UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023
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DIVISION 03 - CONCRETE

SECTION 03 31 30

MARINE CONCRETE

02/19

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NOTE: This guide specification covers the requirements for reinforced concrete exposed to marine and chloride environments for projects with no specific requirements for service life design. In addition, use this guide specification for projects with concrete exposed to weather in locations with Environmental Severity Classifications (ESC) of C4 and C5 and where deicing salts are used on the structure. See UFC 1-200-01 for determination of the ESC for project locations.

This guide specification provides prescriptive requirements for marine concrete. It contains specific requirements for quality control (actions taken by the Contractor) and quality assurance (actions that may be taken by the Government). This guide specification is for projects where service life modeling is not required or deemed beneficial by the Government. If it is determined that concrete service life modeling is required, then Section 03 31 29 MARINE CONCRETE WITH SERVICE LIFE MODELING should be used.

This guide specification should be considered for projects that meet the following conditions:

o Required service life: equal to or less than 60 years; and

o Volume of concrete works: equal to or less than 10,000 cubic yard; and

o Monetary construction value of the entire project: equal to or less than $15M; and

o Service life modeling is not required by the Government.

Other criteria to consider when evaluating the

applicability of service life design include:

o Mission Criticality based on the Mission Dependency Index (MDI) Score. For example, a MDI score between 1 to 54 should assess if service life modeling is beneficial. MDI scores greater than 54 should incorporate service life modeling unless there is a specific determination made by the Government not to.

o Consequences of failure: UFC 3-301-01 Risk Categories I, II, or III should assess if service life modeling is beneficial. Higher risk categories should incorporate service life modeling unless there is a specific determination made by the Goveernment not to.

The criteria listed above are provided as guidance to the specifier as to the applicability of this guide specification. Specific project characteristics should be evaluated and the decision to implement service life modeling will ultimately depend upon the project specific requirements and the determination of the Owner, Engineer of Record, and/or Contracting Officer.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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NOTE: Development team of this section considered the International Green Construction Code, which is "the first model code that includes sustainability measures for the entire construction project and its site - from design through construction, certificate of occupancy and beyond. The new code is expected to make buildings more efficient, reduce waste, and have a positive impact on health, safety, and community welfare."
http://www.iccsafe.org/cs/igcc/pages/default.aspx

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NOTE: The following information shall be shown on

the project drawings:

1. Design assumptions.

2. Assumed temperature range when temperature stresses are a factor in design.

3. Material strengths used in design, f'c.

4. Yield strength of reinforcement required 414 mPa 60,000 psi or other grade as available.

5. Details of concrete sections, showing dimensions, reinforcement cover, and required camber.

6. Joint details, showing locations and dimensions.

7. Details and locations of critical construction joints, including water stop locations and splices, keys, and dowels when required, and location of fiber-reinforced concrete elements.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO M 182	(2005; R 2017) Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats

AASHTO R 80	(2017) Standard Practice for Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction
AASHTO T 358	(2017) Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 117	(2010; Errata 2011) Specifications for Tolerances for Concrete Construction and Materials and Commentary
ACI 121R	(2008) Guide for Concrete Construction Quality Systems in Conformance with ISO 9001
ACI 201.2R	(2016) Guide to Durable Concrete
ACI 211.1	(1991; R 2009) Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete
ACI 214R	(2011) Evaluation of Strength Test Results of Concrete
ACI 301	(2016) Specifications for Structural Concrete
ACI 301M	(2016) Metric Specifications for Structural Concrete
ACI 304.2R	(2017) Guide to Placing Concrete by Pumping Methods
ACI 304R	(2000; R 2009) Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 305R	(2020) Guide to Hot Weather Concreting
ACI 306R	(2016) Guide to Cold Weather Concreting
ACI 308.1	(2011) Specification for Curing Concrete
ACI 309R	(2005) Guide for Consolidation of Concrete
ACI 311.4R	(2005) Guide for Concrete Inspection
ACI 318	(2014; Errata 1-2 2014; Errata 3-5 2015; Errata 6 2016; Errata 7-9 2017) Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)
ACI 318M	(2014; ERTA 2015) Building Code Requirements for Structural Concrete & Commentary

ACI 347R	(2014; Errata 1 2017) Guide to Formwork for Concrete
ACI SP-2	(2007; Abstract: 10th Edition) ACI Manual of Concrete Inspection
ACI SP-15	(2011) Field Reference Manual: Standard Specifications for Structural Concrete ACI 301-05 with Selected ACI References
ACI SP-66	(2004) ACI Detailing Manual

AMERICAN WELDING SOCIETY (AWS)

AWS D1.4/D1.4M	(2011) Structural Welding Code - Reinforcing Steel

APA - THE ENGINEERED WOOD ASSOCIATION (APA)

APA PS 1	(2009) Structural Plywood (with Typical APA Trademarks)

ASTM INTERNATIONAL (ASTM)

ASTM A276/A276M	(2017) Standard Specification for Stainless Steel Bars and Shapes
ASTM A416/A416M	(2018) Standard Specification for Low-Relaxation, Seven-Wire for Prestressed Concrete
ASTM A615/A615M	(2022) Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A706/A706M	(2022a) Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A767/A767M	(2016) Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
ASTM A882/A882M	(2020) Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand
ASTM A886/A886M	(2017) Standard Specification for Steel Strand, Indented, Seven-Wire Stress-Relieved for Prestressed Concrete
ASTM A934/A934M	(2022) Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
ASTM A955/A955M	(2020c) Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement

ASTM A1035/A1035M	(2023 Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement
ASTM A1055/A1055M	(2022) Standard Specification for Zinc and Epoxy Dual Coated Steel Reinforcing Bars
ASTM A1064/A1064M	(2022) Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
ASTM C31/C31M	(2022) Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C33/C33M	(2018) Standard Specification for Concrete Aggregates
ASTM C39/C39M	(2021) Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C42/C42M	(2020) Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C78/C78M	(2022) Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C94/C94M	(2022a) Standard Specification for Ready-Mixed Concrete
ASTM C138/C138M	(2017a) Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C143/C143M	(2020) Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C150/C150M	(2022) Standard Specification for Portland Cement
ASTM C157/C157M	(2017) Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
ASTM C171	(2020) Standard Specification for Sheet Materials for Curing Concrete
ASTM C172/C172M	(2017) Standard Practice for Sampling Freshly Mixed Concrete
ASTM C173/C173M	(2016) Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C192/C192M	(2019) Standard Practice for Making and

	Curing Concrete Test Specimens in the Laboratory
ASTM C231/C231M	(2022) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C260/C260M	(2010a; R 2016) Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C294	(2012; R 2017) Standard Descriptive Nomenclature for Constituents of Concrete Aggregates
ASTM C295/C295M	(2019) Standard Guide for Petrographic Examination of Aggregates for Concrete
ASTM C309	(2019) Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C311/C311M	(2022) Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
ASTM C457/C457M	(2023) Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete
ASTM C469/C469M	(2022) Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
ASTM C494/C494M	(2019; E 2022) Standard Specification for Chemical Admixtures for Concrete
ASTM C496/C496M	(2017) Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
ASTM C595/C595M	(2021) Standard Specification for Blended Hydraulic Cements
ASTM C618	(2023; E 2023) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C666/C666M	(2015) Resistance of Concrete to Rapid Freezing and Thawing
ASTM C805/C805M	(2018) Standard Test Method for Rebound Number of Hardened Concrete
ASTM C920	(2018) Standard Specification for Elastomeric Joint Sealants
ASTM C989/C989M	(2022) Standard Specification for Slag Cement for Use in Concrete and Mortars

ASTM C1017/C1017M	(2013; E 2015) Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
ASTM C1064/C1064M	(2017) Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C1074	(2019) Standard Practice for Estimating Concrete Strength by the Maturity Method
ASTM C1077	(2017) Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1107/C1107M	(2020) Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
ASTM C1152/C1152M	(2020) Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete
ASTM C1157/C1157M	(2020a) Standard Performance Specification for Hydraulic Cement
ASTM C1202	(2022; E 2022) Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
ASTM C1231/C1231M	(2015) Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders
ASTM C1240	(2020) Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C1260	(2021) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1567	(2022) Standard Test Method for Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C1602/C1602M	(2022) Standard Specification for Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM C1610/C1610M	(2021) Standard Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique
ASTM C1611/C1611M	(2021) Standard Test Method for Slump Flow of Self-Consolidating Concrete
ASTM C1621/C1621M	(2017) Standard Test Method for Passing

	Ability of Self-Consolidating Concrete by J-Ring
ASTM D75/D75M	(2019) Standard Practice for Sampling Aggregates
ASTM D512	(2012) Chloride Ion in Water
ASTM D516	(2016) Standard Test Method for Sulfate Ion in Water
ASTM D1179	(2016) Standard Test Methods for Fluoride Ion in Water
ASTM D1751	(2018) Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D1752	(2018) Standard Specification for Preformed Sponge Rubber, Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM D3867	(2016)Standard Test Methods for Nitrite-Nitrate in Water
ASTM D6690	(2015) Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements
ASTM E329	(2021) Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection

CONCRETE REINFORCING STEEL INSTITUTE (CRSI)

CRSI 10MSP	(2018) Manual of Standard Practice

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 39	(1981) Test Method for Coefficient of Linear Thermal Expansion of Concrete
COE CRD-C 61	(1989A) Test Method for Determining the Resistance of Freshly Mixed Concrete to Washing Out in Water
COE CRD-C 572	(1974) Corps of Engineers Specifications for Polyvinylchloride Waterstops

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS SS-S-200	(Rev E; Notice 1; Notice 2) Sealant, Joint, Two-Component, Jet-Blast-Resistant, Cold-Applied, for Portland Cement Concrete Pavement

1.2 DEFINITIONS

a. "Atmospheric zone" is any portion of the waterfront structure above the splash zone.

b. "Buried zone" is any portion of the structure permanently buried in soil.

c. "Cementitious material" as used herein shall include portland cement and any pozzolanic material such as fly ash, natural pozzolans, ground granulated blast-furnace slag and silica fume.

d. "Concrete System" is the term describing a structural element comprised of concrete, reinforcing steel and concrete cover.

e. "Design strength" (f'c) is the specified compressive strength of concrete at time(s) specified by Contracting Officer to meet structural design criteria. Typical duration is 28 days; however, the Contracting Officer and Engineer of Record are encouraged to consider specifying strength at 56 or 90 days. For concrete mixtures containing 35 percent fly ash or more, the duration shall be a minimum of 56 days.

f. "Field test strength" (fcr) is the required compressive strength of concrete to meet structural and durability criteria. Determine (fcr) during mixture proportioning process.

g. "High-volume fly ash concrete" has a minimum of 35 percent Class F fly ash as a partial replacement to portland cement.

h. "Marine concrete" is all concrete that will be in contact with seawater or brackish water, tidal variations, splash, or spray from water in navigable waterways. Piles driven on land that extend below the water table that contains saltwater or brackish water shall be designed as marine concrete. Components of a marine structure that are permanently buried in soil shall be considered marine concrete. In addition, structures may need to be designed using these criteria even though they are not adjacent to the waterfront. For example, structures located several hundred yards from the waterfront often deteriorate prematurely due to salt spray and salt fog brought to the structure by prevailing winds. An assessment of existing structures near the construction site can be an excellent indicator for the Engineer of Record and Owner to decide if the proposed structure should follow the guidelines for marine concrete.

i. "Mass Concrete" is any concrete system that approaches a maximum temperature of 70 degrees C 158 degrees F within the first 72 hours of placement. In addition, it includes all concrete elements with a section thickness of 1 meter 3 feet or more regardless of temperature.

j. "Mixture proportioning" is the process of designing concrete mixture proportions to enable it to meet the strength, durability and constructability requirements and of the project while minimizing the initial and life-cycle cost.

k. "Mixture proportions" are the masses or volumes of individual ingredients used to make a unit measure (cubic yard or meter) of concrete.

l. "Pozzolan" is a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

m. "Process control sampling" is sampling and testing conducted by the Contractor to monitor the quality of materials or processes. Process control sampling is intended to indicate the quality of materials at critical steps in production that allow intervention prior to using a material on the project.

n. "Quality Acceptance Limit" (QAL) is the limiting value of a test result that indicates acceptable material quality. Quality acceptance limits are based on design criteria that may be either upper-bound limits where smaller values indicate acceptable material, such as D_{oh}; or lower-bound limits where larger values indicate acceptable material, such as compressive strength.

o. "Quality acceptance sampling" is sampling and testing conducted by the Contractor, or an independent testing agency, to evaluate the quality of materials used on the project. Quality acceptance sampling is conducted at regular intervals identified as "lots" to represent the quality of that portion of the material used in the project.

p. "Required compressive strength" (f'c) is the mean compressive strength of concrete required to meet structural criteria. The required strength is the mean concrete strength for tests of properly batched concrete at the age specified herein.

q. "Service life" is the Owner's stated expectation for the number of years that the structure will function without needing major concrete rehabilitation. A service life of 75 years for pile supported piers, wharves and bridges is a reasonable objective. Service life is defined as the number of years before major restoration is necessary given minimal maintenance to the structure during its life. Major restoration is defined as extensive areas that require extensive repairs using a jack hammer or other destructive means to prepare the concrete for rehabilitation. Service life is further defined as the summation of the corrosion initiation period (Ti) and the corrosion propagation period (Tp) for a given concrete system.

r. "Service Life Modeling" in the context of this document refers to a methodology to predict the length of time in service at which a defined level of deterioration will occur. Service life modeling is not required in this specification.

s. "Splash zone" is the portion of the structure just above the tidal zone. This portion of the structure is predominantly dry, but is likely to intermittently wet by wave action and wind driven spray. For the purposes of this specification, the splash zone is defined as follows:

(1) for locations protected by seawalls or otherwise sheltered from open-ocean waves, the 2 meters 6 feet area just above the tidal zone;

(2) for unprotected locations, the 6 meters 20 feet area just above the tidal zone.

t. "Submerged zone" is defined as the submerged portion of the structure. For the purposes of this specification, any element or portion thereof that is located below Mean Lower Low Water (MLLW). In areas with minimal tides, it would be defined as that portion of the element below Mean Sea Level (MSL).

u. "Supplemental Corrosion Protection" includes (but is not limited to) fusion-bonded epoxy-coated steel reinforcing, galvanized steel reinforcing, stainless reinforcing, corrosion inhibitors, barrier coatings to the concrete surface, and cathodic protection.

v. "Supplementary cementing materials" (SCM) include coal fly ash, granulated blast-furnace slag, natural or calcined pozzolans, and ultra-fine coal ash when used in such proportions to replace the portland cement that result in considerable improvement to sustainability, durability and in some cases a reduction in initial cost.

w. "Test Section" is a slab or wall separate from the main structure and constructed prior to main construction as an all inclusive demonstration of methods and materials. The adequacy of the Test Section must be approved by the owner's representative prior to construction of the project.

x. "Tidal zone" is defined as the portion of the structure regularly wetted by wave action. For the purposes of this specification, any element or portion thereof that is located between Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW) is in the tidal zone. In areas with minimal tides, this would be defined as the area located between Mean Sea Level (MSL) and Mean High Water (MHW).

1.3 SUBMITTALS

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NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force, and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Concrete Curing Plan

Concrete Qualification Program; G[, [_____]]

Concrete Quality Control Program; G[, [_____]]

Concrete Placement and Compaction

Concrete Pumping

Curing Concrete Elements

Form Removal Schedule

Laboratory Qualifications; G[, [_____]]

Quality Control Personnel Qualifications; G[, [_____]]

SD-02 Shop Drawings

Construction and Expansion Joints; G[, [_____]]

Formwork

Precast Elements; G[, [_____]]

Reinforcing Steel; G[, [_____]]

Reproductions of contract drawings are unacceptable.

SD-03 Product Data

Admixtures; G[, [_____]]

Air Entraining; G[, [_____]]

Aggregates; G[, [_____]]

Corrosion Inhibitors; G[, [_____]]

Joint Filler

Joint Sealants

Materials for Curing Concrete

Material Safety Data Sheets

Mechanical Reinforcing Bar Connectors; G[, [_____]]

Non-Shrink Grout

Preformed Joint Filler

Prestressing Steel; G[, [_____]]

Reinforcing Bars; G[, [_____]]

Reinforcement and Protective Coating; G[, [_____]]

Reinforcement Supports

Sealer-Hardener

Waterstops

Welded Wire Fabric

SD-04 Samples

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NOTE: Where flat surface finishing is important, provide a sample installation to train the crew.
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Mass Concrete Mock-up

Test Section

SD-05 Design Data

Concrete Mixture Requirements; G[, [_____]]

Mixture Designs

Mass Concrete Temperature Control Plans; G[, [_____]]

SD-06 Test Reports

Mass Concrete Mock-up

Air Entraining

Aggregates

Admixtures

Cement

Concrete Mixture Proportions

Concrete Test Reports

Fresh Concrete Properties

Hardened Concrete Properties

Mechanical Reinforcing Bar Connectors

Reinforcing Bars

Reinforcement and Protective Coating

Silica Fume

Supplementary Cementing Materials

Water

SD-07 Certificates

Admixtures

Cementitious Materials

Cementitious Material Mill Certificates

Field Testing Technician and Testing Agency

SD-08 Manufacturer's Instructions

Coatings

SD-11 Closeout Submittals

Aggregate Moisture Content

Aggregate Sampling

Concrete Test Reports

Quality Control Charts

Daily Inspection Reports

Quality Team Meetings

Sampling Logs

1.4 MODIFICATION OF REFERENCES

Accomplish work in accordance with ACI publications except as modified herein. Consider the advisory or recommended provisions to be mandatory, as though the word "shall" had been substituted for the words "should" or "could" or "may," wherever they appear. Interpret reference to the "Building Official," the "Structural Engineer," and the

"Architect/Engineer" to mean the Contracting Officer.

1.5 DELIVERY, PLACING, STORAGE, AND HANDLING OF CONCRETE

Follow ACI 301M ACI 301, ACI 304R, and ASTM A934/A934M requirements and recommendations. Do not deliver concrete until vapor barrier, forms, reinforcement, embedded items, and chamfer strips are in place and ready for concrete placement. Store reinforcement of different sizes and shapes in separate piles or racks raised above the ground. Protect materials from contaminants such as grease, oil, and dirt. Ensure materials can be accurately identified after bundles are broken and tags removed.

1.6 CONCRETE QUALITY CONTROL

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NOTE: The goal is to provide quality concrete with the specified concrete cover to protect the steel, which provides the primary protection mechanism against chemical deterioration and corrosion related damage. All other corrosion protection strategies are considered to be supplemental and include (but are not limited to): barrier coatings to the concrete surface, fusion-bonded epoxy-coated steel, corrosion inhibitors, galvanized, stainless, MMFX, Z-bar reinforcing and cathodic protection. All of which may provide some life extension but by how much is difficult to predict on a numerical basis for real structures exposed to chloride environments. If the available materials in the region of the project are inadequate to meet the requirements for shrinkage, compressive strength, constructability and service life then the Contractor shall prepare a recommendation for review by the agency's Subject Matter Expert in Concrete Materials and approval by the Contracting Officer and Engineer of Record on a case-by-case basis to use supplemental corrosion protection to meet project requirements.

Where they are available, specify only ACI certified personnel. Check the American Concrete Institute (ACI) website for local availability: https://www.concrete.org/certification.

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The objective of the concrete quality control program is for the Contractor to outline the procedures that will be used to construct a structure that will meet the project criteria. The Contractor shall develop and submit for approval a concrete quality control program in accordance with the guidelines of ACI 121R and as specified herein. The plan shall include approved laboratories. The Contractor shall provide direct oversight for the concrete qualification program inclusive of associated sampling and testing. If concrete cylinders tested during production indicate inadequate strength, excessive chloride ion penetration, or inadequate mixing, then the owner may require the Contractor to extract concrete core samples from the hardened concrete for analysis at Contractor's expense to assure that the quality of the concrete as placed and cured will satisfy the project criteria.

Develop and submit for approval a concrete quality control program in accordance with the guidelines of ACI 121R. Maintain a copy of ACI SP-15 and CRSI 10MSP at the project site.

1.6.1 Quality Control Personnel

The contractor shall submit for approval an organizational chart defining the quality control hierarchy, the responsibilities of the various positions, including the names and qualifications of the individuals in those positions.

Submit American Concrete Institute certification for the following:

a. CQC personnel responsible for inspection of concrete operations.

b. Lead Foreman or Journeyman of the Concrete Placing, Finishing, and Curing Crews.

c. Field Testing Technicians: ACI Concrete Field Testing Technician, Grade I.

d. Laboratory Testing Technicians: ACI Concrete Strength Testing Technician and Laboratory Testing Technician, Grade I or II.

e. Petrographer: Bachelor of Science degree in geology or petrography, trained in petrographic examination of concrete aggregate according to ASTM C294 and ASTM C295/C295M and trained in identification of the specific deleterious processes and tests identified in this specification. Resume shall detail the education, training and experience related to the project-specific test methods and deleterious materials and shall be submitted at least 20 days before petrographic and deleterious materials examination is to commence.

f. Concrete Batch Plant Operator: National Ready Mix Concrete Association (NRMCA) Plant Manager Certification at the Plant Manager level.

1.6.1.1 Quality Manager Qualifications

The quality manager shall hold a current license as a professional engineer in a U.S. state or territory with experience on at least five similar projects. Evidence of extraordinary proven experience may be considered by the Contracting Officer as sufficient to act as the Quality Manager.

1.6.1.2 Field Testing Technician and Testing Agency

Submit data on qualifications of proposed testing agency and technicians for approval by the Contracting Officer prior to performing testing on concrete.

a. Work on concrete under this contract shall be performed by an ACI Concrete Field Testing Technician Grade 1 qualified in accordance with ACI SP-2 or equivalent. Equivalent certification programs shall include requirements for written and performance examinations as stipulated in ACI SP-2.

b. Testing agencies that perform testing services on reinforcing steel shall meet the requirements of ASTM E329.

c. Testing agencies that perform testing services on concrete materials shall meet the requirements of ASTM C1077.

1.6.2 Laboratory Qualifications for Concrete Qualification Testing

The concrete testing laboratory shall have the necessary equipment and experience to accomplish required testing. The laboratory shall meet the requirements of ASTM C1077, and be Cement and Concrete Reference Laboratory (CCRL) inspected.

1.6.3 Laboratory Accreditation

Laboratory and testing facilities shall be provided by and at the expense of the Contractor. The laboratories performing the tests shall be accredited in accordance with ASTM C1077, including ASTM C78/C78M and ASTM C1260. The accreditation shall be current and shall include the required test methods, as specified.

a. Aggregate Testing and Mix Proportioning: Aggregate testing and mixture proportioning studies shall be performed by an accredited laboratory and under the direction of a licensed/registered civil engineer in a U.S. state or territory, who shall sign all reports and designs.

b. Acceptance Testing: Furnish all materials, labor, and facilities required for molding, curing, testing, and protecting test specimens at the site and in the laboratory. Furnish and maintain boxes or other facilities suitable for storing and curing the specimens at the site while in the mold within the temperature range stipulated by ASTM C31/C31M.

c. Contractor Quality Control: All sampling and testing shall be performed by an approved, onsite, independent, accredited laboratory.

1.7 CONCRETE DURABILITY

1.7.1 Concrete Mixture Proportions

At least 60 days prior to concrete placement, submit concrete mixture proportions, ingredient material certificates and test data, and trial batch test data for each class of concrete proposed for use on the project. Submittal shall clearly indicate where each mixture will be used when more than one mixture design is submitted. Obtain approval from Contracting Officer prior to placement.

1.7.2 Concrete Design Requirements

Proportion concrete mixtures to meet the requirements listed in Table 1 in accordance with the procedures outlined in ACI 201.2R and ACI 211.1.

The mixture proportions for concrete shall be developed by the Contractor to produce the required compressive strength (f'c), drying shrinkage, durability, and constructability. The amount of cementitious material in the mixture can be minimized as long as the concrete still meets the mixture design requirements for durability and strength.

The mixture proportions and Water-Cementitious Materials Ratio for marine concrete shall be developed by the Contractor to produce the design strength (f'c) and to provide durability, workability, and mixture consistency to facilitate placement, compaction into the forms and around

reinforcement without segregation or bleeding. The requirements for durability specified in Table 1 and Table 2 below shall be incorporated in the mixture proportions.

The use of silica fume is discouraged. Silica fume shall only be used for OCONUS (outside continental United States) projects where Class F fly ash and ground granulated blast furnace (GGBF) slag are not available, and when approved by the Contracting Officer. If needed, the mixture may contain a maximum of 7 percent silica fume by mass of total cementing material. Concrete mixtures containing any percentage of silica fume shall be evaluated at every [76.5] cubic meters ([100] cubic yards) of concrete for the first [382.3] cubic meters ([500] cubic yards), then every [382.3] cubic meters ([500] cubic yards) thereafter to ensure that the silica fume is properly dispersed in hardened concrete samples. A qualified laboratory shall microscopically examine a sectioned sample and document the results. Provide at the Contractor's expense the services of a manufacturer's technical representative, experienced in mixing, proportioning, placement procedures, and curing of concrete containing silica fume.

The concrete mixture shall contain one of the CCM/SCM listed in Table 3, or a linear combination thereof. The minimum amount of portland cement is 50 percent of the total mass of cementitious material.

Air content: Concrete shall be air entrained and shall conform to the air limits specified in ACI 301M ACI 301 for exposure and the aggregate size used and tested in accordance with ASTM C231/C231M. The average spacing factor for three consecutive tests shall not exceed 0.008 in with no individual test exceeding 0.010 in as determined by ASTM C457/C457M. Variations outside the limits specified shall not be reason to reject the concrete in locations not subject to freeze-thaw conditions.

Slump: The concrete mixture shall be proportioned to have, at the point of deposit, a maximum slump of 100 mm 4 inches as determined by ASTM C143/C143M when admixtures that affect slump are not used. Where an ASTM C494/C494M, Type F or G admixture is used, the slump after the addition of the admixture shall not exceed 200 mm 8 inches. Slump tolerances shall comply with the requirements of ACI 117.

Table 1 - Concrete Design Requirements		
Prescriptive requirements	Minimum	Maximum
ASTM C666/C666M Method A Durability Factor at 300 cycles	90	--
Concrete ASTM C157/C157M Drying Shrinkage percent, at 28 days except for high volume fly ash (HVFA) at 56 days.	--	0.05 percent
Initial acid-soluble chloride content in cast-in-place concrete per ASTM C1152/C1152M, percent/cement	--	0.10
Initial acid-soluble chloride content in prestressed concrete determined following ASTM C1152/C1152M, percent/cement	--	0.08

Table 1 - Concrete Design Requirements		
Prescriptive requirements	Minimum	Maximum
Average spacing factor for three specimen following ASTM C457/C457M inch	--	0.008 with no value greater than 0.010
Chloride ion penetrability ASTM C1202 at 56 days, Coulombs	--	1000
Alternatively to ASTM C1202, the concrete surface resistivity AASHTO T 358 at 56 days can be measured, kohm-cm	20	--

Table 2 - Concrete Quality Requirements		
Zone	Exposure Condition	Maximum W/CM
Submerged zone, Tidal Splash Zone	(a) Directly exposed to salt water	0.40
	(b) Subject to severe abrasion	0.40
Atmospheric Zone	(a) Directly exposed to marine atmosphere	0.40
	(b) Protected from direct exposure to marine atmosphere	0.45
Buried Zone	(a) Permanently buried in soil	0.40

Table 3 - Supplementary Cementing Material Requirements	
SCM	Minimum Content
Class N Pozzolan or Class F Fly Ash SiO_2 plus Al_2O_3 plus Fe_2O_3 > 65 percent or where exposed to sulphates as defined in ACI 318 Table 4.2.1	30 percent
Class N Pozzolan or Class F Fly Ash SiO_2 plus Al_2O_3 plus Fe_2O_3 greater than 70 percent	25 percent
Class N Pozzolan or Class F Fly Ash SiO_2 plus Al_2O_3 plus Fe_2O_3 greater than 80 percent	20 percent
Class N Pozzolan or Class F Fly Ash SiO_2 plus Al_2O_3 plus Fe_2O_3 greater than 90 percent	15 percent

Table 3 - Supplementary Cementing Material Requirements	
Ultra fine fly ash/Pozzolan	7 percent
Ground granulated blast-furnace slag	40 percent

1.7.3 Concrete Mixture Qualifications

1.7.3.1 Previously Approved Concrete Mixtures

For identical concrete mixtures previously approved for use within the past 18 months, the previous mixture qualification submittal may be re-submitted without further trial batch testing if accompanied by:

a. A copy of the prior approvals indicating the project name, project number, and location.

b. Ingredient material test data conducted within 12 months of the submittal date.

c. Copies of the previously approved trial batch test data.

d. A log containing at least 15 sequential test results with the calculated mean and standard deviation of the production concrete for air content, and compressive strength.

If the Contractor changes material type, class, sources, or suppliers; chemical composition; and/or mix proportions, the Contractor shall provide a written opinion of the significance of the change(s). The change(s) may require additional testing at the discretion of the Contracting Officer in consultation with the agency's Subject Matter Expert in Concrete Materials.

1.7.3.2 New Concrete Mixtures

a. Submit complete ingredient material test data, including applicable reference specifications. Submit additional data regarding concrete aggregates if the source of aggregate changes.

b. Submit copies of test reports by independent test lab conforming to ASTM C1077 showing that the mixture has been successfully tested to produce concrete with the properties specified and that mixture will be suitable for the job conditions as described. Test reports shall be submitted along with the concrete mixture proportions. Obtain approval before concrete placement.

c. Test a minimum of one trial batch of production concrete. If batching facilities are located such that the haul-time will exceed 30 minutes, a simulated haul time shall be included in the trial batch.

(1) Test and report fresh concrete property tests of each trial batch as follows:

(a) Slump in accordance with ASTM C143/C143M.

(b) Air content in accordance with ASTM C231/C231M or ASTM C173/C173M.

(c) Unit weight in accordance with ASTM C138/C138M.

(d) Temperature in accordance with ASTM C1064/C1064M.

(2) Cast specimens, test, and report hardened concrete property tests of each trial batch as follows:

(a) Compressive strength at 3, 7, 28, 56 and 90 days in accordance with ASTM C39/C39M. Use of unbonded caps in accordance with ASTM C1231/C1231M is permitted.

(b) Drying shrinkage.

(c) Tensile strength (if required).

(d) Freeze-thaw durability factor (if required) shall be determined as the mean of six test specimens comprised of at least two specimens cast from each batch.

(e) Initial chloride ion content.

(f) Spacing factor in accordance with ASTM C457/C457M.

(g) Chloride ion penetrability in accordance with ASTM C1202.

(3) Moist cure concrete intended for cast-in-place applications in accordance with the standard moist curing conditions described in ASTM C192/C192M unless otherwise specified. Moist cure concrete intended for precast applications in the manner proposed for use on the project.

d. For concrete mixtures that are proposed to contain corrosion inhibitors, the Contractor shall submit the chloride ion penetration values from at least one batch of the mixture with and without the admixture making appropriate adjustments to maintain constant water to cementitious materials ratio. The purpose is to establish a correlation with respect to an adjusted value for production chloride ion penetration.

1.7.4 Concrete Qualification Program

1.7.4.1 Fresh Concrete Properties

a. Air Content: The mixture shall be proportioned and tested for qualification.

b. Slump: The mixture shall be proportioned and tested for qualification.

c. Self-Consolidating Concrete: When self-consolidating concrete is proposed for use, the mixture shall be proportioned and tested for qualification using:

(1) ASTM C1611/C1611M slump flow shall not be greater than 610 mm 24 inches, with visual stability index not greater than 1.

(2) ASTM C1621/C1621M Passing ability using the J-ring. Spread within 25 mm 1 inch less than the slump flow.

(3) Passing ability using the L-Box between 4 and 8 seconds

(4) ASTM C1610/C1610M, static segregation shall be less than 4.0 percent.

For process control sampling, the slump flow limit as determined by ASTM C1611/C1611M shall be no greater than 610 mm 24 inches and the visual stability index limit shall be no greater than 1.0.

d. Underwater concrete: When the concrete is intended for placement under water using the tremie technique, the concrete shall be proportioned to be cohesive and flow with minimal segregation. Viscosity modifying admixtures are permitted for underwater concrete. Proportioning guidance in ACI 304R shall be considered. Concrete mixtures shall be qualified for tremie placement methods based on a trial placement approved by the Contracting Officer.

1.7.4.2 Hardened Concrete Properties

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NOTE: Navy waterfront structures typically take a year or more to complete. With time all concrete continues to gain strength. The Engineer of Record is encouraged to design the structural elements based on the compressive strength that will be achieved at 56 or 90 days rather than at 28 days. Doing so will better allow the Contractor to develop and place concrete mixtures with less portland cement. Excessive use of cement leads to more cracks and shorter-lived structures. Embracing this approach will result in structures that are less expensive, greener and more sustainable.

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a. Compressive Strength: The structural engineer shall specify the minimum compressive strength results at [28] [56] days. Determine compressive strength (f'cr) for qualification of concrete mixtures and for quality acceptance testing. A compressive strength test result is defined as the mean of three properly conducted tests on 100 by 200 mm 4 by 8 inch cylinders in accordance with ASTM C39/C39M. Alternatively and for concrete mixtures containing a maximum size aggregate greater than 25.4 mm 1 inch, a strength test result shall be defined as the mean of two properly conducted 28-day tests on 150 by 300 mm 6 by 12 inch cylindrical specimens in accordance with ASTM C39/C39M. In addition:

(1) Specified Compressive Strength: For structural concrete elements exposed in a marine environment, the minimum specified [28] [56] day design strength is denoted as (f'c). Strength of concrete containing 35 percent or more fly ash shall be specified at a minimum of 56 days.

(2) Required Average Strength: The concrete shall be proportioned such that the minimum required average compressive strength (f'cr) exceeds the specified design strength (f'c) as per ACI 301M ACI 301.

(3) The average compressive strength may not exceed the specified strength at the same age by more than 20 percent unless approved by the Engineer of Record.

(4) Strength of any individual concrete placement shall be considered

satisfactory if both the following requirements are met:

(a) The arithmetic mean of any three consecutive lot strength tests is between 1.0 and 1.2 f'c, and;

(b) No individual strength test result is less than 0.90 f'c.

(5) In the event that a placement is represented by single sampling lot, strength shall be considered satisfactory if either:

(a) The mean of the initial test is between 1.0 and 1.2 f'c, or;

(b) The mean of the initial test and retest is between 1.0 and 1.2 f'c, and neither strength test result is less than 0.90 f'c.

(6) For underwater concrete, cast compressive strength samples by placing concrete in four 5-gallon buckets below water using similar placement as the project. Permanently mark buckets as "3 days," "7 days," "[28] [56] days," and "Extra." Include date and station. Provide specimen sets at every [76.5 cubic meters] [100 cubic yards] of concrete for the first [382.3 cubic meters] [500 cubic yards], then every [382.3 cubic meters] [500 cubic yards] thereafter with a minimum of one set per day of underwater concrete placement.

(a) Retrieve buckets at specified intervals and extract three cores from each bucket. Conduct compressive strength test in accordance with ASTM C42/C42M.

(b) Strength of underwater concrete shall be satisfactory if the compressive strength result from extracted cores at the age of the specified strength is between 0.85 and 1.2 f'c with no individual strength test result less than 0.75 f'c.

b. Drying Shrinkage: Determine drying shrinkage for qualification of concrete mixtures prior to the fabrication of the Test Section and from samples made during the fabrication of the Test Section (see the paragraph TEST SECTION). No test results shall exceed the limits in Table 1. A drying shrinkage test result shall be the mean value from three or more individual specimens constituting a test set. If an individual specimen's measurements deviate from the mean value by more than 0.009 percent length change, the specimen's measurements shall be discarded and a new average established. Casting more than three specimens for each set is permitted. Test procedures and test specimens shall conform to the following:

Drying shrinkage specimens, typically 75 by 75 by 285.8 mm 3 by 3 by 11.25 inch prisms for 25.4 mm 1 inchmaximum size aggregate or smaller, shall be fabricated, cured, dried, and measured at 28 days in the manner delineated in ASTM C157/C157M. Mixtures containing 50 percent or more supplementary cementing materials shall meet the shrinkage criteria at 56 days.

c. Tensile strength: Determine splitting-tensile strength of concrete only for qualification of concrete mixtures. Determine and report the splitting-tensile strength result of each class of concrete in accordance with ASTM C496/C496M as the mean of three properly conducted tests at the age specified for f'c and again at 90-days age for information only.

d. Freeze-thaw durability: Determine the freeze-thaw durability factor of concrete for qualification of concrete mixtures, if required by environmental conditions. Determine and report the freeze-thaw durability factor of each class of concrete in accordance with ASTM C666/C666M Method-A. Start testing after [28] days of moist curing. The minimum acceptable durability factor shall be as per Table 1.

e. Acid Soluble Chloride Ion Content: Determine the chloride ion content only for qualification of concrete mixtures. Determine acid soluble chloride ion content in accordance with ASTM C1152/C1152M. The limits for allowable acid-soluble chloride ion concentrations in hardened concrete are listed in Table 1.

f. Chloride Ion Penetrability: Determine the resistance of concrete to the penetration of chloride ions in accordance with ASTM C1202 during the prequalification phase. The average of three samples shall meet the limit specified Table 1.

1.7.4.3 Supplemental Corrosion Protection

Requirements for the use of supplemental corrosion protection, if any, shall be indicated on the plans.

1.7.5 Mass Concrete Temperature Control Plans

a. Thirty days minimum prior to concrete placement, submit for approval a mass concrete temperature control plan that includes:

(1) Location and identification of temperature monitoring sensors.

(2) Product data for automated temperature sensors and recording equipment.

(3) Cooling pipe layout diagram with sizes and materials, if used.

(4) Proposed insulation materials and associated R-values.

(5) Anticipated form removal schedule and curing procedures.

(6) Maximum allowable concrete placement temperature for the range of anticipated ambient temperatures based on thermal modeling.

(7) Monitoring procedures and contingency plans.

Concrete placement temperature shall be based on results of thermal modeling for the element incorporating: the heat of hydration and specific heat capacity for the concrete mixture, solar gain, and heat transfer to the environment through formwork, insulation, and cooling techniques.

Mass concrete temperature control shall be monitored using automated temperature recording devices that allow wireless transmission of data to an on-site host computer for real-time monitoring of temperatures.

Temperature control sensor layout for each placement shall be provided with individual sensor ID identified.

Minimum sensor requirements include at least two sensors for each placement located as follows:

(1) The geometric center of the element cross-section.

(2) Within 76.2 mm 3 inches of the side forms at mid-height.

(3) Within 76.2 mm 3 inches of the top surface located directly above the center sensors.

(4) Within 76.2 mm 3 inches from the top corner at the intersection of side forms.

(5) Ambient temperature sensors placed in a shaded location.

Procedures for installing, protecting sensors during placement, and testing sensors a minimum of 24 hours prior to concrete placement shall be provided. Initiate sensor recording at least 2 hours prior to placement. Verify function of all sensors prior to and upon completion of concrete placing operations. Provide additional sensors for placements greater than 305.8 cubic meters 400 cubic yards at each location.

Submit procedures for controlling concrete temperatures within the following limits:

(1) Maximum temperature shall be less than 70 degrees C 158 degrees F.

(2) Maximum temperature differential between the mean of all functioning center sensor temperatures to any individual surface or corner sensor shall be less than 20 degrees C 36 degrees F.

(3) Temperature control procedures shall remain in effect until the differential between the ambient low temperature and mean of all functioning center sensor temperatures is less than 20 degrees C 36 degrees F.

(4) An additional submittal shall be provided for the Contracting Officer's approval in the event the Contractor fails to control temperatures within the limits listed above. The submittal shall include documentation of any cracks that develop, identify revisions to control procedures to prevent future cracking, and procedures to seal or otherwise mitigate defects.

b. Mass Concrete Mock-up: For concrete mixtures intended for mass concrete, cast thirty-one 100 by 200 mm 4 by 8 inch cylinder specimens in accordance with ASTM C192/C192M, three 75 by 75 by 285.8 mm 3 by 3 by 11.25 inch concrete prisms in accordance with ASTM C157/C157M, and at least one semi-adiabatic cube from a trial batch.

The semi adiabatic cube shall have a minimum dimension of 3 feet per side, and shall be insulated all sides with a minimum R-value of 30. Install pairs of thermocouples at the center of mass, the middle of each side, the top surface, and the top corner. Automatically record the temperature of each sensor hourly for one week. Additional cubes may be cast to calibrate active cooling system performance.

(1) Conduct compressive strength development testing at 3, 7, [28] [56], and 90 days age using three specimens per age in accordance

with ASTM C39/C39M, and develop a compressive strength prediction equation for the concrete mixture in accordance with ASTM C1074.

(2) Conduct tensile strength tests at 3, 7, [28] [56], and 90 days on two specimens per age in accordance with ASTM C496/C496M, and develop a tensile strength prediction equation for the concrete mixture in accordance with ASTM C1074.

(3) Conduct elastic modulus tests at 3, 7, [28] [56], and 90 days on two specimens per age in accordance with ASTM C469/C469M, and develop an elastic modulus prediction equation for the concrete mixture in accordance with ASTM C1074.

Conduct coefficient of thermal expansion testing in accordance with COE CRD-C 39 after 28 days of moist curing. Test specimens in a saturated condition.

Report all test results and predictive equations in the mock-up submittal. The predictive equations may be used by the Contractor to establish the duration of temperature control and form removal based on the allowable temperature differential between the concrete core and ambient low temperature.

1.8 CONCRETE

1.8.1 Drawings

Fabrication Drawings for concrete formwork, reinforcement materials, precast elements, wall forms, and bulkhead forms must indicate concrete pressure calculations with both live and dead loads, along with material types. Provide design calculations by a registered Civil or Structural Engineer for the formwork.

1.8.1.1 Formwork

Prior to commencing work, submit drawings for approval showing details of formwork including, but not limited to: joints, supports, studding and shoring, and sequence of form and shoring removal. Reproductions of contract drawings are unacceptable.

Design, fabricate, erect, support, brace, and maintain formwork so that it is capable of supporting without failure all vertical and lateral loads that may reasonably be anticipated to be applied to the formwork.

ACI 347R. Include design calculations indicating arrangement of forms, sizes, species, and grades of supports (lumber), panels, and related components. Indicate placement schedule, construction, and location and method of forming control joints. Include locations of inserts, pipe work, conduit, sleeves, and other embedded items. Furnish drawings and descriptions of shoring and reshoring methods proposed for slabs, beams, and other horizontal concrete members.

1.8.1.2 Reinforcing Steel

ACI SP-66. Provide bending and cutting diagrams, assembly diagrams, splicing placement and laps of bars, shapes, dimensions, and details of bar reinforcing, accessories, and concrete cover. Do not scale dimensions from structural drawings to determine lengths of reinforcing bars. Only complete drawings will be accepted.

1.8.1.3 Precast Elements

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NOTE: Modify requirements based on the scope of the project.
****

Submit drawings and design calculations indicating complete information for the fabrication, handling, and erection of the precast elements. Drawings shall not be reproductions of contract drawings.

1.8.1.4 Joints

Submit a plan indicating the type and location of each construction joint. Final joint locations are subject to Government approval.

1.8.2 Pre-Construction Submittals

1.8.2.1 Curing Concrete Elements

Submit proposed materials and methods for curing concrete elements.

1.8.2.2 Concrete Curing Plan

Submit proposed materials, methods, and duration for curing and cooling concrete elements in accordance with ACI 308.1.

Minimum moist curing duration shall be seven days.

Begin curing immediately after placement. Protect concrete from premature drying, excessively hot temperatures, and mechanical injury; and maintain minimal moisture loss at a relatively constant temperature for the period necessary for hydration of the cement and hardening of the concrete. The materials and methods of curing are subject to approval by the Contracting Officer.

1.8.2.3 Form Removal Schedule

Submit schedule for form removal indicating element and minimum length of time for form removal. Submit technical literature of forming material or liner, form release agent, form ties, and gasketing to prevent leakage at form and construction joints. Provide a full description of materials and methods to be used to patch form-tie holes.

1.8.2.4 Concrete Placement and Compaction

a. Submit technical literature for equipment and methods proposed for use in placing concrete. Include concrete pumping or conveying equipment including type, size and material for pipe, valve characteristics, and the maximum length and height concrete will be pumped. No adjustments shall be made to the mixture design to facilitate pumping.

b. Submit technical literature for equipment and methods proposed for vibrating and compacting concrete. Submittal shall include technical literature describing the equipment including vibrator diameter, length, frequency, amplitude, centrifugal force, and manufacturer's description of the radius of influence under load. Where flat work is to be cast, provide similar information relative to the proposed

compacting screed or other method to ensure dense placement.

1.8.2.5 Concrete Report

Provide a Report inclusive of materials and methods used, test results, and the field test strength (fcr) for concrete that shows compliance with the structural and durability requirements.

1.8.2.6 Coatings

Coatings are considered to be "supplemental Corrosion Projection". Surface preparation and installation of any coatings on concrete shall be conducted in strict compliance with written manufacturer instructions. Submit the product data and written manufacturer instructions. A manufacturer representative shall train installers, witness initial installation, and certify that the installation was conducted in accordance with the instructions.

1.8.2.7 Preconstruction Testing of Materials

All sampling and testing shall be performed by, and at the expense of, the Contractor. Use an approved commercial laboratory or, for cementitious materials and chemical admixtures, a laboratory maintained by the manufacturer of the material. No material shall be used until notice of acceptance has been given. The Contractor will not be entitled to any additional payment or extension of time due to failure of any material to meet project requirements, or for any additional sampling or testing required. Additional tests may be performed by the Government at the discretion of the Contracting Officer; such Government testing will not relieve the Contractor of any testing responsibilities.

1.8.2.8 Material Safety Data Sheets

Submit Material Safety Data Sheets (SDS) for all materials that are regulated for hazardous health effects. Prominently post the SDS at the construction site.

1.8.2.9 Mixture Designs

Provide a detailed report of materials and methods used, test results, and the field test strength (fcr) for marine concrete required to meet structural and durability requirements.

1.8.3 Sampling

The Contractor shall be responsible for conducting concrete production process control sampling and testing in compliance with this specification.

1.8.3.1 Ingredient Material Sampling

a. Cementitious material mill certificates and test reports shall be provided for each shipment. Record the date delivered and quantity of material represented by the certificate.

b. Conduct and log aggregate moisture content at a minimum frequency of twice daily for each day's production. Use of moisture sensors in storage bins is recommended practice, but does not satisfy this requirement.

c. Aggregate sampling for gradation and dry-rodded unit weight shall be conducted for each 100 tons delivered for use on the project, or portion thereof.

1.8.4 Reporting

1.8.4.1 Daily Inspection Reports

Contractor shall prepare daily inspection reports for all inspection activities such as base preparation, formwork preparation, reinforcement installation, concrete placement log, and temperature control activities. Submit sample forms and describe the procedure used to organize, archive, and retrieve inspection records in the Quality Program submittal.

1.8.4.2 Sampling Logs

Contractor shall maintain a concrete placement log as an electronic spreadsheet or database identifying each placement date, placement location, volume of concrete, batch ticket numbers, lot identification code, fresh concrete properties, compressive strength results, transport properties, inspection comments, and acceptance status. Contractor shall provide/transmit the concrete testing log to the Contracting Officer weekly. The Contractor shall provide copies of supporting documents for any placement requested by the Contracting Officer immediately upon request.

1.8.4.3 Quality Control Data

The Contractor shall prepare, maintain, and report separate quality control charts illustrating the slump, temperature, plastic air content, compressive strength, and chloride ion penetration test results for each lot of each concrete mixture used on the project.

1.8.4.4 Quality Team Meetings

The contractor shall conduct regular quality control team meetings to review plans for future placements, review test results, and discuss dispensation of non-conforming materials. The quality team shall include the Contractor's quality manager, the project manager, the project superintendent, the Contracting Officer, and representatives of the testing agency and concrete producer, or approved substitutes. It is recommended that the meetings be held on a weekly or bi-weekly basis during the service life modeling submittal phases and then monthly, as the construction progresses. The transition from the weekly or bi-weekly meetings to the monthly meetings shall be with the Contracting Officer's approval.

The Contractor shall prepare quality control team meeting minutes for each meeting. The minutes shall include the date of each meeting, attendees, key discussion points, findings, recommendations, assigned tasks, assigned personnel, task completion dates, and status of each task.

1.8.4.5 Non-conforming materials

The exact location of non-conforming concrete as placed shall be identified and the Contracting Officer and Engineer of Record shall be notified immediately. There are numerous possible indicators that the as-placed concrete is non-conforming including (but not limited to) excessive compressive strength, inadequate compressive strength, excessive

slump, chloride ions penetration out of limits, excessive voids and honeycombing, and concrete delivery records that indicate excessive time between mixing and placement and/or excessive water was added to the mixture during delivery and placement. Any of these indicators alone are sufficient reason for the Contracting Officer to request additional sampling, testing, and service life modeling to quantify the concrete properties. If justified, cores may be extracted for testing, and an investigation into the cause for non-conformance shall be conducted. The investigation may include statistical analysis of the test data collected to date; appropriateness of the pre-defined QAL based on statistical analysis of production data; the impact of the non-conforming material on the structure strength and/or service life; and recommendations for concrete production process improvements, mitigation, or remediation, as appropriate.

Investigations into non-conforming materials shall be conducted at the Contractor's expense. The Contractor shall be responsible for the investigation and shall make written recommendations to adequately mitigate or remediate the non-conforming material. The Contracting Officer may accept, accept with reduced payment, require mitigation, or require removal and replacement of non-conforming material at no additional cost to the Government.

1.8.5 Test Reports

Concrete Test Reports shall be identified by a sequential report identification code. Each report shall identify the placement date, placement location, weather, name of testing technician, time of sampling, batch ticket number, fresh concrete test results, and hardened concrete test results.

1.8.5.1 Concrete Mixture Requirements

a. Submit copies of test reports conforming to ASTM C1077 showing that the mixture has been successfully tested to produce concrete with the properties specified and that mixture will be suitable for the job conditions. Test reports shall be submitted along with the concrete mixture proportions. Obtain approval before concrete placement.

b. Fully describe the processes and methodology whereby mixture proportions were developed and tested and how proportions will be adjusted during progress of the work to achieve, as closely as possible, the designated levels of relevant properties.

1.8.5.2 Supplementary Cementing Materials

Submit test results in accordance with ASTM C618 and the physical and chemical analysis in accordance with applicable ASTM standards such as ASTM C311/C311M for fly ash. Submit test results performed within 6 months of submittal date. Update this report during construction as necessary to assure that the supplementary cementing materials used on the projects meets the ASTM criteria and the report on file is never older than 6 months.

1.8.5.2.1 Ground Granulated Blast-Furnace Slag

Submit test results in accordance with ASTM C989/C989M for ground granulated blast-furnace slag. Submit test results performed within 6 months of submittal date. Update this report during construction as

necessary to assure that the report on file is never older than 6 months.

1.8.5.2.2 Ultra Fine Fly Ash or Pozzolan

Submit test results in accordance with ASTM C618 as a Class F fly ash or Class N pozzolan with the following additional requirements:

a. The strength activity index at 28 days shall be at least 95 percent of the control.

b. The average particle size shall not exceed 6 microns.

c. The sum SiO_2 plus Al_2O_3 plus Fe_2O_3 shall be greater than 77 percent.

Submit test results performed within 6 months of submittal date. Update this report during construction as necessary to assure that the report on file is never older than 6 months.

1.8.5.3 Silica Fume

Submit test results in accordance with ASTM C1240 for silica fume. Data shall be based upon tests performed within 6 months of submittal. Update this report during construction as necessary to assure that the report on file is never older than 6 months.

1.8.5.4 Aggregates

Aggregate samples shall be obtained in accordance with ASTM D75/D75M and shall be representative of the materials to be used for the project. Submit test results for aggregate quality in accordance with ASTM C33/C33M, and the combined gradation curve proposed for use in the work and used in the mixture qualification, and ASTM C295/C295M for results of petrographic examination. Confirm that the potential for alkali-silica reaction are within allowable limits by conducting tests in accordance with ASTM C1260. Submit results of all tests during progress of the work in tabular and graphical form as noted above, describing the cumulative combined aggregate grading and the percent of the combined aggregate retained on each sieve. Submit test results performed within 12 months of submittal date.

1.8.5.5 Admixtures

Submit test results in accordance with ASTM C494/C494M and ASTM C1017/C1017Mfor concrete admixtures, ASTM C260/C260M for air-entraining admixture, and manufacturer's literature and test reports for corrosion inhibitors and anti-washout admixture. Submitted data shall be based upon tests performed within 6 months of submittal. Submit certified copies of test results for the specific lots or batches to be used on the project. Test results shall be not more than 6 months old prior to use in the work. Chemical admixtures that have been in storage at the project site for longer than 6 months or that has been subjected to freezing will be retested at the expense of the Contractor.

1.8.5.6 Portland Cement

Portland cement[, ground granulated blast furnace (GGBF) slag,][and pozzolan] will be accepted on the basis of manufacturer's certification of compliance, accompanied by mill test reports showing that the material in each shipment meets the requirements of the specification under which it

is furnished. Mill test reports shall be no more than 1 month old, prior to use in the work. No cementitious material shall be used until notice of acceptance has been given by the Contracting Officer. Cementitious material may be subjected to check testing by the Government from samples obtained at the mill, at transfer points, or at the project site. If tests prove that a cementitious material that has been delivered is unsatisfactory, it shall be promptly removed at Contractor's expense from the site of the work. Cementitious material that has not been used within 6 months after testing shall be retested at the Contractor's expense and shall be rejected if test results are not satisfactory. Submit test results in accordance with ASTM C150/C150M portland cement and/or ASTM C595/C595M and ASTM C1157/C1157M for blended cement.

1.8.5.7 Testing During Construction

During construction, the Contractor is responsible for sampling and testing aggregates, cementitious materials, and concrete as specified herein. The Government will sample and test concrete and ingredient materials as considered appropriate. Provide facilities and labor as may be necessary for procurement of representative test samples. Testing by the Government will in no way relieve the Contractor of the specified testing requirements.

1.8.5.8 Test Section

a. Horizontal Placements. No more than 90 days prior to construction, construct a Test Section 3048 mm by 3048 mm by 203.2 mm 10 by 10 feet by 8 inches thick near the job site, but not as part of the structure. The Test Section shall meet all specification requirements and be acceptable to the Contracting Officer in all respects, including but not limited to delivery time, placement, consolidation, curing and surface texture. Use the Test Section to develop and demonstrate to the satisfaction of the Contracting Officer the proposed techniques of mixing, hauling, placing, consolidating, finishing, curing, initial saw cutting, start-up procedures, testing methods, plant operations, and the preparation of the construction joints. The mixing plant shall be operated and equipment calibrated prior to start of placing the Test Section. Use the same equipment, materials, and construction techniques on the Test Section as will be used in all subsequent work. Concrete production, placing, consolidating, curing, construction of joints, and all testing shall be in accordance with applicable provisions of this specification. At a minimum of three days after completion of the Test Section, extract a sufficient number of concrete cores 100 by 200 mm 4 by 8 inch to conduct tests to evaluate strength, air void spacing factor, homogeneity, consolidation, segregation, and chloride ion penetration properties. Test Results that are unacceptable Test Section will necessitate construction of an additional Test Section at no additional cost to the Government

b. Vertical Placements. No more than 90 days prior to construction, construct a Test Section that represents the vertical placements, (if applicable) near the job site, but not as part of the structure. Test Section shall meet all specification requirements and being acceptable to the Contracting Officer in all respects, including but not limited to delivery time, placement, consolidation, curing and surface texture. Use the Test Section to develop and demonstrate to the satisfaction of the Contracting Officer the proposed techniques of mixing, hauling, placing, consolidating, finishing, curing, initial

saw cutting, start-up procedures, testing methods, plant operations, and the preparation of the construction joints. The mixing plant shall be operated and equipment calibrated prior to start of placing the Test Section. Use the same equipment, materials, and construction techniques on the Test Section as will be used in all subsequent work. Concrete production, placing, consolidating, curing, construction of joints, and all testing shall be in accordance with applicable provisions of this specification. At a minimum of three days after completion of the Test Section, extract a sufficient number of concrete cores to evaluate strength, air void spacing factor, homogeneity, consolidation, segregation, and chloride ion penetration properties. If any of the test results are unacceptable, the Contracting Officer may require that a new Test Section be accomplished at no additional cost to the Government.

1.8.5.9 Acceptability of Work

The materials and the structure itself will be accepted on the basis of tests made by the Contractor and shall be in compliance with the criteria herein. The Government may make check tests at its expense to validate the results of the Contractor's testing. Testing performed by the Government will in no way relieve the Contractor from the specified testing requirements.

PART 2 PRODUCTS

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NOTE: Delete any reference to any products that are not to be used on the project. Coordinate all product requirements with the appropriate agency's Contracting Officer.
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2.1 CEMENTITIOUS MATERIALS

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NOTE: Edit these paragraphs as appropriate for the particular project. Guidance for use of cementitious materials should be sought from the agency's Subject Matter Expert in Concrete Materials. Consideration should be given to the use of fly ash or GGBF slag for partial replacement of portland cement up to 50 percent. Type III cement should not be specified.
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NOTE: Supplementary Cementitious Materials (SCM)

When granulated slag, coal fly ash, and natural pozzolans are used as cementing materials for replacement of portland cement in a concrete mixture, and if by doing so the sustainability, durability and the initial cost of the concrete mixture show considerable improvement then these materials are called "supplementary cementitious materials" (SCM).

The Engineer of Record is encouraged to specify the

use of supplementary cementing materials. For example, 50 percent replacement of the portland cement using Class F fly ash has been successfully demonstrated to offer the required compressive strength (f'cr), drying shrinkage, lower permeability, constructability, and the potential to accomplish a structure with the design service life while being less expensive with a smaller carbon footprint.
****

Cementitious materials shall be portland cement or cement blended with supplementary cementing materials. New submittals are required when the cementitious materials change sources or types.

The Contractor shall provide cementitious materials meeting the requirements of the applicable specification, and as modified herein. Provide mill certificates and test results conducted within six-months of the submittal date as part of the concrete mixture qualification submittal.

Provide a single manufacturer of cementitious material for each type of cement and supplementary cementing materials supplied to the project.

2.1.1 Portland Cement

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NOTE: Use Type II or Type V cement in project locations with Environmental Severity Classifications (ESC) of C3 thru C5 or where deicing salts are used on the structure. See UFC 1-200-01 for determination of ESC for project locations.
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Provide portland cement conforming to ASTM C150/C150M, Type [I] [II] [V], low alkali [including false set requirements] with tri-calcium aluminates (C3A) content less than 10 percent and a maximum cement-alkali content of 0.80 percent Na2Oe (sodium oxide equivalent). Type III cement shall be used only with concurrence of the agency's Subject Matter Expert in Concrete Materials. When HVFA mixtures are specified, they should be blended with Type II portland cement. HVFA is required instead of using Type V cement in high-sulfate areas. Low alkali cement may be required if the proposed aggregates are found to be expansive.

ASTM C150/C150M cements shall be combined with supplementary cementing materials in the concrete mixture.

2.1.2 Blended Cements

Blended cement shall conform to ASTM C595/C595M, Type IP or IS, including the optional requirement for mortar expansion [and sulfate soundness] and consist of a mixture of ASTM C150/C150M Type I, or Type II cement and a supplementary cementing material. The slag added to the Type IS blend shall be ASTM C989/C989M ground granulated blast-furnace slag. The pozzolan added to the Type IP blend shall be ASTM C618 Class F and shall be interground with the cement clinker. The manufacturer shall state in writing that the amount of pozzolan in the finished cement will not vary more than plus or minus 5 mass percent of the finished cement from lot-to-lot or within a lot. The percentage and type of mineral admixture used in the blend shall not change from that submitted for the aggregate

evaluation and mixture proportioning.

2.1.3 Pozzolan

2.1.3.1 Fly Ash

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NOTE: Class C fly ash is not permitted.

Use loss on ignition not exceeding 3 percent for frost areas to reduce carbon interference with air entraining admixture.

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Fly ash shall conform to ASTM C618, Class F, including the optional requirements for uniformity and effectiveness in controlling Alkali-Silica reaction and shall have a loss on ignition not exceeding [3][6] percent. Class F fly ash for use in mitigating Alkali-Silica Reactivity shall have a Calcium Oxide (CaO) content of less than 8 percent and a total equivalent alkali content less than 1.5 percent. Add with cement.

2.1.3.2 Raw or Calcined Natural Pozzolan

Natural pozzolan shall be raw or calcined and conform to ASTM C618, Class N, including the optional requirements for uniformity and effectiveness in controlling Alkali-Silica reaction and shall have a loss on ignition not exceeding 3 percent. Class N pozzolan for use in mitigating Alkali-Silica Reactivity shall have a Calcium Oxide (CaO) content of less than 13 percent and total equivalent alkali content less than 3 percent.

2.1.3.3 Ultra Fine Fly Ash and Ultra Fine Pozzolan

Ultra Fine Fly Ash (UFFA) and Ultra Fine Pozzolan (UFP) shall conform to ASTM C618, Class F or N, and the following additional requirements:

a. The strength activity index at 28 days of age shall be at least 95 percent of the control specimens.

b. The average particle size shall not exceed 6 microns.

c. The sum of SiO_2 + Al_2O_3 + Fe_2O_3 shall be greater than 77 percent.

2.1.4 Ground Granulated Blast-Furnace (GGBF) Slag

Ground Granulated Blast-Furnace Slag shall conform to ASTM C989/C989M, [Grade 100 or Grade 120]. Add with cement.

2.1.5 Silica Fume

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NOTE: Silica Fume shall only be used for OCONUS projects where Class F fly ash and GGBF slag are not available, and when approved by the Contracting Officer. Guidance for use of silica fume should be sought from the agency's Subject Matter Expert in Concrete Materials.

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Silica fume shall conform to ASTM C1240, including the optional limits on

reactivity with cement alkalis. Silica fume may be furnished as a dry, densified material or as slurry. Proper mixing is essential to accomplish proper distribution of the silica fume and avoid agglomerated silica fume, which can react with the alkali in the cement resulting in premature and extensive concrete damage. Supervision at the batch plant, finishing, and curing is essential. Provide at the Contractor's expense the services of a manufacturer's technical representative, experienced in mixing, proportioning, placement procedures, and curing of concrete containing silica fume. This representative must be present on the project prior to and during at least the first 4 days of concrete production and placement using silica fume. A High Range Water Reducer (HRWR) shall be used with silica fume. Finishing may be more difficult. Proper curing is essential because there is a tendency for plastic shrinkage cracking.

2.1.6 Supplementary Cementitious Materials (SCM) Content

The concrete mix shall always contain supplementary cementing materials whether or not the aggregates are found to be reactive in accordance with the paragraph AGGREGATES. Concrete mixtures shall be designed and proportioned to meet the requirements for strength, constructability, shrinkage, and durability.

****

NOTE: This specification requires that the structural requirements (f'c) be met and concrete strength is between 1.0 f'c and 1.2 f'c. If the prequalified mixture as approved by the Engineer of Record should produce a higher design strength (fcr), that strength shall be used instead of f'c. Maintain required w/cm ratio regardless of strength requirements.

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2.2 AGGREGATES

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NOTE: The largest possible aggregate size that meets the nominal maximum size requirements of ACI 318 should be used. Larger aggregates permit a leaner mixture with low paste content while maintaining workability.

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NOTE: In some tropical locations where standard aggregate such as gravel or manufactured aggregates are not readily available, the use of coral aggregate is acceptable. The specific gravity of any coralline material must not be less than 2.40. Specify coral aggregates with higher specific gravity wherever available. Wash aggregates dredged from the ocean or lagoons with fresh water to remove as much salt as possible. Include bracketed paragraph where coral will be used as an aggregate.

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Comply with ASTM C33/C33M Class 4S, except as modified herein.

The quantities to be retained on each sieve may be adjusted only where

available aggregates are elongated or slivered and cause interference with mix mobility, or available aggregate gradations do not comply with the 18-8 requirement. When necessary to satisfy local conditions and when permitted, the combined aggregate percentages may be changed to not more than 22 percent nor less than 6 percent retained on any individual sieve. The combined aggregates in the mixture (coarse, intermediate, and fine) shall be well graded with no more than 18 percent nor less than 8 percent of the combined aggregate retained on any individual sieve, unless satisfactory performance can be demonstrated. The 300 micrometers No. 50 sieve may have less than 8 percent retained; sieves finer than 300 micrometers No. 50 shall have less than 8 percent retained, and the coarsest sieve may have less than 8 percent retained. Use intermediate sizes for blending where necessary, to provide a well graded combined aggregate.

a. Provide gradation of individual aggregate sizes using standard concrete aggregate sieves including 37.5 mm 1-1/2 inches, 25 mm one inch, 19 mm 3/4 inch, 12.5 mm 1/2 inch, 9.5 mm 3/8 inch, 4.75 mm No. 4, 2.36 mm No. 8, 1.18 mm No. 16, 600 micrometers No. 30, 300 micrometers No. 50, and 150 micrometers No. 100.

b. Provide aggregates for exposed concrete from one source. Aggregate reactivity shall be limited per the paragraph AGGREGATES. Provide aggregate containing no deleterious material properties as identified by ASTM C295/C295M.

c. Where a size designation is indicated, that designation indicates the nominal maximum size of the coarse aggregate.

d. Aggregate tests shall be conducted within 6 months from the date of concrete mixture submittal.

e. Provide ASTM C1260 or ASTM C1567 test results conducted with 6 months of the submittal date showing the proposed coarse and fine aggregates are either: innocuous to alkali silica reaction; or that reactivity has been mitigated by the proposed cementitious materials as modified herein. Maximum allowable expansion is 0.08 percent at 14 days per ASTM C1260. If this is not met, then maximum allowable expansion for the proposed concrete mixture/s shall be 0.08 percent at 14 days per ASTM C1567. All aggregate sources shall be tested. Also, provide documentation that the aggregate has no history of chemical deterioration in concrete. Fine and coarse aggregates to be used in all concrete shall be evaluated and tested for alkali-aggregate reactivity. Both coarse aggregate size groups shall be tested.

f. Should the test data indicate a potential risk of alkali-aggregate reaction, the aggregate(s) shall be rejected or procedures from AASHTO R 80 shall be followed.

[g. Coral may be used as a coarse aggregate when conventional concrete aggregate is not available. Coral aggregate must be washed to eliminate chloride ions from the aggregate. Specific gravity of coral must be at least 2.40.

]2.3 WATER

Water shall comply with the requirements of ASTM C94/C94M and ASTM C1602/C1602M, except that the chloride and sulfate limits as tested in accordance with ASTM D512 and ASTM D516 shall not exceed 500 parts per

million chloride ion and not more than 1000 parts per million of sulfate ion as SO4. Water shall be free from injurious amounts of oils, acids, alkalis, salts, and organic materials. Where non-potable water or water from reprocessed concrete is proposed for use in the work, submit results of tests in accordance with ASTM C1602/C1602M. Submit test results in accordance with ASTM D512 and ASTM D516.

2.4 ADMIXTURES

a. Provide certifications that chemical admixtures comply with the requirements shown in Table 4 and are compatible with each other. Use admixtures in accordance with manufacturer's recommendations, as appropriate for the climatic conditions and construction needs.

b. Do not use calcium chloride or admixtures containing chloride ion content in more than trace amounts from impurities in admixture ingredients or potable water. Provide maximum concentrations of corrosion-inducing chemicals as shown in Table 4. For concrete that may be in contact with prestressing steel tendons, the concentration shall not exceed 60 percent of the limits given in Table 4. For the concentration in grout for prestressing ducts, do not exceed 25 percent of the limits in Table 4.

Table 4 - Limits on Corrosion-Inducing Chemicals

Chemical*	Limits, Percent**	Test Method
Chlorides	0.10	ASTM D512
Fluorides	0.10	ASTM D1179
Nitrates	0.17	ASTM D3867

* Limits refer to water-soluble chemicals

** Limits are expressed as a percentage of the mass of the total cementitious materials.

c. Provide anti-washout or viscosity modifying admixtures for underwater concrete placement. Provide certification that the admixture is compatible with the cementitious materials and other chemical admixtures in the proposed concrete mixture. The anti-washout or viscosity modifying admixture shall require approval by the Contracting Officer and have a proven record of performance with a minimum of five similar projects. Test per COE CRD-C 61 to determine cumulative mass loss shall be performed once for each 267.6 cubic meters 350 cubic yards of underwater concrete and results submitted to Contracting Officer for approval prior to continued use.

d. The total alkali contribution of chemical admixtures shall not increase the total sodium-oxide equivalent content of the concrete mixture by more than 0.3 kg/m3 0.5 lb/yd3.

2.4.1 Air Entraining

Provide air entraining admixtures conforming to ASTM C260/C260M

2.4.2 Accelerating

ASTM C494/C494M, Type C.

2.4.3 Retarding

ASTM C494/C494M, Type B, D, or G.

2.4.4 Water Reducing

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NOTE: The use of high range water reducers can be used to reduce the water-cementitious materials ratio which will produce a more dense concrete matrix and improve resistance to chloride ion penetration in the concrete.
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ASTM C494/C494M, Type A, E, or F.

High Range Water Reducer (HRWR) shall be ASTM C494/C494M, Type F and ASTM C1017/C1017M.

2.4.5 Corrosion Inhibitors

Corrosion inhibitors are considered "supplemental corrosion projection". If used, adjust the quantity of concrete mixing water for the mass of water in the admixture. Accelerating and set adjusted versions are acceptable Concrete setting time and mixture workability shall be evaluated.

2.5 NON-SHRINK GROUT

ASTM C1107/C1107M.

2.6 MATERIALS FOR FORMS

Provide wood, plywood, or steel. Use plywood or steel forms where a smooth form finish is required. Lumber shall be square edged or tongue-and-groove boards, free of raised grain, knotholes, or other surface defects.

Plywood: APA PS 1, B-B concrete form panels or better. Steel form surfaces shall not contain irregularities, dents, or sags.

2.6.1 Form Ties and Form-Facing Material

a. Provide a form tie system that does not leave mild steel after break-off or removal any closer than 50 mm 2 inches from the exposed surface. Do not use wire alone. Form ties and accessories shall not reduce the effective cover of the reinforcement.

b. Form-facing material shall be structural plywood or other material that can absorb air and some of the high water-cementitious materials ratio surface paste that may be trapped in pockets between the form and the concrete. Maximum reuse is three times. Provide forms with a form treatment to prevent bond of the concrete to the forms. Use a controlled permeability form liner in strict accordance with the manufacturer's recommendations.

2.7 REINFORCEMENT

2.7.1 Prestressing Steel

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NOTE: Use prestressing in fender and bearing piles and deck soffits wherever possible. Post-tensioning of pile caps and decks is recommended where feasible. Do not mix coated prestressing strands and plain prestressing strands. This will produce a large corrosion cell between the plain strand and any defect in the coated strand.

****

Use seven-wire stress-relieved or low-relaxation strand conforming to ASTM A416/A416M, Grade 270. Use of indented seven-wire stress-relieved or low-relaxation strand conforming to ASTM A882/A882M, Grade 270; or epoxy-filled seven-wire stress-relieved or low-relaxation strand conforming to ASTM A886/A886M, Grade 270 shall be permitted in lieu of prestressing steel conforming to ASTM A416/A416M. Use prestressing steel free of grease, oil, wax, paint, soil, dirt, and loose rust. Do not use prestressing strands or wire having kinks, bends, or other defects.

2.7.2 Reinforcing Bars

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NOTE: It is intended that plain steel rebar with specified concrete cover of 75 mm 3.0 inches shall normally be specified according to applicable codes.

ASTM A706/A706M bars are mainly used in seismic design or for welding. Do not mix coated rebar and plain reinforcing bars. This may produce a large corrosion cell between the plain bar and any defect in the coated bar.

****

ACI 301M ACI 301 unless otherwise specified and shall meet the design yield strength and ductility requirements. Deformed reinforcing bars meeting the requirements of ASTM A615/A615M with the bars marked A, Grade ASTM A276/A276M stainless steel bars; ASTM A767/A767M Class 1 galvanized; prefabricated epoxy coated, ASTM A934/A934M; ASTM A955/A955M stainless steel bars; ASTM A1035/A1035M MMFX2 bars; ASTM A1055/A1055M Z bars; ASTM A706/A706M; or other approved reinforcing material shall be permitted for use in the cast-in-place concrete system.

The reinforcing selected shall match the structural properties of the reinforcing specified. Alternative reinforcing bars shall have similar structural properties to the specified reinforcing and may be used with the Contracting Officer's approval.

2.7.2.1 Reinforcement and Protective Coating

If applicable, provide coating manufacturer's and coating applicator's test data sheets certifying that applied coating meets the requirements of the concrete system specified on the Plans.

2.7.3 Mechanical Reinforcing Bar Connectors

ACI 301M ACI 301. Provide 125 percent minimum yield strength of the reinforcement bar. Coat connectors in accordance with the requirements of the reinforcing bars.

2.7.4 Welded Wire Fabric

Comply with ASTM A1064/A1064M carbon steel. Provide flat sheets of welded wire fabric for slabs and toppings.

2.7.5 Wire

Comply with ASTM A1064/A1064M carbon steel.

2.8 ACCESSORY MATERIALS

2.8.1 Polyvinylchloride Waterstops

COE CRD-C 572.

2.8.2 Materials for Curing Concrete

2.8.2.1 Impervious Sheeting

ASTM C171; waterproof paper, clear or white polyethylene sheeting, or polyethylene-coated burlap.

2.8.2.2 Pervious Sheeting

AASHTO M 182 or carpet covering the free surface and kept continuously wet throughout the curing period.

2.8.2.3 Liquid Membrane-Forming Compound

Comply with ASTM C309, white-pigmented, Type 2, Class B.

2.8.3 Liquid Chemical Sealer-Hardener Compound

Provide magnesium fluosilicate compound which when mixed with water seals and hardens the surface of the concrete. Do not use on exterior slabs exposed to freezing conditions. Compound shall not reduce the adhesion of resilient flooring, tile, paint, roofing, waterproofing, or other material applied to concrete.

2.8.4 Expansion/Contraction Joint Filler

Comply with ASTM D1751 or ASTM D1752, 13 mm 1/2 inch thick unless otherwise indicated.

2.8.5 Joint Sealants

2.8.5.1 Horizontal Surfaces

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NOTE: For horizontal surfaces subject to jet fuel, specify section 32 01 19.61 SEALING OF JOINTS IN RIGID PAVEMENT.

****

Horizontal surfaces are defined as all surfaces with a 3 percent maximum slope. ASTM D6690 or ASTM C920, Type M, Class 25, Use T.

2.8.5.2 Vertical Surfaces

****

NOTE: Specify ASTM C920 for vertical surfaces greater than 3 percent slope and not subject to jet fuel, gasoline, fuel oil, etc. For vertical surfaces greater than 3 percent slope and subject to jet fuel, specify FS SS-S-200, no sag.

****

Vertical surfaces are defined as all surfaces with a slope greater than 3 percent. ASTM C920, Type M, Grade NS, Class 25, Use T. FS SS-S-200, no sag.

PART 3 EXECUTION

3.1 FORMS

a. Provide formwork with clean-out openings to permit inspection and removal of debris. Formwork shall be gasketed or otherwise rendered sufficiently tight to prevent leakage of paste or grout under heavy, high-frequency vibration. Use a release agent that does not cause surface dusting. Limit reuse of plywood to no more than three times. Reuse may be further limited by the Contracting Officer if it is found that the pores of the plywood are clogged with paste so that the wood does not absorb air and some of the high water-cementitious materials ratio paste that may be trapped in pockets between the form and the concrete.

b. Comply with ACI 301M ACI 301. Concrete for footings may be placed in excavations without forms upon inspection and approval by the Contracting Officer. Excavation width shall be a minimum of 100 mm 4 inches greater than indicated. Set forms rigidly, mortar-tight, and true to line and grade. Chamfer above grade exposed joints, edges, and external corners of concrete 20 mm 0.75 inch unless otherwise indicated. Forms submerged in water shall be watertight.

c. Patch form tie holes with a no shrink patching material in accordance with the manufacturer's recommendations and subject to approval.

3.1.1 Coating

Before concrete placement, coat the contact surfaces of forms with a no staining mineral oil, no staining form coating compound, or two coats of nitrocellulose lacquer. Do not use mineral oil on forms for surfaces to which adhesive, paint, or other finish material is to be applied.

3.1.2 Removal of Forms and Supports

After placing concrete, forms shall remain in place for the time periods specified in ACI 347R, except for concrete placed underwater, forms shall remain in place a minimum of 48 hours. Prevent concrete damage during form removal.

3.1.2.1 Special Requirements for Reduced Time Period

Forms may be removed earlier than specified if ASTM C39/C39M test results of field-cured samples from a representative portion of the structure or other approved and calibrated non-destructive testing techniques show that the concrete has reached a minimum of 85 percent of the design strength.

3.1.3 Reshoring

Do not allow construction loads to exceed the superimposed load that the structural member, with necessary supplemental support, is capable of carrying safely and without damage. Reshore concrete elements where forms are removed prior to the specified time period. Do not permit elements to deflect or accept loads during form stripping or reshoring. Forms on columns, walls, or other load-bearing members may be stripped after 2 days if loads are not applied to the members. After forms are removed, slabs and beams over 3 meters 10 feet in span and cantilevers over 1.2 meters 4 feet shall be reshored for the remainder of the specified time period in accordance with paragraph REMOVAL OF FORMS AND SUPPORTS. Perform reshoring operations to prevent subjecting concrete members to overloads, eccentric loading, or reverse bending. Reshoring elements shall have the same load-carry capabilities as original shoring and shall be spaced similar to original shoring. Firmly secure and brace reshoring elements to provide solid bearing and support.

3.2 PLACING REINFORCEMENT AND MISCELLANEOUS MATERIALS

ACI 301M ACI 301. Remove rust, scale, oil, grease, clay, or foreign substances from reinforcing that would reduce the epoxy coating bond from reinforcing. Do not tack weld. Inspect and verify proper reinforcement grade, quantity, spacing, and clearance requirements prior to concrete placement. Inspect placed steel reinforcing for coating damage prior to placing concrete. Repair all visible damage.

3.2.1 Coated Reinforcing

If coated reinforcement is used, record coating lot on each shipping notice and carefully identify and retag bar bundles from bending plant. Provide systems for handling coated bars that have padded contact areas, nylon slings, etc., to keep bars free of dirt and grit. Carefully handle and install bars to minimize job site patching including lifting and supporting bundled coated bars with strong back, multiple supports, or platform bridge to prevent sagging and abrasion. When possible, assemble reinforcement as tied cages prior to final placement into the forms. Bundling bands shall be padded where in contact with bars. Do not drop or drag bars or bundles. Store coated bars both in shop and in field, aboveground, on wooden or padded cribbing with adequate protective blocking between layers. Schedule deliveries of coated bars to the job site to avoid the need for long term storage. Protect from direct sunlight and weather. Bars to be stored longer than 12 hours at the job site shall be covered with opaque polyethylene sheeting or other suitable equivalent protective material.

Inspect for defects and provide required repairs prior to assembly. After assembly, reinspect and provide final repairs. Excessive nicks and scrapes that expose steel shall be cause for rejection.

a. Immediately prior to application of the patching material, any rust and debonded coating shall be manually removed from the reinforcement

by suitable techniques employing devices such as wire brushes and emery paper. Care shall be exercised during this surface preparation so that the damaged areas are not enlarged more than necessary to accomplish the repair. Damaged areas shall be clean of dirt, debris, oil, and similar materials prior to application of the patching material.

b. Repair and patching shall be done in accordance with the patching material manufacturer's recommendations. These recommendations, including cure times, shall be available at the job site at all times.

c. Allow adequate time for the patching materials to cure in accordance with the manufacturer's recommendation prior to concrete placement.

d. Rinse placed reinforcing bars with ASTM C1602/C1602M compliant water to remove chloride contamination prior to placing concrete.

3.2.2 Reinforcement Supports

Place reinforcement and secure with non-corrodible chairs, spacers, and hangers. Metal hangers may be used, but shall be of similar material to the reinforcing. Support reinforcement on the ground with concrete or other non-corrodible material, having a compressive strength equal to or greater than the concrete being placed and having permeability equal or less than the concrete being placed.

Coated reinforcing bars supported from formwork shall rest on coated wire bar supports, or on bar supports made of dielectric material or other acceptable material. Wire bar supports shall be coated with dielectric material, compatible with concrete, for a minimum distance of 50 mm 2 inches from the point of contact with the coated reinforcing bars. Reinforcing bars used as support bars shall be coated with the same material as the reinforcing. Spreader bars, where used, shall be coated. Non-coated combination bar clips and spreaders used in construction with coated reinforcing bars shall be made corrosion resistant or coated with dielectric material. Coated bars shall be tied with plastic-coated tie wire or other materials acceptable to the Contracting Officer.

3.2.3 Splicing

As indicated. For splices not indicated, comply with ACI 301M ACI 301. Do not splice at points of maximum stress. Overlap welded wire fabric the spacing of the cross wires, plus 50 mm 2 inches. Welded splices shall comply with AWS D1.4/D1.4M and be approved prior to use.

3.2.4 Future Bonding

Plug exposed, threaded, mechanical reinforcement bar connectors with a greased bolt. Bolt threads shall match the connector. Countersink the connector in the concrete. Caulk the depression after the bolt is installed.

3.2.5 Cover

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NOTE: Uniform, high quality concrete cover over the steel reinforcement is critically important for long-term durability.

****

Provide concrete cover thickness as shown on the Plans. If no concrete cover is specified, as a minimum, comply with ACI 318M ACI 318 for concrete cover over the steel reinforcement. Use ACI 117 to determine allowable tolerances for the placement of the steel.

3.2.6 Setting Miscellaneous Material and Prestress Anchorages

Place and secure anchors, bolts, pipe sleeves, conduits, and other such items in position before concrete placement. Plumb anchor bolts and check location and elevation. Temporarily fill voids in sleeves with readily removable material to prevent the entry of concrete. Electrically isolate exposed steel work and its anchor systems from the primary steel reinforcement with at least 50 mm 2 inches of concrete. Coat exposed steel work to reduce corrosion. Take particular care to ensure against corrosion on edges and horizontal surfaces. Use epoxy coatings for protection of carbon steel plates and fittings.

3.2.7 Construction Joints

Locate joints to least impair strength. Continue reinforcement across joints unless otherwise indicated. Final joint locations are subject to Government approval or substantiating calculations from the Contractor.

3.2.8 Expansion Joints and Contraction Joints

Provide expansion joint at edges of interior floor slabs on grade abutting vertical surfaces, and as indicated. Make expansion joints 13 mm 1/2 inch wide unless indicated otherwise. Fill expansion joints not exposed to weather with preformed joint filler material. Completely fill joints exposed to weather with joint filler material and joint sealant. Do not extend reinforcement or other embedded metal items bonded to the concrete through any expansion joint unless an expansion sleeve is used. Place contraction joints, either formed or saw cut or cut with a jointing tool, to the indicated depth after the surface has been finished. Sawed joints shall be completed within 4 to 12 hours after concrete placement. Protect joints from intrusion of foreign matter.

3.2.9 Waterstop Splices

Fusion weld in the field.

3.2.10 Pits and Trenches

Place bottoms and walls monolithically or provide waterstops and keys.

3.3 BATCHING, MEASURING, MIXING, AND TRANSPORTING CONCRETE

ASTM C94/C94M, ACI 301M ACI 301, and ACI 304R, except as modified herein. Batching equipment shall be such that the concrete ingredients are consistently measured within the following tolerances: 1 percent for cement and water, 2 percent for aggregate, and 3 percent for admixtures. Furnish mandatory batch tickets imprinted with mix identification, batch size, batch design and measured weights, moisture in the aggregates, and time batched for each load of ready mix concrete. When a pozzolan is batched cumulatively with the cement, it shall be batched after the cement has entered the weight hopper.

3.3.1 Measuring

Make measurements at intervals as specified in paragraphs SAMPLING and TESTING.

Adjust batch proportions to replicate the mixture design using methods provided in the approved quality assurance plan. Base the adjustments on results of tests of materials at the batch plant for use in the work. Maintain a full record of adjustments and the basis for each.

3.3.2 Mixing

Comply with ASTM C94/C94M and ACI 301M ACI 301. If time of discharge exceeds time required by ASTM C94/C94M, submit a request along with description of precautions to be taken.

3.3.3 Transporting

Comply with ACI 304R.

3.4 PLACING CONCRETE

Comply with ACI 304R and ACI 304.2R. Place concrete as soon as practicable after the forms and the reinforcement have been inspected and approved. Do not place concrete when weather conditions prevent proper placement and consolidation; in uncovered areas during periods of precipitation; or in standing water. Prior to placing concrete, remove dirt, construction debris, water, snow, and ice from within the forms. Deposit concrete as close as practicable to the final position in the forms. Do not exceed a free vertical drop of one m 3 feet from the point of discharge. Place concrete in one continuous operation from one end of the structure towards the other or lifts for vertical construction. Position grade stakes on 6 m 20 foot centers maximum for exterior slabs.

3.4.1 Vibration

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NOTE: The requirement for vibrator spacing shall be considered in the reinforcing steel design by the engineer of record. ACI SP-66 requires that bar bundling be done by the design engineer. It is very important to provide space for placement and consolidation of concrete.

****

Comply with the requirements of ACI 309R [and ASTM A934/A934M for epoxy-coated bar] using vibrators with a minimum frequency of 9000 vibrations per minute (VPM). Use only high cycle or high frequency vibrators. Motor-in-head 60 cycle vibrators may not be used. For walls and deep beams, use a minimum of two vibrators with the first to melt down the mixture and the second to thoroughly consolidate the mass. Provide a spare vibrator at the casting site whenever concrete is placed. Place concrete in 500 mm 18 inch maximum vertical lifts. Insert and withdraw vibrators approximately 500 mm 18 inches apart. Penetrate at least 200 mm 8 inches into the previously placed lift with the vibrator when more than one lift is required. Extract the vibrator using a series of up and down motions to drive the trapped air out of the concrete and from between the concrete and the forms.

For slab construction, use vibrating screeds designed to consolidate the full depth of the concrete. Where beams and slabs intersect, use an internal vibrator to consolidate the beam. Do not vibrate concrete placed with anti-washout admixtures. Vibrators shall be equipped with rubber vibrator heads.

3.4.2 Cold Weather

Comply with ACI 306R. Do not allow concrete temperature to decrease below 10 degrees C 50 degrees F. Obtain approval prior to placing concrete when ambient temperature is below 4 degrees C 40 degrees F or when concrete is likely to be subjected to freezing temperatures within 24 hours. Placement of concrete shall be halted whenever the ambient temperature drops below 5 degrees C 40 degrees F. When the ambient temperature is less than 10 degrees C 50 degrees F the temperature of the concrete when placed shall be not less than 10 degrees C 50 degrees F or more than 25 degrees C 75 degrees F. Heating of the mixing water or aggregates may be necessary to regulate the concrete placing temperature. An accelerating admixture may be used when the ambient temperature is below 10 degrees C 50 degrees F. Covering and other means shall be provided for maintaining the concrete at a temperature of at least 10 degrees C 50 degrees F for not less than 7 days after placing, and at a temperature above freezing for the remainder of the curing period.

3.4.3 Hot Weather

Comply with ACI 305R. Maintain required concrete temperature using Figure 2.1.5, "Effect of Concrete Temperatures, Relative Humidity, and Wind Velocity on the Rate of Evaporation of Surface Moisture From Concrete" in ACI 305R to prevent the evaporation rate from exceeding one kg per square meter 0.2 pound of water per square foot of exposed concrete per hour. If necessary, cool ingredients before mixing or use other suitable means to control concrete temperature and prevent rapid drying of newly placed concrete. Shade the fresh concrete as soon as possible after placing. Start curing when the surface of the fresh concrete is sufficiently hard to permit curing without damage. If the evaporation rate exceeds 0.5 kg per square meter 0.1 pound of water per square foot per hour, fog spray the exposed concrete surfaces until active moist curing is applied. Provide water hoses, pipes, spraying equipment, and water hauling equipment, where job site is remote to water source, to maintain a moist concrete surface throughout the curing period. Provide burlap cover or other suitable, permeable material with fog spray or continuous wetting of the concrete when weather conditions prevent the use of either liquid membrane curing compound or impervious sheets. For vertical surfaces, protect forms from direct sunlight and add water to top of structure once concrete is set.

3.4.4 Prevention of Plastic Shrinkage Cracking

During weather with low humidity, and particularly with high temperature and appreciable wind, develop and institute measures to prevent plastic shrinkage cracks from developing. If plastic shrinkage cracking occurs, halt further placement of concrete until protective measures are in place to prevent further cracking. Periods of high potential for plastic shrinkage cracking can be anticipated by use of Figure 2.1.5 of ACI 305R. In addition to the protective measures concrete placement shall be further protected by erecting shades and windbreaks and by applying fog sprays of water, the addition of monomolecular films, or wet covering. When such water treatment is stopped, curing procedures shall be immediately

commenced. The methods and materials to remove or repair areas affected by plastic shrinkage cracks shall be suggested by the Contractor, reviewed by the agency's Subject Matter Expert in Concrete Materials, and approved by the Contracting Officer. Cracks shall never be troweled over or filled with cement slurry.

3.4.5 Mass Concrete

All mass concrete elements shall be placed per the requirements of the Mass Concrete Temperature Control Plan.

3.4.6 Depositing Concrete Under Water

ACI 301M ACI 301 methods and equipment used shall prevent the washing of the cement from the mixture, minimize the formation of laitance, prevent the flow of water through the concrete before it has hardened, and minimize disturbance to the previously placed concrete. Tremies, if used, shall be watertight and sufficiently large to permit a free flow of concrete. Keep the discharge end continuously submerged in fresh concrete. Keep the shaft full of concrete to a level well above the water surface. Discharge and spread the concrete by raising the tremie to maintain a uniform flow. Place concrete without interruption until the top of the fresh concrete is at the required height.

3.5 SURFACE FINISHES EXCEPT FLOOR, SLAB, AND PAVEMENT

3.5.1 Defects

Repair formed surfaces by removing minor honeycombs, pits greater than 600 square mm one square inch surface area or 6 mm 0.25 inch maximum depth, or otherwise defective areas. Provide edges perpendicular to the surface and patch with non-shrink grout. Patch tie holes and defects when the forms are removed. Concrete with extensive honeycomb including exposed steel reinforcement, cold joints, entrapped debris, separated aggregate, or other defects that affect the serviceability or structural strength will be rejected, unless correction of defects is approved. Obtain approval of corrective action prior to repair. The surface of the concrete shall not vary more than the allowable tolerances of ACI 347R. Exposed surfaces shall be uniform in appearance and finished to a smooth form finish unless otherwise indicated.

3.5.2 Formed Surfaces

3.5.2.1 Tolerances

Comply with ACI 117 and as indicated.

3.5.2.2 As-Cast Rough Form

Provide for surfaces not exposed to public view. Patch holes and defects and level abrupt irregularities. Remove or rub off fins and other projections exceeding 6 mm 0.25 inch in height.

3.5.2.3 As-Cast Form

Provide form facing material producing a smooth, hard, uniform texture on the concrete. Arrange facing material in an orderly and symmetrical manner and keep seams to a practical minimum. Support forms as necessary to meet required tolerances. Material with raised grain, torn surfaces,

worn edges, patches, dents, or other defects that will impair the texture of the concrete surface shall not be used. Patch tie holes and defects and completely remove fins.

3.6 FINISHES FOR HORIZONTAL CONCRETE SURFACES

3.6.1 Finish

Comply with ACI 301M ACI 301. Place, consolidate, and immediately strike off concrete to obtain proper contour, grade, and elevation before bleedwater appears. Permit concrete to attain a set sufficient for floating and supporting the weight of the finisher and equipment. If bleedwater is present prior to floating the surface, drag excess water off or remove by absorption with porous materials. Do not use dry cement to absorb bleedwater.

3.6.1.1 Scratched

Use for surfaces intended to receive bonded applied cementitious applications. After the concrete has been placed, consolidated, struck off, and leveled, the surface shall be roughened with stiff brushes of rakes before final set.

3.6.1.2 Floated

Exterior slabs where not otherwise specified. After the concrete has been placed, consolidated, struck off, and leveled, do not work the concrete further, until ready for floating. Whether floating with a wood, magnesium, or composite hand float, with a bladed power trowel equipped with float shoes, or with a powered disc, float shall begin when the surface has stiffened sufficiently to permit the operation.

3.6.1.3 Broomed

Perform a floated finish, then draw a broom or burlap belt across the surface to produce a coarse scored texture. Permit surface to harden sufficiently to retain the scoring or ridges. Broom transverse to traffic or at right angles to the slope of the slab.

3.6.1.4 Pavement

Screed the concrete with a template advanced with a combined longitudinal and crosswise motion. Maintain a slight surplus of concrete ahead of the template. After screeding, float the concrete longitudinally. Use a straightedge to check slope and flatness; correct and refloat as necessary. Obtain final finish by a burlap drag. Drag a strip of clean, wet burlap from 900 to 3000 mm wide and 600 mm longer 3 to 10 feet wide and 2 feet longer than the pavement width across the slab. Produce a fine, granular, sandy textured surface without disfiguring marks. Round edges and joints with an edger having a radius of 3 mm 1/8 inch.

3.6.1.5 Concrete Toppings Placement

Remove dirt, laitance, and loose aggregate by means of a stiff wire broom. Keep the base wet for a period of 12 hours preceding the application of the topping. Remove excess water prior to the topping placement. Do not allow temperature differential between the completed base and the topping to exceed 6 degrees C 10 degrees F at the time of placing. Place the topping and finish as specified for pavement.

3.7 CURING AND PROTECTION

Comply with ACI 301M ACI 301 and ACI 308.1 unless otherwise specified. Prevent concrete from drying by misting surface of concrete. Begin curing immediately following final set. Avoid damage to concrete from vibration created by blasting, pile driving, movement of equipment in the vicinity, disturbance of formwork or protruding reinforcement, by rain or running water, adverse weather conditions, and any other activity resulting in ground vibrations. Protect concrete from injurious action by sun, rain, flowing water, frost, mechanical injury, tire marks, and oil stains. Do not allow concrete to dry out from time of placement until the expiration of the specified curing period. Do not use membrane-forming compound on surfaces where appearance would be objectionable, on any surface to be painted, where coverings are to be bonded to the concrete, or on concrete to which other concrete is to be bonded. If forms are removed prior to the expiration of the curing period, provide another curing procedure specified herein for the remaining portion of the curing period. Provide moist curing for those areas receiving liquid chemical sealer-hardener or epoxy coating.

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NOTE: When the use of alkali-reactive aggregates is permitted, add the following paragraph.

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Furnish ASTM C39/C39M test results to verify the anticipated rate of strength development for the proposed concrete design mixture. Submit an increased curing period and minimum time to strip formwork based upon the reduced rate of strength development.

3.7.1 Wet Curing

Wet cure marine concrete using ASTM C1602/C1602M compliant water for a minimum of 7 days. Do not allow construction loads to exceed the superimposed load that the structural member, with necessary supplemental support, is capable of carrying in current condition safely and without damage.

Leaving the forms in place for seven days is a suitable alternative to wet curing.

3.7.1.1 Ponding or Immersion

Continually immerse the concrete throughout the seven-day curing period. Water shall not be 11 degrees C 20 degrees F less than the temperature of the concrete. For temperatures between 4 and 10 degrees C 40 and 50 degrees F, increase the curing period by 50 percent.

3.7.1.2 Fog Spraying or Sprinkling

Apply water uniformly and continuously throughout the curing period. For temperatures between 4 and 10 degrees C 40 and 50 degrees F, increase the curing period by 50 percent.

3.7.1.3 Pervious Sheeting

Completely cover surface and edges of the concrete with two thicknesses of wet sheeting. Overlap sheeting 150 mm 6 inches over adjacent sheeting.

Sheeting shall be at least as long as the width of the surface to be cured. During application, do not drag the sheeting over the finished concrete or over sheeting already placed. Wet sheeting thoroughly and keep continuously wet throughout the curing period.

3.7.1.4 Impervious Sheeting

Wet the entire exposed surface of the concrete thoroughly with a fine spray of water and cover with impervious sheeting throughout the curing period. Lay sheeting directly on the concrete surface and overlap edges 300 mm 12 inches minimum. Provide sheeting not less than 450 mm 18 inches wider than the concrete surface to be cured. Secure edges and transverse laps to form closed joints. Repair torn or damaged sheeting or provide new sheeting. Cover or wrap columns, walls, and other vertical structural elements from the top down with impervious sheeting; overlap and continuously tape sheeting joints; and introduce sufficient water to soak the entire surface prior to completely enclosing.

3.7.2 Liquid Membrane-Forming Curing Compound

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NOTE: Stay in place forms and moist curing are the preferred method for curing concrete. Use of a liquid membrane-forming curing compound is only permitted when approved by the Contracting Officer.

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Seal or cover joint openings prior to application of curing compound. Prevent curing compound from entering the joint. Apply in accordance with the recommendations of the manufacturer immediately after any water sheen that may develop after finishing has disappeared from the concrete surface. Provide and maintain compound on the concrete surface throughout the curing period. Do not use this method of curing where the use of Figure 2.1.5, "Effect of Concrete Temperatures, Relative Humidity, and Wind Velocity on the Rate of Evaporation of Surface Moisture From Concrete" in ACI 305R indicates that hot weather conditions will cause an evaporation rate exceeding one kg pf water per square meter per hour 0.2 pound of water per square foot per hour.

3.7.2.1 Application

Mechanically agitate curing compound thoroughly during use. Use approved power-spraying equipment to uniformly apply two coats of compound in a continuous operation. The total coverage for the two coats shall be 5 square meters maximum per L 200 square feet maximum per gallon of undiluted compound unless otherwise recommended by the manufacturer's written instructions. The compound shall form a uniform, continuous, coherent film that will not check, crack, or peel. Immediately apply an additional coat of compound to areas where the film is defective. Respray concrete surfaces subjected to rainfall within 3 hours after the curing compound application.

3.7.2.2 Protection of Treated Surfaces

Prohibit pedestrian and vehicular traffic and other sources of abrasion at least 72 hours after compound application. Maintain continuity of the coating for the entire curing period and immediately repair any damage.

3.7.3 Liquid Chemical Sealer-Hardener

Apply the sealer-hardener in accordance with manufacturer's recommendations. Seal or cover joints and openings in which joint sealant is to be applied as required by the joint sealant manufacturer. The sealer-hardener shall not be applied until the concrete has been moist cured and has aged for a minimum of 30 days. Apply a minimum of two coats of sealer-hardener.

3.7.4 Curing Periods

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NOTE: Add the following if concrete will be underwater: [Cure land-cast elements for a minimum of 7 days prior to submerging].

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Moist cure concrete using ASTM C1602/C1602M compliant water for a minimum of 7 days. Continue additional curing for a total period of 21 days. Begin curing immediately after placement. Protect concrete from premature drying, excessively hot temperatures, and mechanical injury; and maintain minimal moisture loss at a relatively constant temperature for the period necessary for hydration of the cement and hardening of the concrete. The materials and methods of curing shall be subject to approval by the Contracting Officer.

3.8 FIELD QUALITY CONTROL

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NOTE: Consider the size and complexity of job to determine if all tests are required.

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3.8.1 Fresh Concrete Properties

For each concrete mixture, the Contractor shall take samples in accordance with ASTM C172/C172M, test and record the slump, and temperature. If the slump deviates from the previous batch by more than 25.4 mm 1 inch, air content shall also be determined. Adjustment of air content and/or slump with chemical admixture is permitted provided the water to cementitious material ratio is not exceeded.

3.8.1.1 Slump Tests

ASTM C143/C143M. Take concrete samples during concrete placement. The maximum slump may be increased as specified with the addition of an approved high range water reducing (HRWR) admixture provided that the water-cementitious ratio is not exceeded. Perform tests at commencement of concrete placement, when test cylinders are made, and for each batch (minimum) or every 40 cubic meters 50 cubic yards (maximum) of concrete. If concrete does not pass slump test, adjust using a HRWR and test every concrete batch until two consecutive batches meet slump without adjustment.

3.8.1.2 Temperature Tests

a. Test the concrete delivered and the concrete in the forms. Perform tests in hot or cold weather conditions below 10 degrees C and above 27 degrees C below 50 degrees F and above 80 degrees F for each batch (minimum) or every 40 cubic meters 50 cubic yards (maximum) of

concrete, until the specified temperature is obtained, and whenever test cylinders and slump tests are made.

b. Determine temperature of each concrete sample in accordance with ASTM C1064/C1064M. Temperatures must comply with the Concrete Temperature Control Plans.

3.8.1.3 Air Content Tests

ASTM C231/C231M or ASTM C173/C173M. Perform tests at commencement of concrete placement each day, when test cylinders are made, and if slump test varies by more than 25.4 mm 1 inch from previous results or concrete does not pass slump test.

3.8.1.4 Unit Weight Test

ASTM C138/C138M. Take concrete samples during concrete placement. Perform tests at commencement of concrete placement, when test cylinders are made, and for each batch (minimum) or every 38.2 cubic meters 50 cubic yards(maximum) of concrete.

3.8.2 Hardened Concrete Properties

****

NOTE: The Engineer of Record must specify the frequency of testing during the construction phase. Sufficient testing must be done to maintain confidence that the concrete, as delivered and placed, remains consistent. For example: sample and test every 75 cubic meters 100 cubic yards for the first 382 cubic meters 500 cubic yards, then every 382 cubic meters 500 cubic yards once confidence is established in uniformity. However, this is only a guideline, and the owner and Engineer of Record should agree on the frequency of sampling as best suits the particulars of each project and budget.

For example, a sampling interval for a new pier may be as follows:

o During the first week of casting piles
o During the second week of casing piles
o Midway through the casting of all piles
o During the final week of casting piles
o At the first pile cap and every tenth bent thereafter
o During the two first concrete deck pours
o During the final concrete deck pour

****

Sample and test each lot at [75] cubic meters [100] cubic yards for the first [382] cubic meters [500] cubic yards, then every [382] cubic meters [500] cubic yards thereafter.

Cast and cure specimens in accordance with ASTM C172/C172M, ASTM C31/C31M, and applicable requirements of ACI 305R and ACI 306R.

For each lot, record the date and time sampled, the batch ticket code, cylinder ID code the location of placement, total volume of concrete

represented by the sample, and fresh concrete properties; ASTM C143/C143M for slump or ASTM C1611/C1611M for slump flow and visual stability index (VSI), ASTM C231/C231M for air content, ASTM C1064/C1064M for temperature, and ASTM C138/C138M unit weight.

For each lot sample, cast twelve 150 by 300 mm 6 by 12 inch cylinder specimens for strength and three 100 by 200 mm 4 by 8 inch cylinder specimens for chloride ion penetration testing. These cylinders shall be wrapped completely with slightly damped paper towels with water only. The wrapped cylinders shall be placed in either a vacuum package or double layers of sealed plastic bags. Package cylinders to prevent damage and ship to the approved testing laboratory.

In the event quality acceptance test results and retest results fail to meet the quality acceptance criteria, the entire lot shall be considered non-conforming material, refer to the paragraph REPAIR, REHABILITATION and REMOVAL.

3.8.2.1 Compressive Strength Tests

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NOTE: When the same mix design is used for multiple elements such as slabs, beams, and walls, the design element type may be specified in addition to the mix design to better identify deficient concrete.

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ACI 214R tests for strength - conduct strength tests of concrete during construction in accordance with the following procedures:

a. Test cylinders in accordance with ASTM C39/C39M. Test three cylinders at 3 days, three cylinders at 7 days, and three cylinders at the age when the compressive strength requirement was specified. Hold the remaining three cylinders in storage. If one specimen in a test shows evidence of improper sampling, molding or testing, discard the specimen and consider the strength of the remaining cylinder to be the test result. If more than one specimen shows excess defects, the Contracting Officer may allow the entire test to be discarded. Test results shall not exceed the specified compressive strength by more than 20 percent for the age specified.

b. If the average strength test results are less than the specified strength (f'c) extract three core samples from the structure in accordance with ASTM C42/C42M, from the area that correlates to the low test results. These extracted cores shall not contain steel reinforcing. Repair core holes with non-shrink grout. Match color and finish of adjacent concrete. For concrete not meeting strength criteria, the Contractor shall prepare a remediation strategy for the review by the Contracting Officer.

c. Strength test reports shall be provided within 7 days of test completion.

3.8.2.2 Chloride Ion Penetration Test

Test cylinder concrete for chloride ion penetration at 56 days. Concrete representative of the tested concrete with values greater than the quality acceptance values determined in Table 1, will require retesting using spare samples. If the retest exceeds the quality acceptance limit, this

shall be grounds to stop concrete placement and to review quality control issues.

3.8.2.3 Chloride Ion Concentration

Comply with ACI 318M Table 1. Determine water soluble chloride ion concentration. Perform test once for each mix design.

3.8.2.4 Anti-Washout Admixture

Comply with COE CRD-C 61. Determine cumulative mass loss. Perform test once for each 267.6 cubic meters 350 cubic yards of underwater concrete.

3.8.2.5 Non-Destructive Tests

Use of a rebound hammer to obtain data on the strength of the concrete surface shall be in accordance with ASTM C805/C805M. Test results from the rebound hammer and other non-destructive testing may be helpful in selecting areas to extract concrete cores for destructive testing.

3.8.3 Core Samples and Compressive Strength Testing

Obtain and test cores in accordance with ASTM C42/C42M.

If concrete in the structure is dry under service conditions, air dry cores (temperature 16 to 27 degrees C 60 to 80 degrees F, relative humidity less than 60 percent) for 7 days before testing and test dry. Otherwise, test the cores, after moisture conditioning, in accordance with ASTM C42/C42M.

Acceptance criteria for cylinder compressive strength are provided in paragraph ACCEPTANCE OF CONCRETE STRENGTH.

Take at least three representative cores from each member or area of concrete in place that is considered potentially strength deficient. Impair the strength of the structure as little as possible. If, before testing, extracted cores show evidence of having been damaged subsequent to or during removal from the structure, take replacement cores.

Fill core holes with low slump concrete or mortar of a strength equal to or greater than the original concrete.

The Contracting Officer will evaluate and validate core tests in accordance with the specified procedures.

3.8.4 Acceptance of Concrete Strength

3.8.4.1 Standard Molded and Cured Strength Specimens

The acceptance of concrete strengths shall be based on averages of results from three consecutive compressive strength tests. When the averages of all sets of three consecutive compressive strength test results are between 1.0 and 1.2 times the field test strength (fcr), and no individual strength test falls below fcr by more than 3.45 MPa 500 psi, the strength of the concrete is satisfactory. These criteria also apply when accelerated strength testing is specified unless another basis for acceptance is specified.

3.8.4.2 Non-Destructive Tests

Non-destructive tests may be used when permitted to evaluate concrete where standard molded and cured cylinders have yielded results not meeting the criteria.

3.8.4.3 Extracted Core Tests

When the average compressive strengths of the representative cores are between 0.85 fcr and 1.2 fcr and if no single core is less than 0.75 fcr, the strength of concrete is satisfactory.

3.8.5 Inspection

ACI 311.4R. Inspect concrete placed under water with qualified divers.

3.9 REPAIR, REHABILITATION AND REMOVAL

Before the Owner accepts the structure and final payment is made the Contractor shall inspect the structure for cracks, damage, and substandard concrete placements that may adversely affect the service life of the structure. A report documenting these defects shall be prepared that includes recommendations for repair, removal and/or remediation which, will be reviewed by the agency's Subject Matter Expert in Concrete Materials and submitted to the Contracting Officer for approval before any corrective work is accomplished.

3.9.1 Crack Repair

Prior to final acceptance, all cracks in excess of 0.50 mm 0.02 inches wide shall be documented and repaired. The proposed method and materials to repair the cracks shall be submitted to the Contracting Officer for approval. The proposal shall address the amount of movement expected in the crack due to temperature changes and loading.

3.9.2 Repair of Weak Surfaces

Weak surfaces are defined as mortar-rich, rain-damaged, uncured, or containing exposed voids or deleterious materials. Concrete surfaces with weak surfaces less than 6 mm 1/4 inch thick shall be diamond ground to remove the weak surface. Surfaces containing weak surfaces greater than 6 mm 1/4 inch thick shall be removed and replaced or mitigated in a manner acceptable to the Contracting Officer.

3.9.3 Failure of Quality Assurance Test Results

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NOTE: Test results accomplished on concrete samples during concrete production that fall short of the acceptance criteria alert the Contractor to something in the production and placement process that has drifted out of calibration or that an error has been made. The goal is to track down the problem and correct it as quickly as possible. Unless the concrete producer makes a large error in batching or in placing, the chance that hardened concrete needs to be removed is remote. Removal and replacement is a last resort.

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Proposed mitigation efforts by the Contractor to restore the original design intent shall be reviewed by the agency's Subject Matter Expert in Concrete Materials and approved by the Contracting Officer prior to proceeding.

-- End of Section --