8 Compressive Strength

Acceptance of concrete will be based on 28 day compressive strength of concrete cylinders performed by the contracting agency.

1.3.7.8.1 Sampling and Curing

The contracting agency shall sample according to AASHTO R 60 and cast and initially cure the cylinders according AASHTO T 23.

For class I concrete items randomly select and cast one set of 3 standard 6X12 inch cylinders for each mix grade and placement type at a minimum frequency of one test per 500 CY of concrete, and in any event, not less than one test for each ½ day of placement.

For class II concrete items randomly select and cast one set of 2 standard 6x12 cylinders for each mix grade and placement type at a minimum frequency of one test per 200 CY of concrete.

Do not cast more than one set of cylinders from a single truckload of concrete.

The contracting agency shall provide facilities for initial curing and transport the specimens to a qualified laboratory for standard curing according to AASHTO M 201 for 28 days.

1.3.7.8.2 Compressive Strength Testing

The contracting agency shall have a certified technician, in a qualified laboratory, perform compressive strength testing and document the results. For class I concrete randomly select 2 cylinders to test at 28 days. For class II concrete select 2 cylinders to test at 28 days.

Determine the 28-day compressive strength in psi of each cylinder according to AASHTO T 22. Test each cylinder to failure. Use a compression machine that automatically records the date, time, rate of loading, and maximum load of each cylinder. Include a printout of this information with the compressive strength documentation for each cylinder tested.

For Class I concrete compare the strengths of the 2 randomly selected cylinders and determine the 28-day average strength as follows:

- If the lower strength divided by the higher strength is 0.9 or more, average the 2 cylinders.
- If the lower strength divided by the higher strength is less than 0.9, break one additional cylinder and average the 2 higher strength cylinders.

For Class II concrete determine the 28-day average strength by averaging the 2 cylinders.

1.3.7.8.3 Compressive Strength Evaluation

The contracting agency shall furnish the contractor with a copy of all test reports

For Class I concrete no less than one test for each 500 cubic yards of concrete placed will be required, and in any event, not less than one test for each ½ day of placement.

For Class II concrete no less than one test for each 200 cubic yards of concrete placed will be required.

If the average 28 day compressive strength is less than 3250 psi or if either of the two 28 day cylinders has a compressive strength less than 3000 psi the engineer may direct the contractor to core the subject area to determine its structural adequacy and whether to direct removal. Cut and test cores according to AASHTO T 24 as and where the engineer directs. Have a certified technician perform or observe the coring. Fill all core holes with an approved grout, and provide traffic control during coring at the contractors expense.

The concrete is conforming if the compressive strengths of all cores from the represented area are 3000 psi or greater or the engineer does not require coring.

The concrete is nonconforming if the compressive strength of any core from the represented area is less than 3000 psi.