Guide Performance-Based Specification for Concrete Materials

Section 03300 for Cast-in-place Concrete

National Ready Mixed Concrete Association
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Foreword:

There is considerable interest in performance-based specifications for concrete construction. The National Ready Mixed Concrete Association initiated an effort to evolve specifications for concrete materials to minimize prescriptive requirements and suggest performance based alternatives – typically referred to as the P2P initiative. This allows qualified concrete producers to develop and optimize concrete mixtures for performance required by the contractor (fresh concrete properties) and the designer of the structure (hardened concrete properties). Some information related to performance based specifications is available on the NRMCA website – www.nrmca.org/p2p. Considering this an important evolution, ACI formed an Innovative Task Group – ITG-8 that developed a report on performance specifications for concrete materials in 2 years. ACI subsequently formed ACI Committee 329 on performance requirements for concrete materials. ACI Committee 329 will manage the ITG-8 report as a committee document and work to evolve industry standards towards performance based requirements.

This document suggests some revisions to the traditional MasterSpec that is used by most design firms to develop their office master specifications for concrete. The intent is to use the format familiar to specification writers and to provide suggestions for minimizing prescription limitations and suggest performance-based requirements, which can be used as applicable to projects. Not all suggestions may be applicable for all projects or for different concrete structural members within a project. Some recommendations include higher level of testing and can increase testing costs. Notes to the engineer have been included to suggest including or deleting alternatives.

This document has been developed through a review and comment process with practicing design engineers and the technical committee (Research Engineering and Standards Committee) of the NRMCA. Only sections of this specification relevant to concrete materials are addressed. For other sections not relevant to this effort, only a section title has been retained. The definitions, test methods, and quality requirements are considered current state of the practice for the industry at the time of publication. This document 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.

There are many recommendations in this document that can be easily implemented to minimize prescription in current concrete specifications. It is understood that performance-based specifications will need a higher level of proficiency by concrete producers and testing agencies. Some qualification requirements are suggested. The engineer should consider Code requirements, practice and level of proficiency in the jurisdiction of the project when evolving to performance-based specifications.

Revisions to the original MasterSpec document, including specification articles and notes to the engineer (blue text) are highlighted and marked in cross-out and underline format to indicate the revisions.

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.

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. This document is only provided as a guide and cannot be incorporated by reference in project specifications. It is intended that the language contained herein will be modified, as necessary, to fit within the project contractual conditions and local Code requirements and 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. 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.
4. 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 033000 - CAST-IN-PLACE CONCRETE

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section specifies cast-in place concrete, including formwork, reinforcement, concrete materials, mixture design, placement procedures, and finishes, for the following:

Adjust list below to suit Project.

1. Footings.
2. Foundation walls.
3. Slabs-on-grade.
4. Suspended slabs.
5. Concrete toppings.
6. Building frame members.
7. Building walls.

B. Related Sections include the following:

List below only products and construction that the reader might expect to find in this Section but are specified elsewhere.

1. Division 03 Section "Architectural Concrete" for general building applications of specially finished formed concrete.
2. Division 03 Section "Concrete Topping" for emery- and iron-aggregate concrete floor toppings.
3. Division 31 Section "Earth Moving" for drainage fill under slabs-on-grade.
4. Division 32 Section "Concrete Paving" for concrete pavement and walks.
5. Division 32 Section "Decorative Concrete Paving" for decorative concrete pavement and walks.

1.3 DEFINITIONS

Definition in paragraph below refers to those materials that make up the cementitious component of the water-cementitious materials ratio.

A. Cementitious Materials: Portland cement alone or in combination with one or more of the following: blended hydraulic cement, fly ash, metakaolin and other pozzolans, ~~ground granulated blast-furnace~~ slag cement, and silica fume; subject to compliance with requirements.

B. Qualified Lab: Laboratory that performs acceptance testing complying with the requirements of ASTM C1077. Tests results shall be certified by a engineer licensed in the state where the project is being constructed.

C. Laboratory developing test data for project submittals complying with the requirements for ASTM C1077, with the exception of the requirement of being under the direction of a PE ~~licensed in the state where the testing is being performed~~. ~~Test data shall be signed by a PE.~~

1.4 SUBMITTALS

A. Product Data: For each type of product indicated.

Retain Section B for projects that have the stated goal of obtaining LEED® Green Building certification. Retain subparagraph below if fly ash, ground granulated blast-furnace slag, silica fume, or other materials are used as portland cement replacements for LEED-NC Credit ID 1.1. To achieve this credit, replacement materials must be substituted for at least 40 percent of the portland cement that would otherwise be used. Any requirement to require quantities cement replacement materials should be evaluated for impact on early age strength requirements on project – related to post-tensioning, tilt-up construction, removal of forms, etc. Requiring higher quantities of cement replacement materials may impact the stage at which the age of concrete strength acceptance requirements.

B. 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, “Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces.” 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.

C. Design Mixtures: Submit field or laboratory test records used to document that proposed mixture will achieve the required average compressive strength and other specified requirements in Section 2.15 for each class of concrete. ~~For each concrete mixture.~~

1. When project conditions, weather, test results, or other circumstances warrant adjustments to the mixture submit field or laboratory test records to document that the adjusted mixture will achieve the required average compressive strength and other specified requirements. Adjustments to chemical admixture dosage rates to maintain air content, set time and workability levels do not require additional testing. ~~Submit anticipated adjustments to alternate design mixtures when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant adjustments.~~

2. Submit list of ingredients used for the composition of design mixtures

~~1. Indicate on delivery tickets amounts of mixing water to be withheld for later permitted addition at Project site, when applicable.~~

D. Steel Reinforcement Shop Drawings: Placing drawings that detail fabrication, bending, and placement. Include bar sizes, lengths, material, grade, bar schedules, stirrup spacing, bent bar diagrams, bar arrangement, splices and laps, mechanical connections, tie spacing, hoop spacing, and supports for concrete reinforcement.

Delete first paragraph and subparagraph below if not required.

E Formwork Shop Drawings: Prepared by or under the supervision of a qualified professional engineer detailing fabrication, assembly, and support of formwork.

Delete subparagraph below if no shoring and reshoring are required.

1. Shoring and Reshoring: Indicate proposed schedule and sequence of stripping formwork, shoring removal, and installing and removing reshoring.

F. Samples: For [**waterstops**] [**vapor retarder**] <**Insert products**>.

Retain paragraph below if procedures for welder certification are retained in "Quality Assurance" Article.

G. Welding certificates.

Coordinate paragraph below with qualification requirements in Division 01 Section "Quality Requirements" and as supplemented in "Quality Assurance" Article.

H. Qualification Data: For [**Installer**] [**manufacturer**] [**testing agency**].

Delete paragraph and subparagraph below if material test reports are not required.

I. Material Test Reports: For the following, from a qualified testing agency, indicating compliance with requirements as required for structural members in 2.15.

Retain requirements where concrete material test reports for prequalification of mixtures are required for the project.

1. Alkali silica reactivity in accordance with ASTM C1567
2. Shrinkage in accordance with ASTM C157
3. Modulus of elasticity in accordance with ASTM C469
4. Indication of permeability of concrete in accordance with ASTM C1202
5. Freeze-thaw Durability in accordance with ASTM C457 or ASTM C666

~~Retain option in subparagraph below if retaining service record data with "Normal Weight Aggregates" Paragraph in Part 2 "Concrete Materials" Article.~~

~~Aggregates. Provide certification of aggregates documenting compliance with ASTM C33. [**Include service record data indicating absence of deleterious expansion of concrete due to alkali aggregate reactivity**].~~

Delete paragraph and subparagraphs below if material certificates are not required.

J. Material Certificates: For each of the following, signed by manufacturers:

Edit list to suit Project.

1, Cementitious materials.
2. Aggregates
3. Admixtures.
4. Mixing water – for non-potable sources of water, documented conformance to mandatory requirements of ASTM C1602.
5. Form materials and form-release agents.
6. Steel reinforcement and accessories.
7. Fiber reinforcement.
8. Waterstops.
9. Curing compounds.
10. Floor and slab treatments.
11. Bonding agents.
12. Adhesives.
13. Vapor retarders.
14. Semirigid joint filler.
15. Joint-filler strips.
16. Repair materials.

Retain paragraph below if Contractor engages testing agency for measuring floor surface flatness and levelness.

K. Floor surface flatness and levelness measurements to determine compliance with specified tolerances.

Retain paragraph below if Contractor is responsible for field quality-control testing and inspections other than special inspections.

L. Field quality-control test [**and inspection**] reports.

Delete paragraph below if no Thermal Control Plan is required for mass concrete members

M. Thermal control plan for structural members identified as mass concrete.

Delete paragraph below if no preinstallation conference.

N. Minutes of preinstallation conference.

1.5 QUALITY ASSURANCE

Delete first paragraph below if not required. See Division 01 Section "Quality Requirements" for general installer qualifications. Verify availability of qualified personnel with a local ACI chapter or concrete contractors. These desirable programs may have limited grass-roots penetration.

A. Installer Qualifications:
1. Employs project personnel on the finishing crew qualified as ACI Flatwork Finisher Technician, or equivalent. The supervisor shall be certified as an ACI Concrete Flatwork Finisher, or equivalent
2. When requested, the installer shall furnish a Quality Control Plan ~~A qualified installer who employs on Project personnel qualified as ACI certified Flatwork Technician and Finisher and a supervisor who is an ACI certified Concrete Flatwork Technician.~~

B. Manufacturer Qualifications: A firm experienced in manufacturing ready-mixed concrete products and that complies with ASTM C 94/C 94M requirements for production facilities and equipment.

Delete subparagraphs below if not required.

1. Manufacturer certified according to NRMCA's "Certification of Ready Mixed Concrete Production Facilities or State DOT."
2. Submit quality control plan for production of ready-mixed concrete
3. Person responsible for developing concrete mixture proportions certified as NRMCA Concrete Technologist Level 2, State DOT certification, or equivalent. Requirement waived if individual is a licensed professional engineer in the jurisdiction of the Work. ~~Test data submittals shall be signed by a licensed professional engineer.~~

Retain paragraph below if Contractor or manufacturer selects testing agency for concrete mixture design, material test reports, or field quality control. Retain option if field quality-control testing agency employed by Contractor must be approved by authorities having jurisdiction.

C. Testing Agency Qualifications: An independent agency, [**acceptable to authorities having jurisdiction,**] qualified according to ASTM C 1077 and ASTM E 329 for testing indicated, as documented according to ASTM E 548.

Retain subparagraph below, required by ACI 301 and ASTM C 31/C 31M, if emphasis is needed. ASTM C 1077 notes relevant field or laboratory technician certification by ACI, NRMCA, and PCA, or the National Institute for Certification in Engineering Technologies may demonstrate evidence of competence.

1. Personnel conducting field tests shall be qualified as ACI Concrete Field Testing Technician, Grade 1, according to ACI CP-01 or an equivalent certification program.

Retain subparagraphs below if requiring minimum qualifications for laboratory personnel performing testing and for laboratory supervisor.

2. Personnel performing laboratory tests shall be ACI-certified Concrete Strength Testing Technician and Concrete Laboratory Testing Technician - Grade I. Testing Agency laboratory supervisor shall be an ACI-certified Concrete Laboratory Testing Technician - Grade II.
3. Test results used for acceptance of concrete shall be certified by a licensed engineer employed with the Testing Agency

Retain subparagraphs below only if pertinent to Work. This might be appropriate for architectural concrete with exposed concrete surfaces or for architectural concrete only.

D. Source Limitations: Obtain each type or class of cementitious material of the same brand from the same manufacturer's plant, obtain aggregate from one source, and obtain admixtures through one source from a single manufacturer.

Delete first paragraph below if no welding. Retain "Welding certificates" Paragraph in "Submittals" Article if retaining below. AWS states that welding qualifications remain in effect indefinitely unless welding personnel have not welded for more than six months or there is a specific reason to question their ability.

E. Welding: Qualify procedures and personnel according to AWS D1.4, "Structural Welding Code--Reinforcing Steel."

F. ACI Publications: Comply with the following unless modified by requirements in the Contract Documents:

Retain second option in first subparagraph below if ACI 301, Section 7, for structural lightweight concrete is applicable.

1. ACI 301, "Specification for Structural Concrete," [**Sections 1 through 5.**][**Sections 1 through 5 and Section 7, "Lightweight Concrete."**]
2. ACI 117, "Specifications for Tolerances for Concrete Construction and Materials."

Delete paragraph below if the concrete supplier is provided an option of not submitting a quality plan that documents the ability to perform material evaluation tests and develop design concrete mixtures.

G. Concrete Testing Service: When the manufacturer does not comply with 1.5.B.3, engage a qualified independent testing agency to perform material evaluation tests and to design concrete mixtures. The manufacturer is permitted to engage a qualified independent testing agency to perform specific tests for project submittals

Delete paragraph and subparagraphs below if not required. If retaining, indicate location, concrete type, and other details of mockups on Drawings or by inserts. Revise wording if only one mockup is required or if mockup of concrete in another location in a building is required.

H. Mockups: Cast concrete [**slab-on-grade**] [**and**] [**formed-surface**] panels to demonstrate typical joints, surface finish, texture, tolerances, and standard of workmanship.

Revise size of panel in subparagraph below if required. Panel for slab-on-grade may need to be enlarged if powered riding trowels will be used and if it could be a portion of the floor slab.

1. Build panel approximately [**200 sq. ft. (18.6 sq. m) for slab-on-grade**] [**and**] [**100 sq. ft. (9.3 sq. m) for formed surface**] <**Insert area**> in the location indicated or, if not indicated, as directed by Architect.

Delete subparagraph below if default requirement in Division 01 Section "Quality Requirements" is to demolish and remove mockup.

2. Approved panels may become part of the completed Work if undisturbed at time of Substantial Completion.

Preinstallation conference below, which is desirable for major concrete installations, helps minimize misunderstandings and reviews Project conditions that might lead to significant problems. Delete paragraph and subparagraphs if Work of this Section is not extensive or complex enough to justify a preinstallation conference. If retaining, coordinate with Division 01.

I. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 01 Section "Project Management and Coordination."

Retain subparagraph and associated subparagraphs below if warranted by complexity of design mixtures and quality control of concrete materials.

1. Before submitting design mixtures, review concrete design mixture and examine procedures for ensuring quality of concrete materials. Require representatives of each entity directly concerned with cast-in-place concrete to attend, including the following:
   a. Contractor's superintendent.
   b. Independent testing agency responsible for concrete ~~design mixtures~~ acceptance testing.
   c. Ready-mix concrete manufacturer.
   d. Concrete subcontractor.
   e. Engineer of Record
2. Review [**special inspection and testing and inspecting agency procedures for field quality control,**] [**concrete finishes and finishing,**] [**cold- and hot-weather concreting procedures,**] [**curing procedures,**] [**construction contraction and isolation joints, and joint-filler strips,**] [**semirigid joint fillers,**] [**forms and form removal limitations,**] [**shoring and reshoring procedures,**] [**vapor-retarder installation,**] [**anchor rod and anchorage device installation tolerances,**] [**steel reinforcement installation,**] [**floor and slab flatness and levelness measurement,**] [**concrete repair procedures,**] and concrete protection.

1.6 DELIVERY, STORAGE, AND HANDLING

PART 2 - PRODUCTS

2.1 MANUFACTURERS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products.

Edit this Article with other Part 2 articles in which manufacturers and products, or manufacturers only, are named. See Division 01 Section "Product Requirements" for an explanation of the terms "Available Products," "Products," "Available Manufacturers," and "Manufacturers" and the effect these terms have on "Comparable Product" and "Product Substitution" requirements.

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
   1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, products specified.

2. Products: Subject to compliance with requirements, provide one of the products specified.
3. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.
4. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.2 FORM-FACING MATERIALS

2.3 STEEL REINFORCEMENT

2.4 REINFORCEMENT ACCESSORIES

2.5 CONCRETE MATERIALS

A. Cementitious Material: Use the following cementitious materials, ~~of the same type, brand, and source, throughout Project:~~

Select type, or other characteristics of cementitous materials from options in subparagraphs below only when pertinent to Work. Color selection might be appropriate for exposed architectural concrete.

1. Portland Cement: Unless otherwise noted for specific structural member in 2.15, use ASTM C 150, Type [**I**] [**II**] [~~**I/II**~~] [**III**] [**V**], [**gray**] [**white**]~~.[**Supplement with the following:**]~~

Retain subparagraph below to permit ~~if factory~~ blended hydraulic cement ~~is permitted; verify availability of options before specifying. Fly ash, slag, or pozzolanic materials in the nonportland cement part of blended hydraulic cement may slow rate of concrete strengthening and affect color uniformity.~~

2. Blended Hydraulic Cement: ASTM C 595, Unless otherwise noted for specific structural member in 2.15, use Type [**IS, portland blast-furnace slag**] [**IP, portland-pozzolan**] **[IT]**~~**[I (PM), pozzolan-modified portland**~~] [~~**I (SM), slag-modified portland**~~] ~~cement.~~
3. Performance Cement: ASTM C 1157, Unless otherwise noted for specific structural member in 2.15, use Type **[GU – general use] [MH, moderate heat] [LH, low heat] [MS, moderate sulfate resisting] [HS, high sulfate resisting]** cement.

~~Select~~ Permit supplementary cementing materials from subparagraphs below. Classes of fly ash or grades of slag cement may be subject to local availability and should not be restricted unless required for performance requirements or concerns. ~~if permitted~~. ~~Ready-mix concrete manufacturer blends these materials with portland cement. Fly ash, slag, or pozzolanic materials may slow rate of concrete strengthening and affect color uniformity. Availability of Class F fly ash predominates over Class C fly ash.~~

4. Supplementary Cementitious materials Unless otherwise noted for specific structural member in 2.15, use~~.[**Supplement with the following:**]~~

   a. Fly Ash, natural pozzolan or metakaolin: ASTM C 618, Class [**C**] [**F**] [**N**].
   b. ~~Ground Granulated Blast Furnace~~ Slag Cement: ASTM C 989, Grade **[100] [120]**.
   c. Silica Fume: ASTM C1240

~~Silica fume below is most often used in high strength concrete and in special applications such as bridge decks to enhance durability by lowering permeability of concrete. ACI 301 identifies silica fume as a cementitious material.~~

~~Silica Fume: ASTM C 1240, amorphous silica.~~

Select class of aggregate from options in paragraph below or revise to suit Project. ASTM C 33 limits deleterious substances in coarse aggregate depending on climate severity and in-service location of concrete. Classes in first set of options are ASTM C 33 default classes for concrete exposed to weather for Severe, Moderate, and Negligible weathering regions, respectively. Revise first two options to Class 4S or 4M if concrete will be exposed to frequent wetting. Retain last option if damage caused by concrete expansion from alkali silica or alkali carbonate reactions is anticipated.

B. Normal-Weight Aggregates: Use normal weight coarse aggregates that conform to ASTM C 33, Class [**3S**] [**3M**] [**1N**] <**Insert class**> coarse aggregate ~~or better, graded~~. ~~Provide aggregates from a single source~~[~~**with documented service record data of at least 10 years' satisfactory service in similar applications and service conditions using similar aggregates and cementitious materials**~~].

Select coarse-aggregate size from three options in subparagraph below; add gradation requirements if preferred. Aggregate size limits relate to spacing of steel reinforcement, depth of slab, or thickness of concrete member.

1. Nominal Maximum Coarse-Aggregate Size: As defined for each structural member in 2.15. ~~[**1 1/2 inches (38 mm)**] [**1 inch (25 mm)**] [**3/4 inch (19 mm)**] nominal~~.

Retain subparagraph below if ~~optional restriction for fine aggregate in~~ requirements in addition to those in ASTM C 33 is required.

2. Fine Aggregate: Use normal weight fine aggregates that conform to ASTM C33 **<State additional requirements>** ~~Free of materials with deleterious reactivity to alkali in cement~~.

Retain first paragraph below if using lightweight aggregate for structural lightweight concrete. Select size limit from four options below.

C. Lightweight Aggregate: ASTM C 330, ~~[**1 inch (25 mm)**] [**3/4 inch (19 mm)**] [**1/2 inch (13 mm)**] [**3/8 inch (10 mm)**]~~ nominal maximum aggregate size as defined for each structural member in 2.15.

D. Water: ASTM C 1602 ~~94/C 94M~~[~~**and potable**~~].

Retain paragraph to request documentation in accordance with ASTM C1602 when non-potable water is proposed for use.

1. For non-potable sources of water, submit documentation on the acceptability of water used as mixing water in concrete in accordance with the mandatory requirements of ASTM C 1602

Retain paragraph and select specific requirements to request documentation in accordance with optional requirements of ASTM C1602 when non-potable water is proposed for use and the limits are pertinent to the project. 500 ppm chlorides applies for prestressed concrete; 1000 ppm chloride limit applies for reinforced concrete or containing aluminum embedments or dissimilar metals or with galvanized metal forms that will stay in place.

2. For non-potable sources of water provide documentation for these characteristics in accordance with the optional limits of ASTM C1602: **[Chloride as Cl^- less than 500 ppm] [Chloride as Cl^- less than 1000 ppm] [Sulfate as SO_4 less than 3000 ppm] [Alkalis as (Na_2O + 0.658 K_2O) less than 600 ppm] [Total solids by mass less than 50,000 ppm]**

2.6 ADMIXTURES

If subparagraphs titled "Available Products," "Products," "Available Manufacturers," or "Manufacturers" are retained in this Article, coordinate with Part 2 "Manufacturers" Article. Retain "Available" for nonproprietary and delete for semiproprietary specifications.

A. Air-Entraining Admixture: ASTM C 260.

B. Chemical Admixtures: ~~Provide admixtures certified by manufacturer to be compatible with other admixtures and that will not contribute water-soluble chloride ions exceeding those permitted in hardened concrete. Do not use calcium chloride or admixtures containing calcium chloride.~~

~~Select~~ Permit ~~one or more~~ chemical admixtures ~~from six subparagraphs~~ listed below.

1. Water-Reducing Admixture: ASTM C 494/C 494M, Type A.
2. Retarding Admixture: ASTM C 494/C 494M, Type B.
3. Accelerating Admixtures, ASTM C494/C494M Type C, Type E
4. Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type D.
4. High-Range, Water-Reducing Admixture: ASTM C 494/C 494M, Type F.
5. High-Range, Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type G.
6. Plasticizing and Retarding Admixture: ASTM C 1017/C 1017M, Type II.
7. Admixtures for corrosion inhibition: ASTM C1582
8. Class S – ASTM C 494/C 494M for specific use. Provide admixture manufacturer document for specific use performance data.
9. Admixtures with no standard (ASTM or other) designation shall be used with the permission of the engineer of record when their use for specific properties is required

~~Retain paragraph and subparagraphs below if set-accelerating corrosion inhibitors are required. Set-accelerating products are usually calcium nitrite-based admixtures and comply with ASTM C 494/C 494M, Type C.~~

~~B. Set-Accelerating Corrosion-Inhibiting Admixture: Commercially formulated, anodic inhibitor or mixed cathodic and anodic inhibitor; capable of forming a protective barrier and minimizing chloride reactions with steel reinforcement in concrete and complying with ASTM C 494/C 494M, Type C.~~

~~1. [**Available**]Products:~~

~~a. Boral Material Technologies, Inc.; Boral BCN.~~
~~b. Euclid Chemical Company (The); Eucon CIA.~~
~~c. Grace Construction Products, W. R. Grace & Co.; DCI.~~
~~d. Master Builders, Inc.; Rheocrete CNI.~~
~~e. Sika Corporation; Sika CNI.~~
~~f. <**Insert manufacturer's name; product name or designation.**>~~

~~Retain paragraph and subparagraphs below if corrosion inhibitors that do not affect concrete setting time are required.~~

~~C. Non-Set-Accelerating Corrosion-Inhibiting Admixture: Commercially formulated, non-set-accelerating, anodic inhibitor or mixed cathodic and anodic inhibitor, capable of forming a protective barrier and minimizing chloride reactions with steel reinforcement in concrete.~~

~~1. [**Available**]Products:~~

~~a. Axim Concrete Technologies; Catexol 1000CI.~~
~~b. Boral Material Technologies, Inc.; Boral BCN2.~~
~~c. Cortec Corporation; MCI [**2000**] [**2005NS**].~~
~~d. Grace Construction Products, W. R. Grace & Co.; DCI-S.~~
~~e. Master Builders, Inc.; Rheocrete 222+.~~
~~f. Sika Corporation; FerroGard 901.~~
~~g. <**Insert manufacturer's name; product name or designation.**>~~

Retain paragraph and subparagraphs below for integrally colored concrete.

C. Color Pigment: ASTM C 979, synthetic mineral-oxide pigments or colored water-reducing admixtures; color stable,[**free of carbon black,**] nonfading, and resistant to lime and other alkalis.

~~[**Available**]Manufacturers:~~

~~h. Bayer Corporation.~~
~~i. ChemMasters.~~
~~j. Conspec Marketing & Manufacturing Co., Inc.; a Dayton Superior Company.~~
~~k. Davis Colors.~~
~~l. Elementis Pigments, Inc.~~
~~m. Hoover Color Corporation.~~
~~n. Lambert Corporation.~~
~~o. Scofield, L. M. Company.~~
~~p. Solomon Colors.~~
~~q. <**Insert manufacturer's name.**>~~

Select one of three options in subparagraph below.

1. Color: [**As indicated by manufacturer's designation**] [**Match Architect's sample**] [**As selected by Architect from manufacturer's full range**].

Add other admixtures, such as integral waterproofing admixtures, if required.

2.7 FIBER REINFORCEMENT

If subparagraphs titled "Available Products" or "Products" are retained in this Article, coordinate with Part 2 "Manufacturers" Article. Retain "Available" for nonproprietary and delete for semiproprietary specifications.

Retain paragraph and subparagraphs below if using steel-fiber reinforcement. Select from first set of options for length of fiber and from second set for aspect ratio, the ratio of length to effective diameter.

A. Carbon-Steel Fiber: ASTM A 820, deformed, minimum of [**1.5 inches (38 mm)**] [**2 inches (50 mm)**] [**2.4 inches (60 mm)**] <**Insert dimension**> long, and aspect ratio of [**35 to 40**] [**45 to 50**] [**60 to 65**] <**Insert ratio**>.

1. [**Available**]Products:

~~r. Bekaert Corporation; Dramix.~~
~~s. Fibercon International, Inc.; Fibercon.~~
~~t. SI Concrete Systems; Zorex.~~

~~a. <Insert requirement manufacturer's name; product name or designation.>~~

Select type of carbon-steel fiber from two options in subparagraph below. Type ~~1~~I ~~includes "Dramix" by Bekaert and "Zorex" by SI Concrete Systems.~~ or Type ~~2~~II includes "Fibercon" by Fibercon International.

2. Fiber: Type[**~~1~~I, cold-drawn wire**] [**or**] [**~~2~~II, cut sheet**].

Retain paragraph and subparagraphs below if using synthetic-fiber reinforcement. Revise fiber type if adding polyester or nylon fibers. Monofilament fibers help reduce plastic shrinkage cracking. Manufacturers claim fibrillated fibers also improve hardened concrete properties.

B. Synthetic Fiber: [**Monofilament**] [**or**] [**fibrillated**] polypropylene fibers engineered and designed for use in concrete pavement, complying with ASTM C 1116, Type III, [**1/2 to 1-1/2 inches (13 to 38 mm)**] <**Insert dimensions**> long.

1. [**Available**]Products:

a. Monofilament Fibers:

~~Axim Concrete Technologies; Fibrasol IIP.~~
~~Euclid Chemical Company (The); Fiberstrand 100.~~
~~FORTA Corporation; Forta Mono.~~
~~Grace Construction Products, W. R. Grace & Co.; Grace MicroFiber.~~
~~Metalcrete Industries; Polystrand 1000.~~
~~SI Concrete Systems; Fibermix Stealth.~~
1. ~~**<Insert requirement manufacturer's name; product name or designation.>**~~

b. Fibrillated Fibers:

~~Axim Concrete Technologies; Fibrasol F.~~
~~Euclid Chemical Company (The); Fiberstrand F.~~
~~FORTA Corporation; Forta.~~
~~Grace Construction Products, W. R. Grace & Co.; Grace Fibers.~~
~~SI Concrete Systems; Fibermesh.~~
1. ~~**<Insert requirement manufacturer's name; product name or designation.>**~~

2.8 WATERSTOPS

2.9 VAPOR RETARDERS

2.10 FLOOR AND SLAB TREATMENTS

2.11 CURING MATERIALS

2.12 RELATED MATERIALS

2.13 REPAIR MATERIALS

2.14 CONCRETE MIXTURES, GENERAL

A. Prepare design mixtures for each type and strength of concrete, proportioned on the basis of laboratory trial mixture or field test data, or both, according to ACI 301.

1. Use a qualified ~~independent~~ testing agency for preparing and reporting proposed mixture designs based on laboratory trial mixtures. Use qualified testing agency to develop supplementary performance test data for additional requirements identified in this specification.

~~Retain first option in paragraph below if required for LEED-NC Credit ID 1.1. This credit can be achieved by replacing at least 40 percent of the portland cement, which would otherwise be used in concrete, with other cementitious materials.~~ Any cementitious materials listed in 2.5 should be permitted, unless special type or restriction is needed for durability or other performance. Retain ~~second~~ option if limiting percentage of cementitious materials that can replace portland cement only when the structural member is assigned an exposure class F3. Neither ACI 301 nor ACI 318 (ACI 318M) limit amount of cementitious materials that can replace portland cement unless concrete is exposed to cycles of freezing and thawing and in continuous contact with moisture and to deicing chemicals, Identify parts of building or structure affected by these limits as Exposure Class F3~~unless extending them to all concrete~~.

B. Cementitious Materials:–Unless otherwise indicated in 2.15 for structural members use any cementitious materials listed in 2.5. [~~**Use fly ash, pozzolan, ground granulated blast furnace slag, and silica fume as needed to reduce the total amount of portland cement, which would otherwise be used, by not less than 40 percent.**~~][**Limit percentage, by weight, of cementitious materials other than portland cement in concrete for structural members assigned with exposure class F3 in 2.15 as follows:**]

Percentages in subparagraphs below repeat ACI 301 limits for concrete exposed to freezing and thawing and in continuous contact with water and with application of deicing chemicals Exposure Class F3. Revise to suit Project.

1. Fly Ash: 25 percent.
2. Combined Fly Ash, metakaolin and Pozzolan: 25 percent.
3. ~~Ground Granulated Blast Furnace~~ Slag cement: 50 percent.

~~Combined Fly Ash or Pozzolan and Ground Granulated Blast Furnace Slag: 50 percent portland cement minimum, with fly ash or pozzolan not exceeding 25 percent.~~

~~Delete three subparagraphs below if no silica fume is permitted. Limits of silica fume alone or in combination with other cementitious materials below are based on ACI 301 and ACI 318 (ACI 318M).~~

4. Silica Fume: 10 percent.

~~Combined Fly Ash, Pozzolans, and Silica Fume: 35 percent with fly ash or pozzolans not exceeding 25 percent and silica fume not exceeding 10 percent.~~

5. Combined Fly Ash, metakaolin or Pozzolans, ~~Ground Granulated Blast Furnace~~ Slag Cement, and Silica Fume: 50 percent; with fly ash, metakaolin or pozzolans not exceeding 25 percent and silica fume not exceeding 10 percent.

Retain the following for concrete structural members that will be exposed to water-soluble sulfates in soil or water in contact with concrete depending on the concentration of sulfates categorized in ACI 318 as follows. Sulfate ion concentration in soils is measured by ASTM C1580; water-soluble sulfate in water is measured by ASTM D512.

Exposure Category	Water soluble sulfate in soil, percent by weight	Water soluble sulfate in water, ppm
S0	<0.10	<150
S1	Between 0.10 and 0.20	Seawater or Between 150 and 1500
S2	Between 0.20 and 2.00	Between 1500 and 10,000
S3	Greater than 2.00	Greater than 10,000

Delete this paragraph for exposure class S0. Specify the type of cementitious materials based on the exposure class established for each structural member..

C. Type of Cementitious Materials: For structural members subject to sulfate exposure as identified in 2.15 use [**For Exposure Class S1, ASTM C150 Type II, ASTM C595 Types IP or IS (<70), tested to comply with the moderate sulfate resistance option (MS), or ASTM C1157**][**For Exposure Class S2, ASTM C150 Type V, ASTM C595 Types IP or IS (<70), tested to comply with the high sulfate resistance option (HS), or ASTM C1157, Type HS**][**For Exposure Class S3, ASTM C150 Type V, ASTM C595 Types IP or IS (<70), tested to comply with the high sulfate option (HS), or ASTM C1157, Type HS and additional pozzolans or slag**]

Retain paragraph below to permit an alternative to cement types defined above for sulfate exposure classes. The qualified mixture can be determined by service record based on use in the region or by testing to expansion limits for each exposure class by ASTM C1012 – for S1 – 0.10% at 6 months; for S2 – 0.05% at 6 months or 0.10% at 12 months (either criteria is acceptable); for S3 – 0.10% at 18 months. Due to the long test period, ACI 318 does permit service record with mixtures used in that area to be used as a basis of acceptable sulfate resistance. Blended cements in accordance with ASTM C595 or C1157 include options whereby cements are tested for moderate sulfate (MS) or high sulfate (HS) resistance. Select the option needed for expansion limit or for documentation of service record

1. Provide documentation of test results in accordance with ASTM C1012, for combinations of cementitious materials providing sulfate resistance for the sulfate exposure category indicated for members in 2.15 **[0.10% at 6 months] [0.05 at 6 months or 0.10% at 12 months] [0.10% at 18 months]**

Retain paragraph below if service record of concrete is permitted in lieu of testing addressed above.

2. Provide documentation of service record of concrete in sulfate exposure consistent with the concrete mixture proposed for Work.

Retain ~~appropriate option in first paragraph~~ below for chloride limits. Identify exposure categories for each structural member in the building. Exposure categories are defined in ACI 318: ~~portions of building with different limits if required. Percentages below repeat ACI 301 limits, respectively, for~~ prestressed (post-tensioned) concrete is subject to the same limit regardless of exposure category. For reinforced concrete Class C0 is for structural members that will be dry in service; Class C1 is for structural members that will be exposed to moisture but not to an external source of chlorides; and Class C2 is for structural

members exposed to moisture and an external source of chlorides in service. ~~chloride, reinforced concrete that will not be dry or protected from moisture, and reinforced concrete that will be dry or protected from moisture.~~ ACI 301 and ACI 318 (ACI 318M) express this percentage by weight of cement, not cementitious material.

D. Limit water-soluble, chloride-ion content in hardened concrete to following limits depending on the exposure category assigned to the structural member identified in 2.15. The limits are stated in terms of chloride ions in percent by weight of cement.
   1. Prestressed and post-tensioned concrete for all exposure categories – 0.06%
   2. Reinforced in Exposure Category C0 – 1.00%
   3. Reinforced in Exposure Category C1 – 0.30%
   4. Reinforced in Exposure Category C2 – 0.15%
   5. Provide documentation from concrete tested in accordance with ASTM C1218 at an age between 28 and 42 days.

E. Admixtures: Use admixtures according to manufacturer's written instructions.

Delete or revise four subparagraphs below to suit Project.

1. Use [**water-reducing**] [**high-range water-reducing**] [**or**] [**plasticizing**] admixture in concrete, as required, for placement and workability.
2. Use water-reducing and retarding admixture when required by high temperatures, low humidity, or other adverse placement conditions.
3. Use water-reducing admixture in pumped concrete, concrete for heavy-use industrial slabs and parking structure slabs, concrete required to be watertight, and concrete with a water-cementitious materials ratio below 0.50.

Add locations and dosage of corrosion-inhibiting admixture to subparagraph below if required.

4. Use corrosion-inhibiting admixture in concrete mixtures where indicated.

Retain paragraph below if integrally colored concrete is required, and indicate locations here or on Drawings.

F. Color Pigment: Add color pigment to concrete mixture according to manufacturer's written instructions and to result in hardened concrete color consistent with approved mockup.

Retain for the required air content based on the exposure category for structural members exposed to cycles of freezing and thawing defined in ACI 318. Assign exposure classes for structural members subject to exposure to cycles of freezing and thawing: Exposure Class F0 for concrete not exposed to freezing and thawing; Exposure Class F1 for concrete exposed to freezing and thawing and occasional exposure to moisture; Exposure Class F2 for concrete exposed to freezing and thawing and in continuous contact with moisture; and Exposure Class F3 for concrete exposed to freezing and thawing that will be in continuous contact with moisture and exposed to deicing chemicals.

G. Air Content: Provide total air content for each class of concrete based on the nominal maximum size of aggregate and the assigned exposure class for resistance to freezing and thawing indicated in 2.15. Concrete for members categories as Exposure Category F0 should be non-air entrained.

Nominal maximum Aggregate size, in.***	Total Air Content (%)	
	Exposure Class F2 and F3	Exposure Class F1

3/8	7.5	6.0
1/2	7	5.5
3/4	6	5
1	6	4.5
1-1/2	5.5	4.5
2	5	4
3	4.5	3.5

Permit the selection of slump by the placement contractor to ensure placeability with slump or slump flow for self consolidating concrete required for each class of concrete to be notified in the submittal. Slump should be used for the basis of ensuring consistency during Project.

H. Slump: Provide documentation in submittal prior to commencement of Work of target slump or slump flow value for each class of concrete. Consistency of concrete shall be established to facilitate placement with minimized potential for segregation.

Retain subparagraphs below when requirements are pertinent and reference requirement in defining requirements for structural members in 2.15.

I. Additional Requirements: Provide documentation in submittal prior to commencement of Work when required for concrete mixtures designed for structural members identified in 2.15.

Retain requirement below when there is a history of reactive aggregates in the region of Project and for structural members that will be exposed to moisture in service.

1. Alkali Silica Reactivity:
   a. Provide documentation of aggregate with a satisfactory service record for a minimum ten year period used in concrete with similar cementitious materials or with an alkali (Na_2O eq.) content in concrete equal or higher than that in the proposed mixture.
   b. Provide ASR test results of all aggregates proposed for use in concrete; aggregates with mortar bar expansion at 14 days in exposure solution, in accordance with ASTM C1260, less than or equal to 0.10% or expansion of concrete prisms at 1 year, in accordance with ASTM C1293, less than or equal to 0.04% shall be considered non-reactive and do not need additional testing per article (c) below
   b. In the absence of service record, or when test results of aggregates indicate potential for deleterious expansion by criteria in (b) above, provide documentation of tests conducted with the cementitious materials and aggregates proposed for Work – ASTM C1567 14-day expansion less than or equal to 0.10%. Each aggregate type shall be tested separately.

Retain requirement below when there is a requirement for reduced shrinkage of concrete mixtures, such as to minimize curling in slabs on grade or to minimize potential for cracking. Shrinkage limit of 0.05% is achievable with proper use of materials and proportioning of mixtures. Reducing this shrinkage limit may be appropriate for more critical construction but is harder to achieve. ASTM C157 has several variations of curing and drying periods that can also be modified in this requirement but will impact the shrinkage limit chosen.

2. Shrinkage: Provide documentation of the tests of concrete conducted in accordance with ASTM C157 for specimens cured for [**7 days in water and placed in drying environment for 21 days**]– length change should be less than **[0.05% at 28 days]** age.

Retain requirement below when there is a modulus of elasticity for concrete in specific structural members.

3. Modulus of Elasticity: Provide documentation of the tests of concrete conducted in accordance with ASTM C469 for specimens cured for 28 days for a modulus of elasticity greater than **[specify Ec required by design]**.

Retain requirements below if rapid chloride requirement is used instead of limit on maximum w/cm.

4. Rapid Chloride Permeability: Provide documentation of the tests of concrete conducted in accordance with ASTM C1202 for specimens cured for 7 days at 73°F and 21 days at 100°F to achieve a value equal to or less than the specified rapid chloride permeability (RCP) for class of concrete for building elements in 2.15.

Retain requirements below if freeze-thaw resistance testing is required for structural members instead of the other limitations on freeze-thaw requirements.

5. Freeze-thaw testing: For structural members indicated in 2.15 provide documentation of the tests of concrete conducted in accordance with ASTM C666 for a minimum durability factor of 60% at 300 cycles. Alternatively provide documentation that the spacing factor of the air void system of concrete specimens is less than 0.010 inches.

Retain one of requirements below to allow for the submittal of a thermal control plan in lieu of complying with temperature limits of concrete as delivered. A thermal control plan is appropriate for mass concrete members with a minimum dimension of 3 feet. Typical limits of maximum temperature of concrete in a structure are 158F and maximum temperature differential is 35F

6. Thermal Control Plan
   a. Provide documentation of procedures to be used to ensure that maximum concrete temperature in the structure will not exceed **[state max temperature in structure]** and the maximum temperature differential will not exceed **[state max temperature differential]**.
   b. Provide documentation of modeling temperature in concrete structure and ambient temperatures to ensure that maximum concrete temperature and temperature differential will have minimized risk of cracking.

2.15 CONCRETE MIXTURES FOR BUILDING MEMBERS

This Article contains examples of building elements that often need different concrete mixtures. Revise, consolidate, or add other building elements if more concrete mixtures are required.

Primary Requirements

Assign exposure classes from ACI 318 Exposure Categories: F for freezing and thawing; S for exposure to water soluble sulfates in soil; P for concrete members in contact with water requiring low permeability; C for concrete members requiring protection from corrosion of reinforcement. Review the definitions of Exposure Categories and requirements for concrete in ACI 318-08.

1. Durability Exposure Classes:
   a. For Exposure to freezing and thawing: [**F0**] [**F1**] [**F2)**] [**F3**].
   b. For Exposure to sulfates: [**S0**] [**S1**] [**S2)**] [**S3**].
   c. For contact with water requiring low permeability: [**P0**] [**P1**].
   d. For corrosion protection of reinforcement: [**C0**] [**C1**] [**C2)**].

Select strength from options below or revise to suit Project. Specified strength should be the more restrictive required for structural design or durability based on assigned exposure class. Coordinate compressive strength with water-cementitious materials ratio if concrete will be subject to ~~special exposure conditions or sulfate exposure~~ Exposure Categories defined in ACI 318-08 (ACI 318M-08).

~~Minimum~~ Specified Compressive Strength: [**5000 psi (34.5 MPa) Exp Class C2**] [**4500 psi (31 MPa) Exposure Class F1, F2, F3, S2, S3**] [**4000 psi (27.6 MPa) Exposure Class S1, P1**] [**3500 psi (24.1 MPa)**] [**3000 psi (20.7 MPa)**] Minimum is 2500 psi. Specified at 28 days or other selected age. State age..

Select water-cementitious materials ratio from three options in subparagraph below, revise to suit Project; if in-service durability conditions are not applicable to the structural member and limits on water-cementitious materials ratio are not required, do not specify w/cm. Select the lowest w/cm as required for the durability Exposure Class defined. Coordinate water-cementitious materials ratio with compressive strength. See Evaluations for discussion.

Maximum Water-Cementitious Materials Ratio: **[0.50 Exposure Class S1, P1] [0.45 Exposure Class F1, F2, F3, S2, S3] [0.40 Exp Class C2]** Instead of w/cm, specify chloride permeability in Additional Requirements.

Select nominal maximum size of aggregate as the smallest based on (1) 1/5 narrowest dimension between sides of forms, (2) 1/3 depth of slabs or (3) ¾ minimum clear spacing between reinforcement.

Select air content based on the exposure classification and the nominal maximum size of aggregate – see notes to 2.14G. For hard-trowel finished slabs, specify that air content should not exceed 3.0%.

Air content should be based on the exposure class established for freeze thaw resistance and nominal maximum aggregate size defined in 2.14.G.

Air Content: In accordance with 2.14.G for the exposure class for Category F defined in 2.15.A.1

The required slump or slump flow (for SCC) of concrete will be selected by the contractor and notified to the Architect/Engineer.

Slump or slump flow: Shall be selected by the contractor and communicated to the concrete supplier to satisfy placement requirements and to minimize segregation. The selected slump or slump flow for this class of concrete shall be notified to the Architect/Engineer. Slump or slump flow during delivery shall be at the level documented with applicable tolerances in ASTM C94.

Select water soluble chloride limits based on exposure class C1, C2 or C3 as addressed in 2.14D.

Select temperature limit and revise to suit Project. Consider option of submitting a thermal control plan in lieu of limits on temperature of concrete

Temperature:

a. Concrete temperature as delivered shall not exceed **[95F]**.

b. In cold weather concrete temperature as delivered shall not be less than **[55F for section size <12 in] [50 F for 12-36 in] [45F for 36-72] [40F for >72 in]**

Primary Requirements

Member	Mix ID	Durability Exposure				Specified Strength, f'_c, psi	Max w/cm	Nom. max aggregate, in.	Air content	Slump / Slump flow	Chloride limit	Temperature limits
		F	S	P	C							
Footings												
Foundation Walls												
Slabs-on-grade												
Exterior slabs												
Suspended slabs (interior)												
Suspended slabs (exterior)												
Frame members												
Columns (interior)												
Columns (exterior)												
Walls (interior)												
Concrete toppings												

Additional Requirements

Replace requirements for w/cm above with requirements for rapid chloride permeability (RCP) tests measured in accordance with ASTM C1202 using the following alternative requirements. Do not include both w/cm and RCP requirements:
w/cm = 0.50 → 2500 coulombs
w/cm = 0.45 → 2000 coulombs
w/cm = 0.40 → 1500 coulombs
For structures governed by the local building code, these alternatives may need approval from the building official.

1. Specified Chloride Permeability: [**2500 coulombs**] [**2000 coulombs**] [**1500 coulombs**].

When required for reduction of shrinkage cracking or curling of slabs, include a shrinkage requirement in accordance with 2.14.I. Specify the value required for test documentation.

When required to test for freezing and thawing resistance – typically instead of the applicable requirements on w/cm or air content or to use a lower air content than required by the Table, include durability factor as per ASTM C666 OR air void spacing factor as per ASTM C457 are options.

When required for structural members documentation of reduced potential for deleterious expansive cracking due to alkali silica reaction – see requirement in accordance with 2.14.I.

When required for structural members documentation of modulus of elasticity – specify value required by design in accordance with 2.14.I.

Specify the submission of a thermal control plan in accordance with 2.14.I. This plan will document procedures to minimize the core temperature and the temperature differential – it is typically required for mass concrete members with minimum dimension of 3 ft and can be used to eliminate limits on concrete temperature as delivered.

Specify one of three options in subparagraph below or revise values or unit weight terminology. "Calculated equilibrium unit weight" is the basis preferred as determined in ASTM C567

Calculated Equilibrium Unit Weight: [**115 lb/cu. ft. (1842 kg/cu. m)**] [**110 lb/cu. ft. (1762 kg/cu. m)**] [**105 lb/cu. ft. (1682 kg/cu. m)**], plus or minus 3 lb/cu. ft. (48.1 kg/cu. m) as determined by ASTM C 567.

Specify any other performance requirements for concrete structural members.

Indicate location, on Drawings, of concrete using steel fiber. Revise application rate to suit Project.

Steel-Fiber Reinforcement: Add to concrete mixture, according to manufacturer's written instructions, at a rate of [**50 lb/cu. yd. (29.7 kg/cu. m)**] <**Insert weight**>.

Synthetic-fiber dosage rates in subparagraph below reflect typical recommendations of manufacturers. Retain first option for synthetic fiber used for reducing plastic shrinkage cracking. Retain second option for synthetic fiber used for improving hardened concrete properties. Revise dosage if required.

Synthetic Fiber: Uniformly disperse in concrete mixture at manufacturer's recommended rate, but not less than [**1.0 lb/cu. yd. (0.60 kg/cu. m)**] [**1.5 lb/cu. yd. (0.90 kg/cu. m)**] <**Insert dosage**>.

Additional Requirements

Member	Mix ID	RCP, C1202	Shrinkage, C157	Freeze Thaw		ASR	MOE	Thermal Control Plan	Density	Other	Other
				C666	C457						
Footings											
Foundation Walls											
Slabs-on-grade											
Exterior slabs											
Suspended slabs (interior)											
Suspended slabs (exterior)											
Frame members											
Columns (interior)											
Columns (exterior)											
Walls (interior)											

2.16 FABRICATING REINFORCEMENT

2.17 CONCRETE ~~MIXING~~ PRODUCTION AND DELIVERY

Retain option for ASTM C1116 in paragraph below if steel or synthetic fibers are required.

A. Ready-Mixed Concrete: Measure, batch, mix, and deliver concrete according to ASTM C 94/C 94M[**and ASTM C 1116**], and furnish batch ticket information in accordance with ASTM C94.

1. Indicate on delivery tickets amounts of mixing water ~~to be~~ withheld for ~~later~~ permitted addition at Project site, when applicable.

1. ~~When air temperature is between 85 and 90 deg F (30 and 32 deg C), reduce mixing and delivery time from 1-1/2 hours to 75 minutes; when air temperature is above 90 deg F (32 deg C), reduce mixing and delivery time to 60 minutes.~~

Delete paragraph and subparagraphs below if volumetric batching and continuous mixing is not permitted.

B. Ready-Mixed Concrete: Measure, batch, mix, and deliver concrete by volumetric batching and continuous mixing in according to ASTM C685, and furnish batch ticket information in accordance with ASTM C685.

Delete paragraph and subparagraphs below if Project-site mixing is not permitted. ACI 301 applies measuring, batching, and mixing requirements from ASTM C 94/C 94M to Project-site mixing.

C. Project-Site Mixing: Measure, batch, and mix concrete materials and concrete according to ASTM C 94/C 94M. Mix concrete materials in appropriate drum-type batch machine mixer.
1. For mixer capacity of 1 cu. yd. (0.76 cu. m) or smaller, continue mixing at least 1-1/2 minutes, but not more than 5 minutes after ingredients are in mixer, before any part of batch is released.
2. For mixer capacity larger than 1 cu. yd. (0.76 cu. m), increase mixing time by 15 seconds for each additional 1 cu. yd. (0.76 cu. m).
3. Provide batch ticket for each batch discharged and used in the Work, indicating Project identification name and number, date, mixture type, mixture time, quantity, and amount of water added. Record approximate location of final deposit in structure.

PART 3 EXECUTION

3.1 FORMWORK

3.2 EMBEDDED ITEMS

3.3 REMOVING AND REUSING FORMS

3.4 SHORES AND RESHORES

3.5 VAPOR RETARDERS

3.6 STEEL REINFORCEMENT

3.7 JOINTS

3.8 WATERSTOPS

3.9 CONCRETE PLACEMENT

A. Before placing concrete, verify that installation of formwork, reinforcement, and embedded items is complete and that required inspections have been performed.

B. Water addition is permitted to the maximum quantity indicated on the delivery ticket as is required to be noted in 2.17.A.1 ~~Do not add water to concrete during delivery, at Project site, or during placement unless approved by Architect.~~

~~Retain paragraph above or first paragraph and subparagraph below. ACI 301 permits water to be added to concrete mixture on site to adjust slump, up to amount allowed in design mixture.~~

~~C. Before test sampling and placing concrete, water may be added at Project site, subject to limitations of ACI 301.~~

~~Delete subparagraph below if high range water-reducing admixtures are not permitted.~~

~~1. Do not add water to concrete after adding high range water-reducing admixtures to mixture.~~

D. Deposit concrete continuously in one layer or in horizontal layers of such thickness that no new concrete will be placed on concrete that has hardened enough to cause seams or planes of weakness. If a section cannot be placed continuously, provide construction joints as indicated. Deposit concrete to avoid segregation.

1. Deposit concrete in horizontal layers of depth to not exceed formwork design pressures and in a manner to avoid inclined construction joints.
2. Consolidate placed concrete with mechanical vibrating equipment according to ACI 301.
3. Do not use vibrators to transport concrete inside forms. Insert and withdraw vibrators vertically at uniformly spaced locations to rapidly penetrate placed layer and at least 6 inches (150 mm) into preceding layer. Do not insert vibrators into lower layers of concrete that have begun to lose plasticity. At each insertion, limit duration of vibration to time necessary to consolidate concrete and complete embedment of reinforcement and other embedded items without causing mixture constituents to segregate.

E. Deposit and consolidate concrete for floors and slabs in a continuous operation, within limits of construction joints, until placement of a panel or section is complete.

1. Consolidate concrete during placement operations so concrete is thoroughly worked around reinforcement and other embedded items and into corners.
2. Maintain reinforcement in position on chairs during concrete placement.

3. Screed slab surfaces with a straightedge and strike off to correct elevations.
4. Slope surfaces uniformly to drains where required.
5. Begin initial floating using bull floats or darbies to form a uniform and open-textured surface plane, before excess bleedwater appears on the surface. Do not further disturb slab surfaces before starting finishing operations.

F. 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, freezing actions, or low temperatures.

Select concrete temperature limit for cold weather placement based on minimum section dimension

1. When average high and low temperature is expected to fall below 40 deg F (4.4 deg C) for three successive days, maintain delivered concrete mixture temperature as indicated in 2.15 ~~**[55°F for min dimension less than 12 inches] [50°F for min dimension between 12 36 inches] [45°F for min dimension between 36 72 inches] [40°F for min dimension greater than 72 inches]** 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 or on surface at a temperature less than 35°F.
3. ~~Do not use calcium chloride, salt, or other materials containing antifreeze agents or chemical accelerators unless otherwise specified and approved in mixture designs.~~

G. Hot-Weather Placement: Comply with ACI 305.1 and as follows:

1. Maintain concrete temperature below 95 deg F at time of placement or as indicated in thermal control plan. Chilled mixing water or chopped ice may be used to control temperature, provided water equivalent of ice is calculated to 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.

3.10 FINISHING FORMED SURFACES

3.11 FINISHING FLOORS AND SLABS

3.12 MISCELLANEOUS CONCRETE ITEMS

3.13 CONCRETE PROTECTING AND CURING

3.14 LIQUID FLOOR TREATMENTS

3.15 JOINT FILLING

3.16 CONCRETE SURFACE REPAIRS

3.17 FIELD QUALITY CONTROL

Retain one of first two paragraphs below.

Retain first option in paragraph below if authorities having jurisdiction require Owner to engage a special inspector. Retain last option if Owner engages testing agency, with or without a special inspector. See "Testing and Inspecting Considerations" Article in the Evaluations.

A. Testing and Inspecting: Owner will engage a [**special inspector**] [**and**] [**qualified testing and inspecting agency**] to perform field tests and inspections and prepare test reports.

B. Provide space and source of electrical power on the project site for facilities to be used for initial curing of concrete test specimens as required by ASTM C31/C31M, for the sole use of Owner's quality assurance testing agency.

1. The Testing Agency shall ensure that standard curing and other requirements for handling and transportation of tests specimens are in accordance with ASTM C31/C31M.

Retain first paragraph below if Contractor engages testing agency.

C. Testing and Inspecting: Engage a qualified testing and inspecting agency to perform tests and inspections and to submit reports.

D. Inspections:

Retain seven subparagraphs below if special inspections are required. Items below are examples of special inspections and are based on IBC requirements; revise to add other inspections or to suit requirements of other building codes.

2. Steel reinforcement placement.
3. Steel reinforcement welding.
4. Headed bolts and studs.
5. Verification of use of required design mixture.
6. Concrete placement, including conveying and depositing.
7. Curing procedures and maintenance of curing temperature.
8. Verification of concrete strength before removal of shores and forms from beams and slabs.

E. Concrete Tests: Testing of composite samples of fresh concrete obtained according to ASTM C 172 shall be performed according to the following requirements:

1. Testing Frequency: Obtain one composite sample for each day's pour of each concrete mixture exceeding 5 cu. yd. (4 cu. m), but less than 25 cu. yd. (19 cu. m), plus one set for each additional 50 cu. yd. (38 cu. m) or fraction thereof.

Retain subparagraph above or below. Above is an example that produces more frequent testing than below, which is testing frequency required to comply with ACI 301.

2. Testing Frequency: Obtain at least one composite sample for each 100 cu. yd. (76 cu. m) or fraction thereof of each concrete mixture placed each day.

Retain first subparagraph below with either subparagraph selected above.

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 C 143/C 143M; one test at point of ~~placement~~ discharge from the transportation unit for each composite sample when strength test specimens are prepared. ~~but not less than one test for each day's pour of each concrete mixture~~. Perform additional tests as required ~~when concrete consistency appears to change~~.

Retain first subparagraph below when slump flow is tested.

a. Slump Flow: ASTM C1611; one test at point of discharge from the transportation unit for each composite sample when strength test specimens are prepared. Perform additional tests as required.

4. Air Content: ASTM C 231, pressure method, for normal-weight concrete; [**ASTM C 173/C 173M, volumetric method, for structural lightweight concrete;**]one test for each composite sample when strength test specimens are prepared. Perform additional tests as required~~, but not less than one test for each day's pour of each concrete mixture~~.
5. Concrete Temperature: ASTM C 1064/C 1064M; ~~one test hourly when air temperature is 40 deg F (4.4 deg C) and below and when 80 deg F (27 deg C) and above, and~~ one test for each composite sample when strength test specimens are prepared.
6. Unit weight: ASTM C138; for each composite sample when test specimens are prepared.

Delete first subparagraph below if no structural lightweight concrete.

7. Unit Weight: ASTM C 567, fresh unit weight of structural lightweight concrete; one test for each composite sample, but not less than one test for each day's pour of each concrete mixture.
8. Compression Test Specimens: ASTM C 31/C 31M.
   a. A compressive strength test result shall be the average of two 6x12 inch or three 4x8 inch cylinders prepared from the same sample of concrete and tested at the same age.
   b. Cast and ~~laboratory~~ standard cure the required number of ~~two standard~~ cylinder specimens for each composite sample based on the test ages indicated in 3.17.E.9.

Field-cured specimens in subparagraph below may be required to verify adequacy of curing and protection of concrete, to verify strength for tilt-up concrete and post-tensioning concrete, or to verify strength for removal of shoring and reshoring in multistory construction. Revise number of test specimens if required.

   c. Cast and field cure [**two**] <**Insert number**> two ~~standard~~ cylinder specimens for each composite sample. Field cure cylinders shall be held at the same temperature and moisture conditions as the member containing the concrete they represent.

Coordinate number of compression test specimens in subparagraph and associated subparagraphs above with number of compressive-strength tests in subparagraph and associated subparagraphs below.

9. Compressive-Strength Tests: ASTM C 39/C 39M; test one set of ~~two laboratory~~ standard-cured specimens at 7 days and one set of ~~two~~ standard-cured specimens at 28 days, unless another age is selected for the class of concrete.

Revise age at testing in first subparagraph below or delete if not required. Limit field testing to concrete in designated structural elements if not required throughout Project.

   a. Test one set of ~~two~~ field-cured specimens at 7 days and of ~~two~~ specimens at 28 days.
   ~~b. A compressive-strength test shall be the average compressive strength from a set of two specimens obtained from same composite sample and tested at age indicated.~~

Delete first subparagraph below if field-cured specimens are not required.

10. When strength of field-cured cylinders is less than 85 percent of companion laboratory-cured cylinders, Contractor shall evaluate operations and provide corrective procedures for protecting and curing in-place concrete.
11. Strength of each concrete mixture will be satisfactory if
    a. every average of any three consecutive compressive-strength tests equals or exceeds specified compressive strength, and
    b. no compressive-strength test value falls below specified compressive strength by more than 500 psi (3.4 MPa) or by more than 10 percent of the specified strength when the specified strength is greater than 5000 psi.

~~Delete first subparagraph below if specified strength is greater than 5000 psi.~~

~~a. Strength of each concrete mixture for specified strength greater than 5000 psi will be satisfactory if every average of any three consecutive compressive strength tests equals or exceeds specified compressive strength and no compressive strength test value falls below specified compressive strength by more than 10 percent of the specified strength.~~

12. Test results shall be reported in writing to Architect, concrete manufacturer, and Contractor within 48 hours of testing. Reports of compressive-strength tests shall contain Project identification name and number, date of concrete placement, name of concrete testing and inspecting agency, location of concrete batch in Work, design compressive strength at 28 days, concrete mixture proportions and materials, compressive breaking strength, and type of break for both 7- and 28-day tests.
13. Nondestructive Testing: Impact hammer, sonoscope, or other nondestructive device may be permitted by Architect but will not be used as sole basis for approval or rejection of concrete.
14. 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 Architect. Testing and inspecting agency may conduct tests to determine adequacy of concrete by cored cylinders complying with ASTM C 42/C 42M or by other methods as directed by Architect.
    a. When an individual strength test result is greater than 500 psi less than the specified strength, at least three cores shall be extracted from that portion of the structure represented by the low strength test result. The cores will be conditioned in accordance with ASTM C42.
    b. The concrete mixture will be satisfactory if the average of three cores is equal to or greater than 0.85 times the specified strength and the compressive strength of each core is equal to or greater than 0.75 times the specified strength.
15. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.
16. Correct deficiencies in the Work that test reports and inspections indicate do not comply with the Contract Documents.

END OF SECTION 033000