Guide Specification for Materials and Construction of Jointed Unreinforced Concrete Pavement Parking Lots

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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.

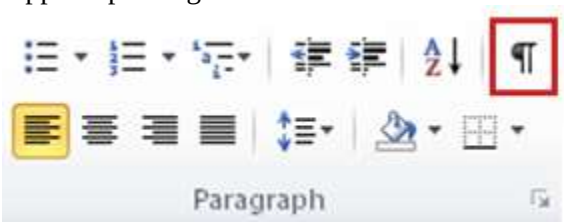
Jointed unreinforced concrete parking lots may be designed using various methods; however, NRMCA recommends using the American Concrete Institute (ACI) procedure 330R-08 *Guide for the Design and Construction of Concrete Parking Lots* which specifically addresses the unique loading conditions, durability considerations, and joint layout patterns inherent to parking lots. ACI 330R-08 can be obtained from ACI at www.concrete.org.

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).

SECTION 32 13 13.50 – CONCRETE PAVEMENT FOR PARKING LOT APPLICATIONS

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PART 1 - GENERAL

1.0 PROJECT IDENTIFICATION

A. This specification is to be used for parking lot 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 parking lots, 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. 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 90ºF (32ºC);
2. high concrete temperature;
3. low relative humidity;
4. wind velocity; and
5. solar radiation.

M. 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.

N. Owner: the corporation, association, partnership, individual, public body, or authority for whom the work is constructed.

O. Panel: an individual concrete slab bordered by joints or slab edges.

P. Project Drawings: graphic presentation of project requirements.

Q. Parking Lot: an area used to park automobiles, trucks, or both.

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. A non-signed tolerance means + or -. 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 C138/C138M: Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
17. ASTM C143/C143M: Standard Test Method for Slump of Hydraulic-Cement Concrete
18. ASTM C150: Standard Specification for Portland Cement
19. ASTM C171: Standard Specification for Sheet Materials for Curing Concrete
20. ASTM C172/C172 M: Standard Practice for Sampling Freshly Mixed Concrete
21. ASTM C173/C173M Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
22. ASTM C231/C231M: Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
23. ASTM C260/C260M: Standard Specification for Air-Entraining Admixtures for Concrete
24. ASTM C309: Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
25. ASTM C494/C494M: Standard Specification for Chemical Admixtures for Concrete
26. ASTM C595: Standard Specification for Blended Hydraulic Cements
27. ASTM C618: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
28. ASTM C989: Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
29. ASTM C1017/C1017M: Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
30. ASTM C1064/C1064M: Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
31. ASTM C1074: Standard Practice for Estimating Concrete Strength by the Maturity Method
32. ASTM C1077: Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
33. ASTM C1116/C1116M: Standard Specification for Fiber-Reinforced Concrete
34. ASTM C1157: Standard Performance Specification for Hydraulic Cement
35. ASTM C1240: Standard Specification for Silica Fume Used in Cementitious Mixtures
36. ASTM C1260: Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
37. ASTM C1293: Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
38. ASTM C1567: Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
39. ASTM C1602/C1602M: Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
40. ASTM D698: Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))
41. ASTM D994/D994M: Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)
42. ASTM D1751: Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)

43. ASTM D1752: Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
44. ASTM D2628: Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements
45. ASTM D3406: Standard Specification for Joint Sealant, Hot-Applied, Elastomeric-Type, for Portland Cement Concrete Pavements
46. ASTM D3963/D3963M: Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars
47. ASTM D5893/D 5893M: Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements
48. ASTM E329: Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection
49. ASTM E548: Standard Guide for Proficiency Testing by Interlaboratory Comparisons
50. ASTM E1980: Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces
51. CRSI's "Manual of Standard Practice," Latest Edition.
52. NRMCA QC 3 – Checklist for Certification of Ready Mixed Concrete Production Facilities, NRMCA, www.nrmca.org

1.5 SUBMITTALS

A. LEED Submittals:

1. Design Mixtures for Innovation and Design Process Credit 1.1:

    a. For each concrete mixture containing fly ash or slag cement as a replacement for portland cement or other portland cement replacements and for equivalent concrete mixtures that do not contain portland cement replacements.
    b. For each concrete plant delivering concrete for the work, indicate the level of NRMCA Sustainable Concrete Plant Certification (Bronze, Silver, Gold or Platinum).

2. Product Data for Materials and Resources Credit 4.1 [or Credit MR 4.2]: For products having recycled content, documentation indicating percentages by weight of postconsumer and preconsumer recycled content.

    a. Include statement indicating costs (selling price of concrete) for each product having recycled content.

3. Product Data for Materials and Resources Credit 5.1 [or Credit 5.2]: For products using regional materials, documentation indicating percentages by weight that are extracted, processed, and manufactured within 500 miles (805 km) of the project site.

4. Heat Island Effect: Non-Roof for Sustainable Site Credit 7.1: 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.

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 ±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. Field quality-acceptance inspection and testing reports as described in Section 3.11.

1.6 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, as documented according to ASTM E548, 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.

1.7 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: Conforms 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: Conforms 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.

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/A775M[1] 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 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.

2.4 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.

[1] 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 replace ASTM A775. Until such time as the new ASTM specification is complete ASTM A775 is acceptable.

2.5 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/yd^2 (305 g/m^2) when dry.

C. Moisture-Retaining Cover: If used, comply with ASTM C171, polyethylene film or white burlap-polyethylene sheet.

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

2.7 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 1.6.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.

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 ±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), unless otherwise permitted. For pavements placed using slipform equipment the maximum slump shall be 2 in. (50 mm), unless otherwise permitted. Tolerance for slump stated in ASTM C94/C94M shall apply.

B. Submit documentation for mixture proportions of concrete mixtures proposed for use in accordance with ACI 301 and Section 1.5.B herein.

Table 1. Required Total Air Content[1].

1. 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
½ (12.5)		5.5	7.0
¾ (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 ± 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 PREPARATION

A. Prepare subgrade as required by the plans. If not specified on the plans or related specification, compact subgrade to a minimum of 95% of the maximum dry density as determined by ASTM D698 and within ± 2% of the optimum moisture content or compact subbase to a minimum of 98% of the maximum dry density as determined by ASTM D698 and within ± 2% of the optimum moisture content.

B. Re-grade and re-compact subgrade disturbed by concrete delivery vehicles or other construction equipment to the requirements of Section 3.1.A.

C. Do not use sand or loose material to obtain final subgrade elevation.

D. At the time of concrete paving the subgrade density and moisture shall be in the condition described in section 3.1.A.

3.2 SUBBASE

A. Use only when required by contract documents. If used, prepare subbase in accordance with Section 3.1, Subgrade Preparation.

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 50ºF (10ºC) 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 drive lane, 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.
5. String lines or other means for setting grade should be checked frequently.

E. Edging:

1. Edge top surface edges to a radius of 1/4 in. (6 mm).

2. Do not tool edges if the joint is to be widened to provide a reservoir for joint sealant.

F. Final Surface Texture: 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/yd^2 (2,035 g/m^2). 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.
d. Other methods of producing final surface texture may be permitted when specified or accepted by the Engineer.

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 95ºF (35ºC) 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 the 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 maximum coverage rate of 180 ft^2/gal. (5 m^2/L).

E. When using liquid membrane-forming compounds, if the evaporation rate[2] during paving operations does not exceed 0.1 lb/ft^2/hr (0.49 kg/m^2/hr), then only 1 coat of membrane curing compound at an individual application rate not to exceed 180 ft^2/gal. (5 m^2/L) is permissible. Do not allow 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.

[2] 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.

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 one of the following methods:

1. Tool contraction joints in fresh concrete after the concrete has set sufficiently to maintain the formed joint to the specified depth and width.
2. Insert plastic strips vertically into the fresh concrete. Depress strips into pavement until flush with surface.
3. Saw-cut concrete after concrete has hardened sufficiently to prevent aggregate being dislodged and soon enough to control pavement cracking. 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 2.6 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. 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. Elevation: 3/4 in. (19 mm)
2. Thickness: +3/8 in., -1/4 in. (+10 mm, -6 mm)
3. Surface: In any direction, the gap below a 10 ft (3 m) unleveled straightedge resting on high spots shall not exceed 1/2 in. (13 mm)

B. Joint reinforcement:

1. Tie bars: alignment of tie bar end relative to line perpendicular to edge of pavement: 1/2 in./ft (13 mm/300 mm) of tie bars

C. Dowels:

1. Lateral alignment and spacing: 1 in. (25 mm)
2. Vertical alignment: 1/4 in. (6 mm)
3. Alignment of dowel bar end relative to line perpendicular to edge of pavement: 1/4 in./ft (6 mm/300 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 FIELD QUALITY ACCEPTANCE

A. Testing and Inspecting: Contractor shall engage a qualified testing and inspecting agency meeting the requirements of Section 1.6.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 [**100 yd^3 (76 m^3)**] **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 40ºF (5ºC) and below and when 80ºF (27ºC) 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. Reporting: Test results shall be reported in writing to Engineer 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.

E. 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.

F. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.

G. Correct deficiencies in the Work that test reports and inspections indicate does not comply with this specification and/or the Contract Documents.

3.12 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.

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, and box outs for fixtures.

END OF SECTION 32 13 13.50