



Guide Specification for Materials and Construction of Jointed Concrete Pavement for Streets and Local Roads

April 2012

Disclaimer

The information contained herein is provided for use by professional personnel who are competent to evaluate the significance and limitations of the information provided and who will accept total responsibility for the application of this information. The project Engineer of Record is responsible for the review and acceptance of the materials and construction specifications. The recommended specification requirements, criteria, and language herein reflect the professional knowledge and experience of the National Ready Mixed Concrete Association (NRMCA). However, NRMCA makes no representations or warranties concerning the fitness of this information for any particular application or installation and **DISCLAIMS** any and all **RESPONSIBILITY** and **LIABILITY** for the accuracy of and the application of the information provided to the full extent of the law.

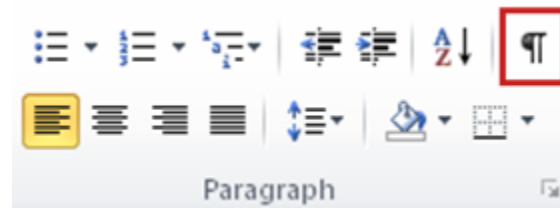
Introduction

The following specification has been developed for use by owners and their design consultants to define material and construction requirements, criteria, and expectations of material suppliers and construction contractors. The definitions, test methods, and quality requirements are considered current state of the practice for the industry at the time of publication. This document is a recommended guide specification and has not been developed through a consensus process typical of industry standards that can be referenced. It should not be incorporated by reference in project specifications or contract documents.

Jointed unreinforced streets and local roads may be designed using various methods; however, NRMCA recommends using the American Concrete Institute (ACI) procedure 325.12R-02 *Guide for the Design of Jointed Concrete Pavements for Street and Local Roads* (www.concrete.org) or the American Concrete Pavement Association's *StreetPave Software* (<http://www.acpa.org/>) both of which specifically address the unique conditions inherent to streets and local roads and provide optimized concrete pavement thicknesses for city, municipal, county, and state roadways.

Notes to Specifier

1. Prior to use on a project, this guide specification should be thoroughly reviewed by the Project Engineer of Record for applicability to the specific project and local conditions. It is intended that the language contained herein will be modified, as necessary, to fit within the project contractual conditions and local preferences and that the referenced test methods will be modified accordingly.
2. All references to NRMCA on the cover page and in the main document header should be removed prior to incorporation into the final project specifications by the Engineer of Record or their representative.
3. The specification includes hidden text throughout which provides guidance to the specifier regarding the applicability or use of a section/subsection. Hidden text may be shown or hidden with the use of the Show/Hide button to see notes about optional language and what should be removed from the specification if it is not applicable. **Hidden text is indicated as blue text.** The hidden text should not be shown in the final project specification. The Show/Hide button in Microsoft Word is highlighted below. Print options can suppress printing of hidden text.



4. There are several locations where the engineer of record needs to input information specific to the project for which this specification is being issued. Without modifying these locations, this specification is incomplete. Locations identified as **<bold text>** indicate required information to be completed by the specifier. Locations identified as **[bold text]** generally indicate choices between one or more options to be selected by the specifier. The specifier is responsible for removing or inserting these for the final project specification. The engineer can also add other clauses as is typical for local practice and standard of care.
5. NRMCA requests feedback regarding this guide specification in terms of clarity of the language, constructability, and specification criteria/parameters. Feedback may be emailed to Publications@nrmca.org. Please include the specification title, revision number, and section/subsection number pertinent to your comment(s).

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SECTION 32 13 13.51 – CONCRETE PAVEMENT FOR STREET AND LOCAL ROAD APPLICATIONS

PART 1 - GENERAL

1.0 PROJECT IDENTIFICATION

- A. This specification is to be used for concrete pavement materials and construction associated with <insert project name and location>.

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions, apply to this Section.

1.2 SUMMARY

- A. This Section covers the requirements for the construction of unreinforced concrete pavements, with or without subbases, and may also include attached or integral curbs.
- B. Related Sections may include the following:
 - 1. Division 03 Section “Concrete Slip Forming” for pavement construction.
 - 2. Division 03 Section “Concrete Reinforcing” for dowel and tie bars.
 - 3. Division 03 Section “Concrete Curing” for concrete pavement and curb curing.
 - 4. Division 31 Section “Base Courses” for subgrade soil stabilization and subbases.
 - 5. Division 32 Section “Curbs, Gutters, Sidewalks, and Driveways” for attached curbs, gutters, and intersecting driveways.

1.3 DEFINITIONS

- A. Accepted: determined to be satisfactory to the engineer.
- B. Cementitious Materials: Portland cement alone or in combination with one or more of the following: blended hydraulic cement, fly ash and other pozzolans, slag cement, and silica fume; subject to compliance with requirements.
- C. Cold Weather: a period when for more than three successive days the average daily outdoor temperature drops below 40°F (5°C). The average daily temperature is the average of the highest and lowest temperature during the period from midnight to midnight. When temperatures above 50°F (10°C) occur during more than half of any 24 h duration, the period shall no longer be regarded as cold weather.
- D. Construction Joint: a joint constructed from two separate placements where the first has undergone final setting before the next placement.

- E. Contraction Joint: formed, sawed, or tooled groove in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure.
- F. Contractor: the person, firm, or entity under contract for construction of the Work.
- G. Contract Documents: a set of documents supplied by Owner to Contractor as the basis for construction; these documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.
- H. Dowel Bars: steel pins, commonly plain round steel bars that extend into adjoining portions of a concrete construction, as at a joint in a pavement slab, to transfer shear loads.
- I. Engineer: the engineer or engineering firm issuing Contract Documents or administering Work under the contract documents, or both.
- J. Exposure Conditions:
 - 1. Negligible: absence of exposure to freezing and thawing or to deicing agents.
 - 2. Moderate: exposure to a climate where the concrete will not be in a saturated condition when exposed to freezing and will not be exposed to deicing agents or other aggressive chemicals.
 - 3. Severe: exposure to deicing chemicals or other aggressive agents or where the concrete can become saturated by continual contact with moisture or free water before freezing.
- K. Free Edge: the edge of pavement abutting an isolation joint or the edge of the pavement against which no concrete is placed.
- L. High-Early-Strength Concrete: concrete that, through the use of additional cement, high-early-strength cement, or admixtures, has accelerated early-age strength development.
- M. Hot Weather: any combination of the following conditions that tend to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise resulting in detrimental results.
 - 1. high ambient temperature above 90°F (32°C);
 - 2. high concrete temperature;
 - 3. low relative humidity;
 - 4. wind velocity; and
 - 5. solar radiation.
- N. Isolation Joint: a separation between adjoining parts of a concrete structure, usually a vertical plane, at a designed location such as to interfere least with performance of the structure, yet such as to allow relative movement in three directions and avoid formation of cracks elsewhere in the concrete and through which all or part of the bonded reinforcement is interrupted.
- O. Owner: the corporation, association, partnership, individual, public body, or authority for whom the work is constructed.
- P. Panel: an individual concrete slab bordered by joints or slab edges.

- Q. Project Drawings: graphic presentation of project requirements.
- R. Project Specifications: the written document that details requirements for Work in accordance with service parameters and other specific criteria.
- S. Subbase (also called base): a layer in the pavement system between the subgrade and the concrete pavement.
- T. Subgrade: the soil prepared and compacted to support the pavement system.
- U. Tie Bar: a reinforcing bar, commonly a deformed steel bar intended to transmit tension, compression, or shear through a construction joint.
- V. Tolerances: the permitted deviation from a specified dimension, location, or quantity. Plus (+) tolerance increases the amount or dimension to which it applies or raises a level alignment. Minus (-) tolerance decreases the amount or dimension to which it applies or lowers a level alignment. Where only one signed tolerance is specified (+ or -), there is no limit in the other direction.
- W. Unreinforced Concrete Pavement: concrete pavement that does not contain distributed deformed steel reinforcing bars or welded wire fabric. Pavement may include dowel bars at the joints (construction and possibly contraction joints) and tie bars in some locations.
- X. Water/Cementitious Ratio (*w/cm*): the ratio of the mass of water, exclusive only of that absorbed by the aggregates, to the mass of cementitious material (hydraulic) in concrete, stated as a decimal.
- Y. Work: the entire construction or separately identifiable parts thereof required to be furnished under the Contract Documents.

1.4 REFERENCED STANDARDS AND MANUALS

- A. All standards and manuals referenced herein shall be the latest versions or editions. Check with the reference organization for latest published version and utilize this version on the project.
 - 1. AASHTO M182: Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats
 - 2. ACI 301: Specifications for Structural Concrete
 - 3. ACI 306.1: Standard Specification for Cold Weather Concreting
 - 4. ACI 308.1: Standard Specification for Curing Concrete
 - 5. ACI CP-1: Technical Workbook for ACI Certification of Concrete Field Testing Technician-Grade 1
 - 6. ASTM A36/A36M: Standard Specification for Carbon Structural Steel
 - 7. ASTM A615/A615M: Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
 - 8. ASTM A775/A775M: Standard Specification for Epoxy-Coated Steel Reinforcing Bars
 - 9. ASTM WK34874: New Specification for Epoxy-Coated Steel Dowels for Concrete Pavement
 - 10. ASTM A820/A820M: Standard Specification for Steel Fibers for Fiber-Reinforced Concrete

11. ASTM C31/C31M: Standard Practice for Making and Curing Concrete Test Specimens in the Field
12. ASTM C33: Standard Specification for Concrete Aggregates
13. ASTM C39/C39M: Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
14. ASTM C42/C42M: Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
15. ASTM C94/C94M: Standard Specification for Ready-Mixed Concrete
16. ASTM C136: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
17. ASTM C138/C138M: Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
18. ASTM C143/C143M: Standard Test Method for Slump of Hydraulic-Cement Concrete
19. ASTM C150: Standard Specification for Portland Cement
20. ASTM C171: Standard Specification for Sheet Materials for Curing Concrete
21. ASTM C172/C172 M: Standard Practice for Sampling Freshly Mixed Concrete
22. ASTM C173/C173M: Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
23. ASTM C174/C174M: Standard Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores
24. ASTM C231/C231M: Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
25. ASTM C260/C260M: Standard Specification for Air-Entraining Admixtures for Concrete
26. ASTM C309: Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
27. ASTM C494/C494M: Standard Specification for Chemical Admixtures for Concrete
28. ASTM C566: Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
29. ASTM C595: Standard Specification for Blended Hydraulic Cements
30. ASTM C618: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
31. ASTM C989: Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
32. ASTM C1017/C1017M: Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
33. ASTM C1064/C1064M: Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
34. ASTM C1074: Standard Practice for Estimating Concrete Strength by the Maturity Method
35. ASTM C1077: Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
36. ASTM C1116/C1116M: Standard Specification for Fiber-Reinforced Concrete
37. ASTM C1157: Standard Performance Specification for Hydraulic Cement
38. ASTM C1240: Standard Specification for Silica Fume Used in Cementitious Mixtures
39. ASTM C1260: Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
40. ASTM C1293: Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
41. ASTM C1567: Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)

42. ASTM C1602/C1602M: Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
43. ASTM D698: Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³))
44. ASTM D994/D994M: Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)
45. ASTM D1751: Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
46. ASTM D1752: Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
47. ASTM D2628: Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements
48. ASTM D3406: Standard Specification for Joint Sealant, Hot-Applied, Elastomeric-Type, for Portland Cement Concrete Pavements
49. ASTM D3963/D3963M: Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars
50. ASTM D5893/D 5893M: Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements
51. ASTM E329: Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection
52. ASTM E548: Standard Guide for Proficiency Testing by Interlaboratory Comparisons
53. ASTM E950/E950M: Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference
54. ASTM E1980: Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces
55. CRSI's "Manual of Standard Practice," Latest Edition.
56. NRMCA QC 3 – Checklist for Certification of Ready Mixed Concrete Production Facilities, NRMCA, www.nrmca.org

1.5 SUBMITTALS

- A. LEED Submittals: As required by the LEED for Neighborhood Development Rating System (Latest Edition).
 1. Prerequisite 4 Construction Activity Pollution Prevention: Demonstrate conformance with the Erosion and Sediment Control Plan pertaining to wash water and other pollutants that may be part of concrete transport and delivery.
 2. Credit 9 Heat Island Reduction: For products (cement and aggregate combined), evidentiary documentation that the Solar Reflectance Index (SRI) is at least 29 calculated using ASTM E1980. For standard grey concrete or concrete using white cement, no testing is required because they are deemed to comply with SRI 29 or greater in LEED.
 3. Credit 15 Recycled Content in Infrastructure: For products having recycled content, documentation indicating percentages by weight of postconsumer and preconsumer recycled content.
- B. Design Mixtures: For each concrete mixture proposed for the Work. Submit changes to design mixtures when characteristics of materials, project conditions, weather, test results, or other circumstances warrant adjustments. Only submit adjustments that involve changes in material

sources or when the quantity of cementitious materials and aggregates vary by more than $\pm 5\%$ of that in the design mixtures or admixture quantities exceed the manufacturers recommended range

1. Indicate on delivery tickets of delivered batches of concrete amounts of mixing water withheld for addition at Project site.
- C. Dowel and Tie Bar Steel Reinforcement Drawings: Drawings that detail placement. Include bar sizes, lengths, material, grade, and supports for concrete reinforcement.
- D. Qualification Data: For each plant supplying, vehicle transporting, installer, laboratory, and technician involved in testing concrete for paving, submit documentation that the appropriate certifications have been obtained and are currently valid.
- E. Material Certificates: For each of the following, signed by manufacturers:
1. Cementitious materials.
 2. Admixtures.
 3. Steel reinforcement and accessories.
 4. Fiber reinforcement.
 5. Curing compounds.
 6. Joint filler.
- F. Quality control plan as described in Section 1.6 and field quality-acceptance inspection and testing reports as described in Section 3.12.
- G. Jointing Plan: If the contractor is responsible for the joint layout and plan, submit plan in accordance with and as described in Section 3.7.B.

1.6 QUALITY CONTROL PLAN

- A. Quality Control Plan: Prepare a plan addressing the elements that affect the quality of the pavement. Submit this plan at least **[14]** or **[insert number of days]** days prior to commencement of concrete paving. The Quality Control plan should also address the conduct of acceptance testing. The plan should address at a minimum the following:
1. Introduction with Project Description and Key Contact Information
 2. Organizational Chart Delineating the Flow of Responsibility
 3. Duties and Responsibilities of Project Personnel
 4. Pre-Paving Meeting Agenda¹
 5. Inspections and Submittals
 6. Process Control Testing Plan and Submittals
 7. Contractor Acceptance Testing Plan and Submittals
 8. Deficiencies Reporting
 9. Conflict Resolution
 10. Defective Pavement Repair
 11. Changes To The QC Plan During Work

¹ See NRMCA Concrete In Practice (CIP) Series 32 – Concrete Pre-Construction Conference for Recommended Pre-Paving Agenda Items (<http://www.nrmca.org/aboutconcrete/cips/default.asp>)

12. Supporting Information as Needed

1.7 QUALITY ASSURANCE

- A. Installer Qualifications: A qualified installer who employs on project personnel qualified as ACI-certified Concrete Flatwork Technician and a supervisor who is an ACI-certified Concrete Flatwork Finisher.
- B. Manufacturer Qualifications: A firm experienced in manufacturing ready-mixed concrete products and that complies with ASTM C94/C94M requirements for production facilities and equipment.
 - 1. Manufacturer's production facilities and delivery vehicles certified according to NRMCA's "Certification of Ready Mixed Concrete Production Facilities" **<optional: and "Sustainable Concrete Plant Certification Bronze level or higher.">**
 - 2. Personnel responsible for quality control/quality assurance of concrete, certified as NRMCA Concrete Technologist Level 2 or equivalent certification required by state highway agency in the jurisdiction of the Work.
- C. Testing Agency Qualifications: An independent agency, complying with the requirements of ASTM C1077 and ASTM E329 for quality assurance testing indicated, or similar and acceptable to the Engineer.
 - 1. Personnel conducting field tests shall be qualified as ACI Concrete Field Testing Technician, Grade 1, according to ACI CP-1 or an equivalent certification program. Equivalent certification programs shall include a component that evaluates performance of the test methods.
 - 2. Personnel performing laboratory tests shall be ACI-certified Concrete Strength Testing Technician or Concrete Laboratory Testing Technician – Level I. Testing Agency laboratory supervisor shall be an ACI-certified Concrete Laboratory Testing Technician – Level II.
- D. Source Limitations: Use the same source of cementitious materials, aggregates, chemical admixtures and other ingredients for concrete mixtures for the duration of the project, unless otherwise permitted.
- E. Concrete Mixture Design: A qualified laboratory shall perform material evaluation tests and design concrete mixtures. The qualified laboratory can be the concrete supplier's laboratory facility or an independent testing agency either of which shall be accredited for testing concrete mixtures and aggregates by the AASHTO Accreditation Program (AAP) or similar as accepted by the Engineer.

1.8 EQUIPMENT

- A. Paving Equipment: Furnish the paving and finishing equipment applicable to the type of construction in this Work, as follows:

1. Slipform Machines: If slipforming, furnish machines capable of spreading, consolidating, screeding, and finishing the freshly placed concrete in one pass to provide a dense and homogeneous pavement requiring minimal hand finishing. Equip the paving machine with the following:
 - a. Automatic controls to control line and grade from either or both sides of the machine, or from averaging-skis that reference the grade.
 - b. Vibrators to consolidate the concrete for the full width and depth of the strip of pavement being placed.
 - c. A positive interlock system to stop all vibration and tamping elements when forward motion of the machine stops.
 2. Self-Propelled Form-Riding Machines: Where used, furnish mechanical, self-propelled spreading and finishing machines capable of consolidating and finishing the concrete with minimal hand finishing. Do not use machines that displace the fixed side forms. Furnish internal immersed tube or multiple spud vibrators. Attach vibrators to the spreader or finishing machine, or attach them on a separate carriage that precedes the finishing machine.
 3. Manual Fixed-Form Paving Machines: Where needed, furnish spreading and finishing machines capable of consolidating and finishing concrete up to 8 in. (200 mm) thick.
- B. **Vibrators:** Operate immersed vibrators at frequencies within 5,000- 8,000 vibrations/minute. Furnish a surface pan vibrator as an alternate to immersed tube or multiple spud vibrators for consolidation of 8 in. (200 mm) or thinner concrete slabs. Operate the surface pan vibrator at a frequency no less than 3,500 vibrations/minute. For construction of irregular areas, use handheld immersed vibrators. Operate the vibrator at a frequency in the range recommended by the manufacturer for the vibrator's head diameter.
- C. **Concrete Saws:** Furnish concrete saws that are capable of sawing newly placed concrete for crack control on all concrete pavements included in the Work. Equip all saws with blade guards and guides or devices to control alignment and depth. Early entry saws may be used and shall provide a minimum sawcut depth of 1 in. (25mm) and contain a skid plate straddling the blade that exerts downward pressure on the surface of the concrete to prevent chipping or raveling of the sawcut.
- D. **Forms:** When used, furnish straight, steel forms with a height equal to the nominal pavement thickness at the edge. For curved edges with radii less than 100 ft. (30 m), furnish flexible or curved forms. Conform to the following:
 1. Use straight forms that are 10 ft. (3 m) minimum in length.
 2. Use forms with a maximum top face deviation of 1/8 in. in 10 ft. (3 mm in 3 m).
 3. Use forms with a maximum inside face deviation of 1/4 in. in 10 ft. (6 mm in 3 m).
 4. Equip each form with devices to adequately secure the form to the subbase or subgrade, and to withstand operation of the paving equipment and pressure of the concrete.
 5. Equip each form with devices to tightly join and lock each end to abutting form sections.
- E. **Joint Sealing:** Furnish joint sealing equipment, if required, according to the sealant manufacturer's recommendations for the sealant specified in the Plans.

- F. Finishing Tools: Furnish aluminum, magnesium or wooden hand finishing tools.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Dowel and Tie Bar Steel Reinforcement: Deliver, store, and handle steel reinforcement to prevent bending and damage. Avoid damaging coatings, if used, on steel reinforcement.

PART 2 - PRODUCTS

2.1 CONCRETE MATERIALS

- A. Comply with ASTM C94/C94M and the following requirements.
 - 1. Cement: Conform to ASTM C150, C595 or C1157.
 - 2. Supplementary Cementitious Materials (SCMs):
 - a. Fly ash conforming to ASTM C618.
 - b. Slag cement conforming to ASTM C989.
 - c. Silica fume conforming to ASTM C1240.
 - 3. Water: Conform to ASTM C1602/C1602M. Provide documentation required by ASTM C1602/C1602M when non-potable water is proposed for use.
 - 4. Aggregates: Conform to ASTM C33.
 - 5. Admixtures:
 - a. Air-Entraining Admixture: Conform with ASTM C260/C260M.
 - b. Chemical Admixtures: The following admixtures are permitted. Do not use calcium chloride or admixtures containing calcium chloride.
 - 1) Water-Reducing Admixture: ASTM C494/C494M, Type A.
 - 2) Retarding Admixture: ASTM C494/C494M, Type B.
 - 3) Water-Reducing and Retarding Admixture: ASTM C494/C494M, Type D.
 - 4) High-Range, Water-Reducing Admixture: ASTM C494/C494M, Type F.
 - 5) High-Range, Water-Reducing and Retarding Admixture: ASTM C494/C494M, Type G.
 - 6) Special Performance Admixture: ASTM C494/C494M, Type S.
 - 7) Plasticizing Admixture for flowing concrete: ASTM C1017/C1017M, Type I.
 - 8) Plasticizing and Retarding Admixture for flowing concrete: ASTM C1017/C1017M, Type II.

2.2 STEEL REINFORCEMENT

- A. Dowel and Tie Reinforcing Bars: When used, dowel and tie bars shall comply with the sizes and grades as shown on the plans. If dowel and tie bar material requirements are not shown on plans, comply with ASTM A615, Grade 60 (Grade 420) and:
1. Dowel bars shall be plain bars cut true to length with ends square and free of burrs.
 2. Epoxy-Coated Joint Dowel Bars shall comply with ASTM A775/A775M² epoxy coated.
 3. Plate Dowels shall be manufactured from hot rolled steel plate meeting ASTM A36.
 4. Tie bars shall be deformed bars.
- B. Bar Supports: Dowel bar chairs or other devices for spacing, supporting, and fastening reinforcing bars in place. Manufacture bar supports from steel wire, plastic, or precast concrete according to CRSI's "Manual of Standard Practice," of greater compressive strength than concrete.

2.3 FIBER REINFORCEMENT

- A. Carbon-Steel Fiber: Comply with ASTM A820, deformed, with a minimum of **<Insert dimension>** long, and an aspect ratio of **<Insert ratio>**.
- B. Synthetic Fiber: Utilize [**Monofilament**] or [**fibrillated**] polypropylene fibers engineered and designed for use in concrete pavement, complying with ASTM C1116/C1116M, Type III, **<Insert dimensions>** long.

2.4 CURING MATERIALS

- A. Liquid Membrane-Forming Compounds: Utilize a Membrane-Forming Curing Compound complying with ASTM C309, Type 2, Class A consisting of a waterborne, monomolecular film forming, manufactured for application to fresh concrete.
- B. Absorptive Cover: If used, comply with AASHTO M182, Class 2, burlap cloth made from jute or kenaf, weighing approximately 9 oz/yd² (305 g/m²) when dry.
- C. Moisture-Retaining Cover: If used, comply with ASTM C171, polyethylene film or white burlap-polyethylene sheet.

2.5 JOINT AND SEALANT MATERIALS

- A. Isolation Joint Materials: When used, comply with ASTM D994/D994M, D1751, or D1752, or as shown on plans.
- B. Joint Sealing Materials: When used, comply with the following:
1. Hot-Poured Elastomeric Type; ASTM D3406

² ASTM Committee A01.05 is currently developing a revised specification for epoxy coated dowel bars entitled *ASTM WK34874: New Specification for Epoxy-Coated Steel Dowels for Concrete Pavement* to supplement or replace ASTM A775. Until such time as the new ASTM specification is complete ASTM A775 is acceptable.

2. Silicone Rubber Type (cold applied); ASTM D5893/D5893M
3. Single-Component Elastomeric Type (preformed); ASTM D2628

2.6 CONCRETE MIXTURES

A. Mixture Design: Prepare design mixtures for each type and strength of concrete required, proportioned on the basis of field test records or laboratory trial mixtures according to ACI 301. Use a qualified laboratory in accordance with Section 1.7.E for preparing and reporting proposed mixture designs when proposed mixtures are based on laboratory trial mixtures.

1. Supplementary Cementitious Materials (SCMs): For concrete that will be in a Severe Exposure Condition, limit percentage of supplementary cementitious materials, by weight of total cementitious materials, to a maximum quantity as follows:
 - a. Fly Ash: 25 percent.
 - b. Slag Cement: 50 percent.
 - c. Silica Fume: 10 percent.
 - d. Total of Fly Ash, Slag, and Silica Fume: 50 percent.³
 - e. Total of Fly Ash and Silica Fume : 35 percent.³
 2. Strength: Specified compressive strength shall be 4,000 psi (28 MPa) at 28 days, unless otherwise specified.
 3. Total Air Content: Comply with Table 1, unless otherwise specified. The tolerance for air content shall be $\pm 1.5\%$.
 4. Aggregates: Nominal maximum aggregate size shall not exceed 1/3 of the specified pavement thickness.
 - a. When required by the Engineer, provide results of aggregate tests for alkali silica reactivity in accordance with ASTM C1260.
 - b. When ASTM C1260 expansion at 14 days measured on each source of aggregate exceeds 0.10%, provide test results with the aggregate and proposed combination of cementitious materials with an expansion that is less than or equal to 0.10% at 14 days, in accordance with ASTM C1567.
 5. Slump: For pavements placed other than by using slipform equipment, nominal slump shall be 4 in. (100 mm) ± 1 in. (25 mm), unless otherwise permitted. For pavements placed using slipform equipment the maximum slump shall be 2 in. (50 mm) +0 and $-1\frac{1}{2}$ in. (40 mm), unless otherwise permitted.
- B. Submit documentation for mixture proportions of concrete mixtures proposed for use in accordance with ACI 301 and Section 1.5.B herein.

³ Fly ash and silica fume shall constitute no more than 25% and 10%, respectively, of the total weight of the cementitious materials.

Table 1. Required Total Air Content¹.

Nominal Maximum Aggregate Size, in. (mm)	Total Air Content, % ²		
	Negligible Exposure	Moderate Exposure	Severe Exposure
3/8 (9.5)	N/A ³	6.0	7.5
1/2 (12.5)		5.5	7.0
3/4 (19.0)		5.0	6.0
1 (25.0)		4.5	6.0
1-1/2 (37.5)		4.5	5.5

Note 1: Measured in accordance with ASTM C173 or C231.

Note 2: Air content tolerance $\pm 1.5\%$

Note 3: Non-air entrained concrete, unless the concrete supplier chooses to entrain air in concrete mixtures.

PART 3 - EXECUTION

3.1 SUBGRADE/SUBBASE PREPARATION

- A. Prepare subgrade/subbase as required by the plans. If not specified on the plans or related specification, compact a minimum depth of 6 in. of subgrade to a minimum of 95% of the maximum dry density as determined by ASTM D698 and within $\pm 2\%$ of the optimum moisture content. Compact entire depth of subbase, if used, to a minimum of 98% of the maximum dry density as determined by ASTM D698 and within $\pm 2\%$ of the optimum moisture content.
- B. Construct subgrade/subbase to ensure that the required pavement thickness is obtained in all locations.
- C. Re-grade and re-compact subgrade/subbase disturbed by concrete delivery vehicles or other construction equipment to the requirements of Section 3.1.A.
- D. Do not use sand or loose material to obtain final subgrade or subbase elevation.
- E. At the time of concrete paving the density and moisture of the subgrade or subbase, if used, shall be in the condition described in section 3.1.A. Test compaction and moisture levels at a minimum frequency of 1 test per [500 yd² (420 m³)] or [insert area] per lift of compacted material.

3.2 SURFACE FIXTURES

- A. Adjust manhole frames and other fixtures within area to be paved to conform to finished surface. Comply with plans for manhole adjustments and water fixture adjustments.
- B. Clean outside of fixture to depth of pavement before concrete placement.
- C. Construct boxouts if necessary for later adjustment of fixtures. Comply with plans for the size and shape of the boxout.

3.3 FORMWORK

- A. Construct formwork so concrete pavement is of size, shape, alignment, elevation, and position indicated and so that the pavement is within the tolerance limits of Section 3.10 Tolerances.
- B. Construct forms tight enough to prevent loss of concrete mortar.
- C. Fabricate forms for easy removal without hammering or prying against concrete surfaces.
- D. Clean forms and adjacent surfaces to receive concrete. Remove debris from forms just before placing concrete.
- E. Retighten forms and bracing before placing concrete, as required, to prevent mortar leaks and maintain proper alignment.
- F. Coat contact surfaces of forms with form-release agent, according to manufacturer's written instructions, before placing reinforcement, if used.
- G. The edge of previously placed concrete may be used as a form. Do not apply form release agent to previously placed concrete, unless prevention of bond between the new and the old concrete is desired.
- H. Formwork may be removed after cumulatively curing at not less than 50°F (10°C) for 24 hours after placing concrete, if concrete is hard enough to not be damaged by form-removal operations and curing and protection operations are maintained.
- I. Clean and repair surfaces of forms to be reused in the Work. Damaged forms will not be acceptable. Apply new form-release agent.
- J. When forms are reused, clean surfaces, remove fins and laitance, and tighten to close joints. Align and secure joints to avoid offsets.

3.4 STEEL REINFORCEMENT

- A. Comply with CRSI's "Manual of Standard Practice" for placing reinforcement.
- B. Clean dowel and tie bar reinforcement of loose rust and mill scale, earth, ice, and other foreign materials.
- C. Place joint reinforcement at locations indicated on project drawings. Align dowels exactly centered over the joint line.
- D. Anchor dowel baskets securely into the subgrade. For paving lane widths greater than 12 ft (3.66 m), install a minimum of 4 stakes on the leave side of both basket legs.
- E. Do not place bent dowel baskets. Do not leave bent dowel baskets in place.
- F. At time of paving, make sure all dowels are parallel to the center line of the roadway, parallel to the base, baskets are properly pinned, and the center of each basket (i.e., the joint location) is clearly marked.

- G. Place and align to meet the requirements of Section 3.10, Tolerances.
- H. For epoxy-coated dowel bar reinforcement, if used, repair cut and damaged epoxy coatings with epoxy repair coating according to ASTM D3963/D3963M.

3.5 CONCRETE PLACEMENT

- A. Measure, batch, mix, and deliver concrete according to ASTM C94/C94M, and ASTM C1116/C1116M when fibers are used, and furnish batch ticket information required by these specifications.
- B. Before placing concrete, verify that installation of formwork, reinforcement, and embedded items is complete and that required inspections have been performed.
- C. When placing and finishing fixed-form concrete pavement, comply with the following steps:
 - 1. Deposit concrete directly from the transporting equipment onto the subgrade or subbase.
 - 2. Do not place concrete on frozen subgrade or subbase.
 - 3. Other methods of conveying the concrete may be used when specified or permitted by the Engineer.
 - 4. Deposit concrete between the forms to a uniform height.
 - 5. Consolidate concrete to remove voids and air pockets. Do not move concrete horizontally with a vibrator.
 - 6. Strike off concrete between forms using a form riding paving machine, vibrating screed, or laser screed. Other strikeoff devices may be used, such as a highway straightedge or scraping straightedge, when approved by the Engineer.
 - 7. Immediately after strikeoff and before bleed water appears on the surface, level concrete with a bullfloat.
 - 8. Do not use steel trowels or power finishing equipment, unless otherwise specified or permitted.
 - 9. Finish the pavement to the elevations, cross slope, and thickness specified in the project drawings and meet the requirements of Section 3.10, Tolerances.
- D. When placing and finishing slipform concrete pavement, comply with the following steps:
 - 1. Deposit and finish concrete in conformance with Section 3.5.C.
 - 2. The slipform paver shall be operated with adherence to continuous forward movement as possible, and as such, all delivery and spreading of concrete shall be coordinated so as to provide uniform progress without stopping and starting the machine. Coordination with the concrete supplier is especially important to achieve the desired result.
 - 3. Adjust the vibrator frequency for varying paver speeds and turn off vibrators when the paver stops.
 - 4. When the slipform paver is to ride on the edge of a new concrete pavement, the concrete strengths of the riding surface shall be greater than 2,000 psi (14 MPa), determined by testing field cured specimens in accordance with ASTM C31 or maturity methods in accordance with ASTM C1074.
 - 5. String lines or other means for setting grade should be checked frequently.
- E. Edging:

1. Edge top surface edges to a radius of 1/8 in. (3 mm).
 2. Do not tool edges if the joint is to be widened to provide a reservoir for joint sealant.
- F. Final Surface Texture⁴: Complete final texturing as soon as possible after finishing, but before the concrete has attained its initial set.
1. Artificial Turf Drag:
 - a. Drag artificial turf longitudinally along the concrete pavement surface after finishing. The turf shall be mounted on a work bridge or a moveable support system capable of varying the area of turf in contact with the pavement.
 - b. The turf drag shall be a single piece of artificial turf of sufficient length to span the full width of the pavement being placed. The turf shall have a means to adjust the height and/or length so as to always maintain a minimum of 4 ft (1.2 m) longitudinal length of turf in contact with the concrete being placed. Where construction operations necessitate and with the approval of the Engineer, the length and width of the turf may be varied to accommodate specific applications.
 - c. The turf used shall be an artificial grass type having a molded polyethylene pile face. The pile shall contain blades that are curled and/or fibrillated. The pile shall not contain straight, smooth monofilament blades. The pile shall include blade lengths of 0.6 to 1.3 in. (15 to 33 mm). The turf shall have a minimum weight of 60 oz/yd² (2,035 g/m²). The backing shall be a strong, durable material not subject to rot, and shall be adequately bonded to withstand use as specified.
 - d. Turf dragging operations should be delayed if there is excessive bleed water.
 - e. Prevent the turf from getting plugged with grout or dragging larger aggregates or foreign materials by cleaning or replacing as necessary.
 - f. Measures should be taken to ensure a surface of uniform appearance that is free from deep striations.
 - g. Turf should be thoroughly cleaned or replaced at the end of each day's use. Damaged or worn turf should be repaired and/or replaced.
 - h. When surface corrections for pavement smoothness are made in the hardened concrete, no additional texturing is required.
 2. Broom Finish:
 - a. Broom concrete surface with a steel or fiber broom to produce corrugations between 1/16 and 1/8 in. (2 and 3 mm) deep.
 - b. Broom perpendicular to nearest edge of pavement. Broom all areas of a panel in the same direction.
 - c. Use the same type and manufacture of broom for all paved surfaces to provide a consistent appearance.
 3. Longitudinal Tining:
 - a. Drag Pretecture: Pretecture the surface of the newly placed pavement in accordance with Section 3.F.1.
 - b. Tining:

⁴ See hidden text for important note regarding projects where pavement/tire noise reduction is important.

- 1) Place longitudinally tined grooves in the surface of the pavement while the concrete is plastic. The tining shall be done with a mechanical device such as a wire comb. The comb shall have a single row of tines that each has a nominal width of $5/64$ to $1/8$ in. (2 to 3 mm). The nominal spacing of the tines shall be $3/4 \pm 1/8$ in. (19 ± 3 mm) center-to-center. The nominal depth of tined groove in the plastic concrete shall be $1/8 \pm 1/32$ in. (3 ± 0.8 mm).
- 2) Longitudinal tining shall be accomplished by equipment with automated horizontal and vertical controls to ensure straight, uniform depth tined grooves. The texture geometry shall be the same as imparted throughout the length of the tining comb.
- 3) A 2 to 3 in. (51 to 76 mm) wide strip of pavement surface shall be protected from tining for the length of and centered about longitudinal joints.
- 4) The tining operation shall be done at such time and manner that the desired surface texture will be achieved while minimizing displacement of the larger aggregate particles and before the surface permanently sets.
- 5) Where abutting pavement is to be placed, the tining shall extend as close to the edge as possible without damaging the edge. If abutting pavement is not to be placed, the 6 in. (152 mm) area nearest the edge or 1 ft (305 mm) from the face of the curb shall not be tined.
- 6) Hand-operated tining equipment that produces an equivalent texture may be used only on small or irregularly shaped areas. Tines should be thoroughly cleaned at the end of each day's use, and damaged or worn tines replaced.
- 7) When surface corrections for pavement smoothness are made in the hardened concrete, no additional texturing is required.

4. Transverse Tining:

- a. Drag Pretexture: Pretexture the surface of the newly placed pavement in accordance with Section 3.F.1.
- b. Tining:
 - 1) Place transversely tined grooves in the surface of a pavement while the concrete is plastic. The tining shall be done with a mechanical device such as a wire comb. The comb shall have a single row of tines that each has a nominal width of $5/64$ to $1/8$ in. (2 to 3 mm). The nominal spacing of the tines shall be $3/4 \pm 1/8$ in. (19 ± 3 mm) center-to-center. The nominal depth of tined groove in the plastic concrete shall be $1/8 \pm 1/32$ in. (3 ± 0.8 mm).
 - 2) Transverse tining shall be accomplished by equipment with automated horizontal and vertical controls to ensure straight, uniform depth tined grooves. The texture geometry shall be uniformly imparted throughout the length of the tining comb and between successive passes of the tining comb. Successive passes of the tining comb shall be overlapped the minimum necessary to attain a continuously textured surface.
 - 3) The tining operation shall be done at such time and manner that the desired surface texture will be achieved while minimizing displacement of the larger aggregate particles and before the surface permanently sets.
 - 4) Where abutting pavement is to be placed, the tining shall extend as close to the edge as possible without damaging the edge. If abutting pavement is not to be placed, the 6 in. (152 mm) area nearest the edge or 1 ft (305 mm) from the face of the curb shall not be tined.

- 5) Hand-operated tining equipment that produces an equivalent texture may be used only on small or irregularly shaped areas.
 - 6) Tines should be thoroughly cleaned at the end of each day's use, and damaged or worn tines replaced.
 - 7) When surface corrections for pavement smoothness are made in the hardened concrete, no additional texturing is required.
- G. Cold-Weather Placement: Comply with ACI 306.1 and as follows. Protect concrete work from physical damage or reduced strength that could be caused by frost, initial freezing, freezing and thawing cycles, or low temperatures.
1. Concrete temperature as delivered and temperature of placed concrete shall be maintained within the temperature range required by ACI 301.
 2. Do not use frozen materials or materials containing ice or snow. Do not place concrete on frozen subgrade or on subgrade containing frozen materials.
 3. Do not use calcium chloride, salt, or other materials containing antifreeze agents or chemical accelerators, unless otherwise specified or permitted.
- H. Hot-Weather Placement: Comply with ACI 301 and as follows:
1. Maintain concrete temperature below 95°F (35°C) at time of placement. Chilled mixing water or ice may be used to control temperature. Quantity of ice used shall be included in the total amount of mixing water. Using liquid nitrogen to cool concrete is Contractor's option.
 2. Fog-spray forms, steel reinforcement, and subgrade just before placing concrete. Keep subgrade uniformly moist without standing water, soft spots, or dry areas.

3.6 CONCRETE PROTECTION AND CURING

- A. Protect freshly placed concrete from damage due to rain. Have available, near the site of the work, materials for protection of the edges and surface of the concrete. Should any damage result, the Engineer will suspend operations until corrective action is taken and may require removal and replacement of the rain-damaged concrete.
- B. Protect freshly placed concrete from premature drying and excessive cold or hot temperatures. Comply with ACI 306.1 for cold-weather protection and ACI 301 for hot-weather protection during curing.
- C. Apply curing compound immediately after final surface texture has been obtained and water sheen has disappeared.
- D. Apply membrane-forming curing compound to all exposed surfaces at a coverage rate of 180 ft²/gal. (5 m²/L).
- E. When using liquid membrane-forming compounds, if the evaporation rate⁵ during paving operations does not exceed 0.1 lb/ft²/hr (0.49 kg/m²/hr), then only 1 coat of membrane curing compound at an individual application rate of 180 ft²/gal. (5 m²/L) is permissible. Do not allow

⁵ Unless an alternate technique is approved by the Engineer, evaporation rate shall be evaluated using the Menzel nomograph or its underlying equations. For more information, refer to the *Guide to Curing Concrete*, ACI 308R-01, ACI International, <http://www.concrete.org>.

the concrete surface to dry before applying the curing compound. Remove any standing pools of bleed water that may be present on the surface before applying the curing compound. Apply the first coat within 10 min. after completing texturing operations. If applicable, apply the second coat within 30 min. after completing texturing operations.

- F. Maintain and promptly repair damage to curing materials on exposed surfaces of concrete pavement continuously for at least 3 curing days, or until the pavement is open to the traveling public, whichever occurs first. A curing day is defined as a 24-hr. period when either the temperature taken in the shade away from artificial heat is above 50°F (10°C) for at least 19 hr. or when the surface temperature of the concrete is maintained above 40°F (5°C) for 24 hr. Curing begins when the concrete curing system has been applied. Stop concrete paving if curing compound is not being applied promptly and maintained adequately.
- G. Apply curing compound to pavement edges after forms, if used, have been removed.
- H. Alternative curing methods may be used in accordance with this specification or with ACI 308.1 when acceptable to the Engineer.

3.7 JOINTS

- A. Construct joints at the locations, depths, and with dimensions indicated on the project drawings or accepted drawings submitted by the contractor.
- B. If jointing requirements are not indicated on the project drawings, the contractor shall submit drawings describing proposed jointing in accordance the requirements of 3.7.B.1 through 3.7.B.9. The contractor shall not proceed with work until the jointing requirements are accepted by the Engineer.
 - 1. Indicate locations of contraction joints, construction joints, and isolation joints. Spacing between contraction joints shall conform to Table 2, unless otherwise permitted.
 - 2. The larger dimension of a panel shall not exceed 125% of the smaller dimension.
 - 3. The minimum angle between two intersecting joints shall be 80 degrees, unless otherwise specified or permitted.
 - 4. Joints shall intersect pavement free edges at 90-degree angles and shall extend straight for a minimum of 1-1/2 ft (0.5 m) from the pavement edge, where possible.
 - 5. Align joints of adjacent panels.
 - 6. Align joints in integral curbs with joints in pavement.
 - 7. Ensure joint depth and width dimensions are as specified.
 - 8. Minimum contraction joint depth, using a conventional saw, hand tools, or inserts, shall be 1/4 of the pavement thickness. Minimum joint width for saw cutting is 1/8 in. (3 mm). When using an early-entry dry-cut saw, the depth of the cut shall be at least 1 in. (25 mm).
 - 9. Use isolation joints only where pavement abuts buildings, foundations, existing pavements, manholes, and other fixed objects.
- C. Construct contraction joints by saw-cutting concrete after concrete has hardened sufficiently to prevent aggregate being dislodged and soon enough to control pavement cracking. For conventional saws the start of the sawing window usually occurs between 8 and 12 hours after placement and between 1 and 4 hours for early entry saws. Discontinue sawing joint if a crack precedes the saw-cut. Resume sawing at the next joint location.

- D. Extend isolation joints through the full depth of the pavement. Fill the entire isolation joint with isolation joint material, unless otherwise required by project drawings or by accepted jointing drawings submitted by the contractor (see Section 2.5 for material requirements).

Table 2. Spacing Between Contraction Joints.

Pavement Thickness, in. (mm)	Maximum Spacing, ft. (m)
3-1/2 (90)	8-1/2 (2.5)
4, 4-1/2 (100, 110)	10 (3)
5, 5-1/2 (125, 140)	12-1/2 (4)
6 or greater (150 or greater)	15 (4.5)

3.8 JOINT FILLING

- A. Prepare, clean, and install joint filler according to manufacturer's written instructions.
- B. Unless otherwise allowed by the Engineer, before any portion of the pavement is opened to the Contractor's equipment or to general traffic, clean and seal joints that require sealing. Remove dirt, debris, saw cuttings, curing compounds, and sealers from joints; leave contact faces of joint clean and dry.
- C. Hot-Poured Liquid Sealants:
1. Place joint sealer when the pavement and surrounding air temperature are 40°F (5°C) or higher.
 2. Where specified, backer rods shall be installed to provide proper shape factor.
 3. Use an indirect heating kettle with an agitator to prevent localized overheating. Discard overheated material.
 4. Use insulated hoses. Fit the application wand with a recirculation line to prevent the temperature of the sealant in the hose from dropping below application temperature.
 5. Make sure that the top of the sealant is 1/8 to 1/4 in. (3 to 6 mm) below the pavement surface.
 6. Clean any spilled or overfilled joint sealant from the concrete surface.
- D. Cold-Poured Silicone Sealants:
1. Place joint sealer when the pavement and surrounding air temperature are 40°F (5°C) or higher.
 2. Where specified, backer rods shall be installed to provide proper shape factor.
 3. Use joint primer provided by the manufacturer to ensure a good bond between the sealant and the joint reservoir face.
 4. Tool non-self-leveling sealants before the material cures.
 5. Clean any spilled or overfilled joint sealant from the concrete surface.
- E. Preformed Compression Sealers:
1. Check joint width for compatibility.
 2. Make sure the joint width doesn't vary, especially at points where the saw reenters the joint.
 3. Clean and dry the saw cut reservoir before sealing the joint. Seal joints only when the joint surfaces appear dry.

4. Follow the manufacturer's recommendation for sealant sizing and installation.
5. Make sure the sealant is lubricated, straight, vertical, and undamaged before installation.
6. Make sure that the installation device does not stretch the sealant.

3.9 OPENING TO TRAFFIC

- A. Do not open the pavement to vehicular traffic until the in-place compressive strength is at least 3,000 psi (21 MPa), or 75% of the specified strength, or until the pavement is accepted by the Engineer for opening to traffic. In-place strength shall be determined using field cured cylinders in accordance with ASTM C31/C31M or maturity methods in accordance with ASTM C1074.

3.10 TOLERANCES

- A. Construct pavement to comply with the following tolerances:
 1. Final Elevation: $\pm 3/4$ in. (± 19 mm)
 2. Concrete Thickness: $+3/8$ in., $-1/4$ in. ($+10$ mm, -6 mm)
- B. Joint reinforcement:
 1. Tie bars: alignment of tie bar end relative to line perpendicular to edge of pavement: $\pm 1/2$ in./ft (± 13 mm/305 mm) of tie bars
- C. Dowels:
 1. Lateral alignment and spacing: ± 1 in. (± 25 mm)
 2. Vertical alignment: $\pm 1/4$ in. (± 6 mm)
 3. Alignment of dowel bar end relative to line perpendicular to edge of pavement: $\pm 1/4$ in./ft (± 6 mm/305 mm) of dowel
- D. Joint Spacing (see Table 2)
 1. Contraction joint depth: $+1/4$ in. ($+6$ mm), -0 in.
 2. Joint width: $+1/8$ in. ($+3$ mm), -0 in.

3.11 QUALITY CONTROL

- A. Aggregates:
 1. Stockpile Grading: ASTM C136; Material producer shall provide the Engineer with testing data demonstrating that the individual stockpile aggregates to be used for production meet the requirements of ASTM C33. A minimum of 10 randomly selected tests shall be provided for each stockpile used for each concrete mix design submitted for paving. One set of tests may be submitted for a stockpile used in multiple mix designs.
 2. Aggregate Moisture: ASTM C566; On the individual stockpiles utilized for each concrete mixture, test at a minimum of every [**150 yd³ (115 m³)**] or [**insert volume**], but not less than one test for each day's pour of each concrete mixture to determine aggregate

moisture content. Make adjustments to batch quantities based on measured aggregate moisture content. Testing requirements for aggregate moisture may be eliminated if moisture probes, calibrated at least every [3 months] or [insert frequency], are used.

- B. Concrete Mixtures: Contractor shall perform quality control testing and test one composite sample at a minimum of every [150 yd³ (115 m³)] or [insert volume], but not less than one test for each day's pour of each concrete mixture. Samples for quality control tests shall be obtained either at the concrete production facility or at the jobsite. It is permitted to obtain this sample after all adjustments are made to the batch and after discharge of at least ¼ yd³ (0.25 m³) of concrete.
1. Slump: ASTM C143/C143M
 2. Air Content: ASTM C231/C231M (normal weight concrete)
 3. Density: ASTM C138/C138M
 4. <Optional: if maturity methods are used for early opening to traffic> Strength-Maturity Relationship (see Section 3.9 Opening to Traffic): ASTM C1074
- C. Statistical Process Control Charts:
1. Prepare statistical process control charts (control charts)⁶ according to the Quality Control Plan described in Section 1.6 and the following requirements Prepare control charts for the following test results:
 - a. Slump
 - b. Air Content
 - c. Density
 2. Control charts shall be developed using the following components:
 - a. The average of test results plotted as the centerline.
 - b. Test data plotted continuously over time with each result representing a single test point.
 - c. Upper and lower control limits, plotted at 2 times the standard deviation (2s) of the test data.
 3. The initial standard deviation for each test parameter shall be developed based upon historical data from the concrete producer and revised as project specific data is obtained. A minimum of 10 project samples shall be used to determine the revised standard deviations. If historical information is unavailable, the following values may be used to calculate one standard deviation (1s) until sufficient data is available.
 - a. Slump = 0.231 * Target Value
 - b. Air Content = 0.097 * Target Value
 - c. Density = 0.007 * Target Value
 4. Investigate process control instability when one of the following occurs:

⁶ Background information related to QC testing and statistical process control charts may be found in the CPTECH Center Report entitled *Testing Guide for Implementing Concrete Paving Quality Control Procedures* dated March 2008 at http://www.cptechcenter.org/publications/mco/testing_guide.pdf

- a. One test result is outside of the 2s limits.
- b. Five consecutive test results are all increasing or decreasing.
- c. Five consecutive test results are on the same side of the average value.
- d. Ten consecutive test results are alternating up and down.

3.12 QUALITY ACCEPTANCE

- A. **Testing and Inspecting:** Contractor shall engage a qualified testing and inspecting agency meeting the requirements of Section 1.7.C to perform tests and inspections and to submit reports for acceptance in accordance with Section 1.5.F.
- B. **Inspections:** Prior to commencement of portions of the work, the inspection agency shall provide verification that the following items meet the specification requirements:
 1. Subgrade and/or subbase density and elevation.
 2. Steel tie and dowel bar reinforcement placement, if used.
 3. Use of required design mixture.
 4. Concrete placement, including conveying and depositing.
 5. Curing procedures.
 6. Concrete strength before removal of forms, if used.
- C. **Concrete Tests:** Testing of composite samples of fresh concrete obtained according to ASTM C172/C172M shall be performed according to the following requirements:
 1. Preliminary Samples/Tests: Preliminary samples to measure slump and air content and to make necessary adjustments to mixtures to achieve specified requirements are permitted in accordance with ASTM C94/C94M.
 2. Testing Frequency: Obtain at least one random composite sample for each [500 yd³ (382 m³)] or [insert volume] or fraction thereof of each concrete mixture placed each day.
 - a. When frequency of testing will provide fewer than five compressive-strength tests for each concrete mixture, testing shall be conducted from at least five randomly selected batches or from each batch if fewer than five are used.
 3. Slump: ASTM C143/C143M; one test at point of placement for each composite sample when compressive strength specimens are made, but not less than one test for each day's pour of each concrete mixture.
 4. Air Content: ASTM C231/C231M, pressure method, for normal-weight concrete; one test for each composite sample, but not less than one test for each day's pour of each concrete mixture.
 5. Density: ASTM C138/C138M; one test for each composite sample when strength specimens are made.
 6. Concrete Temperature: ASTM C1064/C1064M; one test hourly when air temperature is 40°F (5°C) and below and when 80°F (27°C) and above, and one test for each composite sample when strength specimens are made.

7. Compression Test Specimens: ASTM C31/C31M; two sets of two standard-cured cylinder specimens for each composite sample. Specimen sizes of 6 x 12 in. (150 x 300 mm) or 4 x 8 in. (100 x 200 mm) are permitted.
 8. Compressive-Strength Tests: ASTM C39/C39M; test one set of two standard-cured specimens at 7 days and one set of two specimens at 28 days. A compressive-strength test result shall be the average compressive strength from a set of two specimens obtained from same composite sample and tested at age indicated.
 - a. Strength of each concrete mixture is satisfactory if every average of any three consecutive compressive-strength test results equals or exceeds specified compressive strength and no compressive-strength test result falls below specified compressive strength by more than 500 psi (3.5 MPa).
- D. Concrete Thickness: ASTM C174/C174M; Obtain at least one random sample for each [500 yd³ (382 m³)] or [insert volume] or fraction thereof of each concrete mixture placed each day.
- E. Smoothness: Determine smoothness based upon one of the following methods.
1. Straightedge: For pavements with a speed limit of 40 mph (64 kph) or below, use a 10 ft (3 m) metal straightedge to measure the locations marked by the Engineer. A minimum of one test location per 500 feet (152 m) in each travel lane that will carry traffic will be marked. Where there is more than 1/4 in. in 10 ft (6 mm in 3 m), between any two contacts of the straightedge with the surface, the surface requires correction. Following correction, retest the area to verify compliance with this section. Pavement surfaces that have been purposely warped to meet fixtures (manholes, drainage inlets, catch basins, etc.), existing curb and gutter, or cross- and side-road connections are exempt from this straightedge requirement.
 2. Inertial Profiler: For pavements with a speed limit greater than 40 mph (64 kph), perform tests in each travel lane that will carry traffic using an inertial profiler in conformance with ASTM E950/E950M. Coordinate with and obtain authorization from the Engineer before starting testing. Perform tests on the finished surface of the completed project or at the completion of a major stage of construction as approved by the Engineer. Perform tests within 7 days after receiving authorization.

The Engineer may require testing to be performed at times of off-peak traffic flow. Operate the inertial profiler in a manner that does not unduly disrupt traffic flow as determined by the Engineer. When using a lightweight inertial profiler to measure a surface that is open to traffic, use a moving traffic control plan in accordance with the MUTCD and the plans.

IRI values will be calculated for 0.1 mi. (0.1 km) sections using the average of both wheel paths. The maximum allowable IRI for any 0.1 mi. (.1 km) section will be 70 in./mi (1,184 mm/km). For each 0.1 mi. (0.1 km) section measured to be over 70 in./mi (1,184 mm/km) but not exceeding 80 in./mi. (1,262 mm/km) [\$250] or [insert \$ value] will be deducted from the payment for this item. For each 0.1 mi. (0.1 km) section measured to be over 80 in./mi (1,262 mm/km) but not exceeding 90 in./mi. (1,429 mm/km) [\$500] or [insert \$ value] will be deducted from the payment for this item. Use diamond grinding or other approved work methods to correct any 0.1 mi (0.1 km) section

with an average IRI over 90 in./mi (1,429 mm/km). Correct the deficient section to an IRI of 70 in./mi (1,184 mm/km) or less. After making corrections, reprofile the pavement section to verify that corrections have produced the required improvements.

- F. Reporting: Test results shall be reported in writing to Engineer, contractor, and concrete producer if different from contractor within 48 hours of testing. Reports shall contain project identification information, date of concrete placement, name of concrete testing and inspecting agency, and location of concrete batch in Work.
- G. Additional Tests: Testing and inspecting agency shall make additional tests of concrete when test results indicate that slump, air entrainment, compressive strengths, or other requirements have not been met, as directed by Engineer. Testing and inspecting agency may conduct tests to determine adequacy of concrete by cored cylinders complying with ASTM C42/C42M or by other methods as directed by Engineer.
- H. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.
- I. Correct deficiencies in the Work that test reports and inspections indicate does not comply with this specification and/or the Contract Documents.

3.13 MEASUREMENT AND PAYMENT

- A. Measurement: Measurement will be in square yards (square meters) for each different thickness of concrete pavement. The area of manholes, intakes, or other fixtures in the pavement will not be deducted from the measured pavement area. When the curb is integral with the pavement, the width for pavement square yards will be measured from back of curb to back of curb.
- B. Payment: Payment will be at the unit price per square yard (square meters) for each thickness of concrete pavement. Unit price includes, but is not limited to, final trimming of subgrade or subbase, integral curb, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, concrete for rigid headers, box outs for fixtures, and pavement smoothness testing.

END OF SECTION 32 13 13.51

APPENDIX A – Pertinent NRMCA Concrete In Practice (CIP) Series References

The following NRMCA documents may be used for further guidance on topics related to this specification and concrete pavement construction. The requirements, criteria, or language in the above guide specification should supersede if there are any discrepancies between the specification and the CIP documents. The CIP documents are provided for reference only to the specification writer and should not be included in the project specification either directly or through reference.

Concrete In Practice Series Title	CIP #
Joints in Concrete Slabs on Grade	CIP 6
Discrepancies in Yield	CIP 8
Low Concrete Cylinder Strength	CIP 9
Strength of In-Place Concrete	CIP 10
Curing In-Place Concrete	CIP 11
Hot Weather Concreting	CIP 12
Chemical Admixtures for Concrete	CIP 15
Flexural Strength of Concrete	CIP 16
Synthetic Fibers for Concrete	CIP 24
Jobsite Addition of Water	CIP 26
Cold Weather Concreting	CIP 27
Concrete Slab Moisture	CIP 28
Supplementary Cementitious Materials	CIP 30
Ordering Ready Mixed Concrete	CIP 31
Concrete Pre-Construction Conference	CIP 32
Making Concrete Cylinders in the Field	CIP 34
Testing Compressive Strength of Concrete	CIP 35
Concrete Maturity	CIP 39
Acceptance Testing of Concrete	CIP 41