****
USACE / NAVFAC / AFCEC **UFGS-03 31 29 (May 2024)**

Preparing Activity: NAVFAC **Superseding**
UFGS-03 31 29 (February 2019)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2024
****

SECTION TABLE OF CONTENTS

DIVISION 03 - CONCRETE

SECTION 03 31 29

MARINE CONCRETE WITH SERVICE LIFE MODELING

05/24

-- End of Section Table of Contents --

****

USACE / NAVFAC / AFCEC **UFGS-03 31 29 (May 2024)**

Preparing Activity: NAVFAC **Superseding**
UFGS-03 31 29 (February 2019)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2024
****

SECTION 03 31 29

MARINE CONCRETE WITH SERVICE LIFE MODELING
05/24

****

NOTE: This guide specification covers the requirements for reinforced concrete exposed to marine and chloride environments for projects with a defined service life. 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, where service life modeling is appropriate. See UFC 1-200-01 for determination of the ESC for project locations.

The defined service life approach mandates that the Government define the service life expectations of the structure (in years) prior to design. This document is a combination of prescriptive and performance based specifications. 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 includes provisions for performing concrete service life modeling. If it is determined that concrete service life modeling is not required for the project, then Section 03 31 30 Marine Concrete (without Service Life Modeling) should be used.

It is recommended that every significant structure employ service life modeling. Generally, significant structures are defined as having at least one of the following characteristics:

o Required Service Life: Greater than 60 years; or

o Volume of Concrete Works: Greater than 10,000 cubic yards; or

o Monetary Construction Value of the entire project: Greater than $15M; or

o   Service life modeling is required by the Government.

For projects meeting the above criteria, enhanced durability is required, and therefore, service life design aided by service life modeling as described in the specification must be performed.

Other criteria to consider when evaluating the applicability of service life design, and if Service Life Modeling is required, include:

o   Mission Criticality based on the Mission Dependency Index (MDI) Score. For example, consider service life modeling for an MDI score higher than 54.

o   Consequences of Failure: Consider service life modeling for UFC 3-301-01 Risk Categories IV or higher.

The performance-based portion of this document includes requirements to predict the service life of the candidate concrete mixtures prior to proceeding with construction. During construction, concrete cylinders are made from the production concrete at intervals specified by the Engineer of Record to measure transport properties and for microscopic examination of the hardened concrete to verify that the concrete quality remains consistent and acceptable. Conventional requirements for compressive strength and slump remain the same. Service life modeling software is a tool that, when used in combination with other tools and good engineering judgment, enhances the Contractor's and Government's confidence that the completed structure will perform for the defined service life. TR-NAVFAC ESC-CI-1215, the "Navy User's Guide to Quality Assurance of New Concrete Construction" provides a commentary for the user of this methodology. Generally, this version of the marine concrete UFGS is for major projects. For smaller marine concrete projects and for projects without a defined service life the Specifier can consider use of Section 03 31 30 MARINE CONCRETE that excludes service life modeling requirements and testing for transport properties during construction.

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).

****

****

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

****

****

NOTE: The following information must 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.

8. A list of the project structures that are covered by this specification.

****

PART 1 GENERAL

1.1 REFERENCES

****

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.
****

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 2021) Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats
AASHTO R 80	(2017; R 2021) Standard Practice for Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 117	(2010; R 2015) 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	(2020) Specifications for Structural Concrete
ACI 301M	(2020) 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	(2023) Specification for Curing Concrete
ACI 309R	(2005) Guide for Consolidation of Concrete
ACI 311.4R	(2005) Guide for Concrete Inspection
ACI 318	(2019; R 2022) Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)
ACI 318M	(2019; Errata 2022) Building Code Requirements for Structural Concrete & Commentary
ACI 347R	(2014; Errata 1 2017) Guide to Formwork for Concrete
ACI MNL-2	(2019; 11th Edition) ACI Manual of Concrete Inspection
ACI MNL-15	(2020) Field Reference Manual: Specifications for Concrete Construction ACI 301-20 with Selected ACI References
ACI MNL-66	(2020) ACI Detailing Manual

AMERICAN WELDING SOCIETY (AWS)

AWS D1.4/D1.4M	(2018) 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 A184/A184M	(2024) Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement
ASTM A276/A276M	(2024) Standard Specification for Stainless Steel Bars and Shapes
ASTM A416/A416M	(2024) Standard Specification for Low-Relaxation, Seven-Wire for Prestressed Concrete
ASTM A615/A615M	(2024) Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete

	Reinforcement
ASTM A706/A706M	(2024) Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A767/A767M	(2019) Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
ASTM A775/A775M	(2022) Standard Specification for Epoxy-Coated Steel Reinforcing Bars
ASTM A780/A780M	(2020) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM A882/A882M	(2020) Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand
ASTM A884/A884M	(2019; Errata 1) Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement
ASTM A886/A886M	(2024) 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 A970/A970M	(2018) Standard Specification for Headed Steel Bars for Concrete Reinforcement
ASTM A996/A996M	(2016) Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement
ASTM A1022/A1022M	(2016b) Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement
ASTM A1035/A1035M	(2024) Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement
ASTM A1044/A1044M	(2016a; Errata 1) Standard Specification for Steel Stud Assemblies for Shear Reinforcement of Concrete
ASTM A1055/A1055M	(2022) Standard Specification for Zinc and Epoxy Dual Coated Steel Reinforcing Bars

ASTM A1060/A1060M	(2016b) Standard Specification for Zinc-Coated (Galvanized) Steel Welded Wire Reinforcement, Plain and Deformed, for Concrete
ASTM A1064/A1064M	(2024) Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
ASTM C31/C31M	(2024b) Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C33/C33M	(2024) Standard Specification for Concrete Aggregates
ASTM C39/C39M	(2024) 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	(2024c) Standard Specification for Ready-Mixed Concrete
ASTM C138/C138M	(2024a) 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	(2024) 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	(2024a) 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	(2024) 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 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	(2024) Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
ASTM C457/C457M	(2023a) 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	(2024) 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	(2024) 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 C642	(2021) Standard Test Method for Density, Absorption, and Voids in Hardened Concrete
ASTM C666/C666M	(2015) Resistance of Concrete to Rapid Freezing and Thawing
ASTM C672/C672M	(2012) Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals
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	(2024) 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	(2023) Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C1074	(2019; E 2021) Standard Practice for Estimating Concrete Strength by the Maturity Method
ASTM C1077	(2024) 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	(2023) 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	(2023) 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	(2023) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1567	(2023) 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; R 2023) Standard Test Method for

	Passing Ability of Self-Consolidating Concrete by J-Ring
ASTM C1778	(2023) Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete
ASTM C1792	(2014) Standard Test Method for Measurement of Mass Loss versus Time for One-Dimensional Drying of Saturated Concretes
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	(2021) Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements
ASTM D7957/D7957M	(2017) Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement
ASTM E329	(2023) Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection

CONCRETE REINFORCING STEEL INSTITUTE (CRSI)

CRSI 10MSP	(2018; Errata 2019) Manual of Standard Practice
CRSI RB4.1	(2016) Supports for Reinforcement Used in Concrete

INTERNATIONAL FEDERATION FOR STRUCTURAL CONCRETE (fib)

fib Bulletin 34	(2006) Model Code for Service Life Design

NORDTEST (NT)

NT Build 492	(1999) Concrete, Mortar and Cement-Based Repair Materials: Chloride Migration Coefficient from Non-Steady-State Migration Experiments

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

U.S. NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (NAVFAC)

TR-NAVFAC ESC-CI-1215	(2012) Navy User's Guide for Quality Assurance of New Concrete Construction

1.2 DEFINITIONS

a. "Aging factor" is used to estimate the change in the diffusion or migration coefficient over time.

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

c. "Boundary Condition" is the environmental conditions in contact with the concrete. The service life modeling tool must account for the environmental conditions at the boundary interface between the specific concrete element and the environment, including wetting and drying due to daily tidal cycles and/or changes over its lifecycle.

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

e. "Cementitious material" as used herein must include portland cement and any pozzolanic material such as fly ash, natural pozzolans, slag cement and silica fume.

f. "Chloride threshold" (CTH) is the concentration of chloride ions in concrete that is generally assumed to be the minimum necessary to initiate corrosion of the reinforcing steel when all other necessary conditions are satisfied. The threshold value is expressed in parts per million (ppm) by mass of concrete, unless otherwise indicated in this specification.

g. "Chloride migration coefficient" is the main parameter describing the concrete transport properties in the time to corrosion model presented in Appendix B2 of fib Bulletin 34. It is measured using the NT Build 492 test method.

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

i. "Corrosion initiation period" (Ti) is the number of years assumed before the chloride ion reaches the chloride threshold for the reinforcing steel at the depth of the steel. The corrosion initiation period will be determined by numerical modeling in accordance with this specification.

j. "Corrosion Propagation period" (Tp) is the number of years after the corrosion initiation period until corrosion manifests as visible cracking and spalling of the concrete cover to a degree that will require extensive concrete repair. Based on evidence provided by the Contractor and reviewed by the agency's Subject Matter Expert in Concrete Materials, on a case-by-case basis the Contracting Officer may approve extension to the typical corrosion propagation period of 10 to 15 years. Use of supplemental corrosion protection methods and benign environmental conditions are two ways to extend the assumed propagation period.

k. "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 must be a minimum of 56 days.

l. "Effective Diffusion Coefficient" (D_{eff}) is, in the STADIUM® software, a coefficient that combines the ionic diffusion coefficient D_{oh} and volume of permeable voids.

m. "Exposure Conditions" are the environmental parameters used in service life modeling for each type of concrete element based on the structure location and anticipated boundary conditions.

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

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

p. "Ionic Diffusion Coefficient" (D_{oh}) is, in the STADIUM® software, the ionic diffusion coefficient as determined per the ionic diffusion coefficient migration testing for the service life modeling.

q. "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 must be designed using marine concrete. Components of a marine structure that are permanently buried in soil must 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 Contracting Officer to decide if the proposed structure should follow the guidelines for marine concrete.

r. "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.

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

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

u. "Moisture Transport Coefficient" (MTC) is, in the STADIUM® software, the value determined per the moisture transport coefficient drying test.

v. "Permeability" (K) is, in the STADIUM® software, the intrinsic permeability of the concrete evaluated from the moisture transport coefficient drying test.

w. "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.

x. "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.

y. "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; or lower-bound limits where larger values indicate acceptable material, such as compressive strength.

z. "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.

aa. "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.

bb. "Service life" is the Contracting Officer's stated expectation for the number of years that the structure will function without needing major concrete rehabilitation. 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.

cc. "Service Life Modeling" in the context of this document refers to a rational numerical approach to predict the time before the chloride ion contamination will reach a content, at the depth of the reinforcing steel, that is likely to result in the initiation of steel corrosion. Service life modeling is a tool to be used with engineering judgment to aid in the design, material selection, and construction methods to produce a durable structure. Two service life modeling tools are covered herein, including the STADIUM® software and the time to corrosion model presented in Appendix B2 of fib Bulletin 34.

dd. "Specified Effective Diffusion Coefficient" (D_{spec}) is, in the STADIUM® software, the calculated effective diffusion coefficient at which the service life is achieved.

ee. "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.

ff. "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).

gg. "Supplemental Corrosion Protection" includes (but 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.

hh. "Supplementary cementing materials" (SCM) include coal fly ash, slag cement, 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.

ii. "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 Contracting Officer's representative prior to construction of the project.

jj. "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).

kk. "Tolerance Limit" is defined for each transport parameter as the characteristic value that will be surpassed in 1 of 10 batches, at a 90 percent confidence level. This definition is provided for reference only, additional documentation and evaluation is needed prior to it being suggested as prescriptive criteria.

ll. "Transport properties" refers to the properties that characterize the rate of chloride penetration into a concrete element. These properties include for the STADIUM® software: volume of permeable voids (phi), ionic diffusion coefficient (D_{oh}), aging factor, and moisture transport coefficient (MTC) These properties include for the time to corrosion model presented in Appendix B2 of fib Bulletin 34: chloride migration coefficient.

mm. "Transport property testing" refers to the testing procedures that characterize the rate of chloride penetration into a concrete element. These properties are used as input data for the service life modeling.

nn. "Volume of Permeable Voids" (phi) is, in the STADIUM® software, the porosity of the concrete as determined by ASTM C642.

1.3 SUBMITTALS

****

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 and Air Force 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.
****

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. Submittals not having a "G" or "S" classification are 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

****
NOTE: Reproductions of contract drawings are unacceptable.
****

Contraction and Expansion Joints; G

Formwork and Falsework

Precast Elements; G, [_____]

Reinforcing Steel; G, [_____]

Construction Joints; G, [_____]

SD-03 Product Data

Admixtures; G, [_____]

Air Entraining, e.g., Corrosion Inhibitors, Anti-washout; 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 Reinforcement

SD-04 Samples

****
NOTE: Where flat surface finishing is important, provide a sample installation to train the crew.
****

Mass Concrete Mock-up

Test Section

SD-05 Design Data

****
NOTE: Concrete Mixture Requirements document the required criteria controlling the design of a particular concrete mix design while the Mixture Design documents the constituent materials used and the achieved performance during pre-construction phase.
****

Concrete Mixture Requirements; G, [_____]

Mixture Design Report

Mass Concrete Temperature Control Plans; G, [_____]

SD-06 Test Reports

Mass Concrete Mock-up

Air Entraining

Aggregates

Admixtures

As-Built Report

Cement

Concrete Mixture Proportions

Concrete Test Reports

Durability Modeling Report

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

As-Built Report including Observed Defects ans Transport Property Test Results

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 "must" 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

****

NOTE: Service Life Design Framework and Service Life Modeling

The fib Bulletin 34 methodology is the overall service life design framework implemented in this specification. This framework includes two basic durability strategies: the avoidance approach and the design to resist approach. Two sub-levels of the design to resist approach are implemented here including the deemed-to-satisfy approach and, what is referred to here as, the service life modeling approach. Two service life modeling tools are acceptable to the Navy: the STADIUM® software and the time to corrosion model presented in Appendix B2 of the fib Bulletin 34. The service life modeling tools output requirements to the concrete cover thickness and performance requirements for the concrete mixture as described here.

This methodology enhances the Navy's confidence that the structure will perform without major repairs for

the defined service life. It is recommended that every significant marine structure employ this section inclusive of service life modeling.

The Contracting Officer, the Engineer of Record, [and][or] the Contracting Officer must determine if this approach is applicable. Additional information is provided in TR-NAVFAC ESC-CI-1215.

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. 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 considered to be speculation 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 must 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**.**

****

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 obtain the design service life. The Contractor must develop and submit for approval a concrete quality control program in accordance with the guidelines of ACI 121R and as specified herein. The plan must include approved laboratories. The Contractor must provide direct oversight for the concrete qualification program inclusive of service life modeling, associated sampling and testing. If concrete cylinders tested during production indicate inadequate strength, excessive ion-transport properties, or inadequate mixing, then the Contracting Officer 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 defined service life.

Develop and submit for approval a concrete quality control program in accordance with the guidelines of ACI 121R and able to meet the defined service life using the methodology herein. Maintain a copy of ACI MNL-15 and CRSI 10MSP at the project site.

1.6.1 Quality Control Personnel

The contractor must 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. If using STADIUM® for service life modeling: STADIUM® certified laboratory and users of STADIUM® software.

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 must 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 must be performed by an ACI Concrete Field Testing Technician Grade 1 qualified in accordance with ACI MNL-2 or equivalent. Equivalent certification programs must include requirements for written and performance examinations as stipulated in ACI MNL-2.

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

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

d. Testing agencies or engineering companies that characterize the transport properties of the concrete and/or conduct service life modeling analysis must be pre-approved by the Contracting Officer with concurrence of the agency's Subject Matter Expert in Concrete Materials.

1.6.2 Laboratory Qualifications for Concrete Qualification Testing

The concrete testing laboratory must have the necessary equipment and experience to accomplish required testing. The laboratory must meet the requirements of ASTM C1077 and be Cement and Concrete Reference Laboratory (CCRL) inspected. If STADIUM® soft ware is used, the laboratory must be a STADIUM® certified laboratory. If the time to corrosion model presented in Appendix B2 of fib Bulletin 34 is used, the laboratory must be equipped and experienced in the use of the NT Build 492 test.

1.6.3 Laboratory Accreditation

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

a. Aggregate Testing and Mix Proportioning: Aggregate testing and mixture proportioning studies must be performed by an accredited laboratory and under the direction of a licensed/registered civil engineer in a U.S. state or territory, who must 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 must be performed by an approved, onsite, independent, accredited laboratory.

1.7 CONCRETE DURABILITY

1.7.1 Service Life Design

Unless otherwise specified, the concrete structures must be designed for a 75-year service life. The total service life is the summation of the corrosion initiation period (Ti) and the corrosion propagation period (Tp).

The modeling for the corrosion initiation period (Ti) must use a full probabilistic approach. The corrosion initiation time must meet a target reliability index of 1.3. The corrosion propagation period can be determined using a deterministic approach.

The modeling of the corrosion initiation period (Ti) must be in accordance with one of the following service life modeling tools:

a. The STADIUM® software: Only certified STADIUM® laboratories and users can perform the testing and modeling.

b. Time to corrosion model presented in Appendix B2 of fib Bulletin 34: The model used for the corrosion initiation period (Ti) must be a full probablistic approach as per Appendix B2. The choice of each input parameter must be documented in the Durability Modeling Report; it must be demonstrated how the choice of input parameters is reasonable and applicable to the project. Calculations must be checked, the Contracting Officer may request a copy of the calculations for review. Testing of the concrete transport property, the chloride migration coefficient, must be in accordance with the NT Build 492 test method.

Regardless of the selected service life modeling tool, applicable deterioration mechanisms other than chloride-induced reinforcement corrosion must be listed in the Durability Modeling Report and mitigated using the deemed-to-satisfy or avoidance durability strategy within the fib Bulletin 34 framework. The use of supplemental corrosion protection must not be used in lieu of the fundamental requirement to meet the defined service life. Extensions to corrosion propagation period may be approved by the Contracting Officer based on evidence provided by the Contractor and reviewed by the agency's Subject Matter Expert in Concrete Materials on a case-by-case basis.

The Contractor must forward a Durability Modeling Report prepared by the consultant that conducts the service life assessment of the proposed concrete system for each concrete mixture. The Durability Modeling Report must present the service life design including the corrosion initiation time modeling. As a minimum, the report must contain:

a. Durability-related requirements for the concrete mixture proportions.

b. The concrete cover to reinforcing steel. The cover to all reinforcing bars must be clearly delineated with allowance for placement tolerances per ACI 117.

c. The environmental exposure conditions and associated applicable deterioration mechanisms for each type of concrete element.

d. The selected durability strategies (i.e., avoidance or deemed-to-satisfy) and mitigation measures to address applicable deterioration mechanism(s) other than chloride-induced reinforcement corrosion. Selected mitigation measures must be supported by design codes and guidelines, including but not limited to ACI 201.2R, ACI 301M ACI 301, AASHTO R 80, and ASTM C1778.

e. The concrete transport properties and materials characteristics that, for the specified exposure zones, satisfies the minimum required service life of the structural element. Variability of transport properties during production is to be an input parameter in the service life modeling tool and need not be verified during the trial batch process.

f. A narrative describing the modeling process including assumptions and recommendations to accomplish the service life using quality concrete and specified cover. In the event that locally available materials cannot be shown to accomplish the service life then the Contractor must prepare a proposal for review by the agency's Subject Matter Expert in Concrete Materials and approval by the Contracting Officer to use alternative sources of materials and/or supplemental corrosion protection methods.

g. If using the STADIUM® software: Letter regarding the certificate of completion for the STADIUM® training.

h. The UFGS Laboratory Certification letter for the accredited laboratory.

1.7.2 Project Environment

1.7.2.1 Location Details

The values of Table 1 define the location and exposure conditions to be used in service life modeling. The Engineer of Record must define these values. Alternatively, the use of default values in accordance with the STADIUM® software or the time to corrosion model in Appendix B2 of fib Bulletin 34 may be approved by the Engineer of Record.

Table 1 - Environmental Design Conditions

Latitude	[_____] degrees Y' Z" [N][S]
Longitude	[_____] degrees Y' Z" [E][W]
MLLW Elevation, meter feet	[_____] meter feet
MHHW Elevation, meter feet	[_____] meter feet
Anticipated severity of exposure to de-icing chemicals	[N/A][Moderate][Severe]
Annual mean water temperature, C F	[_____] Degrees C F
Annual maximum ambient temperature, C F	[_____] Degrees C F
Annual mean ambient temperature, C F	[_____] Degrees C F
Annual minimum ambient temperature, C F	[_____] Degrees C F
Annual mean relative humidity, percent	[_____] percent
If using STADIUM software:	
Salinity, ppt (Submerged zone)	[_____] ppt
Salinity, ppt (Tidal zone)	[_____] ppt
Salinity, ppt (Splash zone)	[_____] ppt
Salinity, ppt (Atmospheric zone)	[_____] ppt
If using the time to corrosion model in Appendix B2 of fib Bulletin 34:	
Chloride surface concentration (Submerged zone)	[_____] percent by mass of total cementitious materials
Chloride surface concentration (Tidal zone)	[_____] percent by mass of total cementitious materials
Chloride surface concentration (Splash zone)	[_____] percent by mass of total cementitious materials
Chloride surface concentration (Atmospheric zone)	[_____] percent by mass of total cementitious materials

1.7.2.2 Exposure Conditions by Element

****
NOTE: Information on sulfate exposure categories can be found in Chapter 19 of ACI 318.
****

The Contractor must use service life modeling and exposure conditions listed above to provide concrete system(s) that meet or exceed the service life requirement. Evaluate the service life of each element for its severest service condition.

Concrete elements permanently buried in soil or seabed must be considered in the [S0][S1][S2][S3] exposure class.

1.7.3 Concrete Mixture Proportions

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

1.7.4 Concrete Design Requirements

Proportion concrete mixtures to meet the requirements listed in Table 2 in accordance with the procedures outlined in ACI 201.2R and ACI 211.1.

The mixture proportions for concrete must be developed by the Contractor to produce the required compressive strength (f'c), drying shrinkage, and constructability for mixtures that have the potential to accomplish a structure with the design service life.

For concrete elements permanently buried in soil or seabed, provide concrete meeting the requirements in ACI 301M ACI 301 for the sulfate exposure class assigned.

Table 2 - 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. Samples must be cured for 28 days except for high volume fly ash (HVFA) which must be cured for 56 days.	--	0.05 percent after 28 days drying
Initial acid-soluble chloride ion content in cast-in-place concrete per ASTM C1152/C1152M, percent/cement	--	0.10

Table 2 - Concrete Design Requirements		
Prescriptive requirements	Minimum	Maximum
Initial acid-soluble chloride ion content in prestressed concrete determined following ASTM C1152/C1152M, percent/cement	--	0.08
Average spacing factor following ASTM C457/C457M (inch)	--	0.008 with no value greater than 0.010
Concrete chloride ion transport properties: test methods and requirements as per the Durability Modeling Report.		
ASTM C672/C672M Scaling resistance, visual rating after 50 cycles	--	3

1.7.5 Concrete Mixture Qualifications

Proportion concrete mixtures to achieve fresh and hardened concrete properties in the paragraph CONCRETE QUALIFICATION PROGRAM. Qualification of concrete mixtures must be demonstrated through one of the following means:

1.7.5.1 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 6 months of the submittal date.

c. Copies of the previously approved trial batch test data, including concrete transport properties and tests required in Table 2.

d. A log containing at least 15 sequential test results (i.e., results from 15 consecutive tested concrete batches) with the calculated mean and standard deviation of the production concrete for air content, compressive strength and concrete transport properties.

If the Contractor changes material type, class, sources, or suppliers; chemical composition; and/or mix proportions, the Contractor must 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.

1.7.5.2 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 must be submitted along with the concrete mixture proportions. Obtain approval before concrete placement.

c. Test a minimum of one trial batch of production concrete to establish the specified transport properties. The transport properties measured from the trial batch must meet the input values assumed in the service life calculations. If batching facilities are located such that the haul-time will exceed 30 minutes, a simulated haul time must be included in the trial batch.

   If the concrete mixture for construction is proposed to contain corrosion inhibitors then transport properties in item (4)(b) and (5) below must be conducted from concrete with and without corrosion inhibitor added. The Contractor must obtain approval from the Contracting Officer for use of corrosion inhibitors.

   Trial batch testing must include, as a minimum:

   (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.

      (e) If applicable, tests of self-consolidating concrete listed in Section 1.7.6.1.c.

   (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 may be determined from three samples cast from one batch of a given mixture design.

      (c) Tensile strength (if required) may be determined using specimens cast from one batch of a given mixture design. The required number of specimens must be agreed with the Contracting Officer.

      (d) Freeze-thaw durability factor (if required) must be determined as the mean of three test specimens cast from one batch of a given mixture design.

      (e) Initial chloride ion content may be determined from a minimum of one sample from one batch of a given mixture design.

(f) Spacing factor (if required)may be determined using two separate specimens cast from one batch of a given mixture design.

(g) Scaling resistance (if required) may be determined from a minimum of two specimens from one batch of a given mixture design.

(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.

(4) If using the STADIUM® software: Cast twelve 100 by 200 mm 4 by 8 inch cylinders from the trial batch concrete, test and report ion transport properties as follows:

(a) Determine the porosity at 28-days and 90-days of standard moist curing. Two cylinders must be tested at each age. Calculate the mean porosity at each test age.

(b) Determine the D_{oh} at 28-days and 90-days of standard moist curing. Two cylinders must be tested at each age. Calculate the mean D_{oh} at each test age.

(c) Determine the MTC at 28-days of standard moist curing.

(d) Calculate the aging coefficient as the ratio of the mean 90-day, or longer, D_{oh} to the mean 28-day standard moist cure D_{oh}.

(e) Retain unused specimens in storage. These specimens may be tested later to refine the actual aging factor. This is advisable in the event that any production concrete falls short of the service life as it will provide evidence to better predict the service life.

(5) If using the time to corrosion model presented in Appendix B2 of fib Bulletin 34: Cast three 100 by 200 mm 4 by 8 inch cylinders from the same concrete batch, test and report ion transport properties as follows:

(a) Determine the chloride migration coefficient at 28 days as per NT Build 492 test procedure.

(6) Special handling will be necessary for shipments of transport property specimens. These cylinders must be wrapped completely with slightly damp paper towels with distilled water only. The wrapped cylinders must be placed in either a vacuum package or double layers of sealed plastic bags. Package the test cylinders to prevent damage and ship to an approved testing laboratory.

d. For concrete mixtures that are proposed to contain corrosion inhibitors, the Contractor must submit 28-day values for transport properties (D_{oh} for the STADIUM® software or chloride migration coefficient for time to corrosion model presented in Appendix B2 of fib Bulletin 34) from at least three batches of the mixture with and without the admixture making appropriate adjustments to maintain constant water to cementitious ratio. The purpose is to establish a correlation with respect to an adjusted value for production tested values.

e. At the option of the Contractor, a revised service life submittal may be provided as a value engineering proposal using refined properties calculated from production data. Extensions to corrosion propagation period may be reviewed by the agency's Subject Matter Expert in Concrete Materials and approved by the Contracting Officer based on evidence provided by the Contractor on a case-by-case basis.

1.7.6 Concrete Qualification Program

1.7.6.1 Fresh Concrete Properties

a. Air Content: Concrete that is air entrained must 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. Variations outside the limits specified must not be the reason to reject the concrete in locations not subject to freeze-thaw conditions.

b. Slump: The concrete mixture must 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 must not exceed 200 mm 8 inches. Slump tolerances must comply with the requirements of ACI 117.

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

(1) ASTM C1611/C1611M slump flow must not be greater than 609.6 mm 24 inches, with visual stability index not greater than 1.

(2) ASTM C1621/C1621M Passing ability using the J-ring. Spread within 25.4 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 must be less than 4.0 percent.

For process control sampling, the slump flow limit as determined by ASTM C1611/C1611M must be no greater than 609.6 mm 24 inches and the visual stability index limit must be no greater than 1.0.

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

1.7.6.2 Hardened Concrete Properties

****

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 may lead to more cracking and potential for associated deterioration. Embracing this approach will result in structures that are less expensive, greener, and more sustainable.
****

a. Compressive Strength: The structural engineer must 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 must 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 must be specified at a minimum of 56 days.

(2) Required Average Compressive Strength (f'cr): The concrete must 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 must 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 must 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 must 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. Test results must not exceed 0.05 percent. A drying shrinkage test result must 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 must be discarded and a new average established. Casting more than three specimens for each set is permitted. Test procedures and test specimens must conform to the following:

(1) Drying shrinkage specimens, typically 75 by 75 by 285.8 mm 3 by 3 by 11.25 inch prisms for 25.4 mm 1 inch maximum size aggregate or smaller, must be fabricated, cured, dried, and measured after 28 days of drying in the manner delineated in ASTM C157/C157M. Samples must be cured for 28 days, except for high-volume fly ash (HVFA) which must be cured for 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 after 300 cycles of rapid freezing and thawing is 90 percent.

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 2.

f. Scaling resistance: Determine the scaling resistance only for qualification of concrete mixtures. Determine scaling resistance in accordance with ASTM C672/C672M. The limits are listed in Table 2.

g. Silica fume must only be used for OCONUS projects where Class F fly ash and slag cement are not available, and when approved by the

Contracting Officer. If justified by service life modeling the mixture may contain a maximum of 7 percent silica fume by mass of total cementitious materials. Concrete mixtures containing any percentage of silica fume must 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 must 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.

h. Transport Properties if using STADIUM® software: Determine ion transport properties of the concrete in accordance with test procedures outlined by SIMCO, maker of STADIUM® software. Ion Transport properties are required as inputs for service life modeling and include: the volume of permeable voids (porosity); the ion diffusion coefficient (D_{oh}); the moisture transport coefficient (MTC), and an aging factor. A brief description of the test procedures is provided below. See TR-NAVFAC ESC-CI-1215 for further details.

(1) Porosity: The volume of permeable voids (porosity) of concrete is determined in accordance with ASTM C642. Porosity is determined for qualification of concrete mixtures and for quality acceptance testing.

(2) Ion Diffusion Coefficient (D_{oh}): This test is a modified version of ASTM C1202 and uses an electrical field to migrate chloride ions through a vacuum saturated concrete specimen for approximately 14 days. The electrical charge flowing through the concrete is related to the diffusion coefficient of ionic species in cementitious materials. A test is defined as the average of two specimens run together and whose results are analyzed together to produce a single D_{oh} value. The service life modeling software uses the cementitious materials proportions and porosity measurements to analyze the electrical measurements and determine the D_{oh}. The D_{oh} is determined for qualification of concrete mixtures and for quality acceptance testing.

(3) Moisture Transport Test: The ASTM C1792 test determines the drying rate of pre-saturated cementitious materials by measuring the evaporative mass loss of concrete slices with different thickness exposed to constant temperature and relative humidity environment. The moisture transport coefficient (MTC) is then determined by analyzing the mass loss data from ASTM C1792 testing using the STADIUM® software.

This test is only used for qualification of concrete mixtures, not for production concrete.

(4) Aging factor: The aging factor is a necessary value to estimate the change in diffusion coefficient over time. The aging factor is defined as the ratio of the ultimate D_{oh} to the 28-day D_{oh} per TR-NAVFAC ESC-CI-1215. Since we cannot wait for two or more years to characterize project concrete, a surrogate aging factor is used in this specification. This surrogate aging factor is calculated as the ratio of 90-day, or longer, D_{oh} to the 28-day D_{oh}. The aging factor is determined only for qualification of concrete

mixtures in compliance with TR-NAVFAC ESC-CI-1215.

i. Transport Properties if using the time to corrosion model in Appendix B2 of fib Bulletin 34: Determine the transport properties of the concrete in accordance with test procedures outlined by fib Bulletin 34. Transport properties are required as inputs for service life modeling and include: the chloride migration coefficient measured as per the NT Build 492 test procedure. The NT Build 492 test is performed at 28 maturity days on a 50 mm 2 inch thick sample sliced from a standard test cylinder. The sample is immersed in a saline solution to which a voltage is applied to accelerate the penetration of chlorides through the concrete for a period of generally 24 hours. At this time, the sample is split in half across its diameter and the depth of the chloride penetration is measured at seven points along the fractured surface. This data is used to calculate the rate at which chlorides penetrate the concrete. This rate is called the chloride migration coefficient and is a direct input value into the service life modeling. One NT Build 492 test is defined as the average of three specimens run together and whose results are averaged together to produce a single chloride migration coefficient value. The chloride migration coefficient is determined for qualification of concrete mixtures and for quality acceptance testing.

During trial batch testing, the chloride migration coefficient value must be less than or equal to the maximum allowable migration coefficient. The maximum allowable migration coefficient is equivalent to the mean chloride migration coefficient value determined through service life modeling.

1.7.6.3 Reinforcing Steel Corrosion Properties

The corrosion properties of the reinforcing steel used for service life modeling must be as follows unless otherwise approved by the Contracting Officer after review by the agency's Subject Matter Expert in Concrete Materials:

Table 3 - Chloride Threshold Level at the Reinforcing Steel Depth and Corrosion Propagation Time

Description	UNS Alloy	EN No.	Chloride Threshold (CTH), ppm	Corrosion Propagation Period (Tp) max, years
ASTM A706/A706M (Low alloy carbon steel)	[_____]	[_____]	500 or as specified in fib Bulletin 34	10
ASTM A615/A615M (Carbon steel)	[_____]	[_____]	500 or as specified in fib Bulletin 34	10
ASTM A416/A416M (carbon steel 7-wire strand)	[_____]	[_____]	500 or as specified in fib Bulletin 34	10

Table 3 - Chloride Threshold Level at the Reinforcing Steel Depth and Corrosion Propagation Time				
Description	UNS Alloy	EN No.	Chloride Threshold (CTH), ppm	Corrosion Propagation Period (Tp) max, years
ASTM A882/A882M (indented 7-wire strand)*	[_____]	[_____]		
ASTM A886/A886M (epoxy-filled 7-wire strand)*	[_____]	[_____]		
ASTM A934/A934M (Purple Epoxy)*	[_____]	[_____]		
ASTM A775/A775M (Green Epoxy) Not allowed	[_____]	[_____]		
ASTM A767/A767M (Galvanized Class 1)*	[_____]	[_____]		
ASTM A1035/A1035M (MMFX2 bars)*	[_____]	[_____]		
ASTM A1055/A1055M (Z bars)*	[_____]	[_____]		
ASTM A955/A955M (as applicable) XM Stainless Grades				
XM-28 (Nitronic 32)	S24100		500	15
XM-29 (Nitronic 33)	S24000		500	15
XM-19 (Nitronic 50)	S20910		500	15
ASTM A276/A276M Austenitic Stainless 304L	S30403	1.4307	3000	15
ASTM A276/A276M Duplex Stainless 2304	S32304	1.4362	4000	15
ASTM A955/A955M Austenitic Stainless 316L	S31603	1.4404	5000	15
ASTM A955/A955M Austenitic Stainless 316LN	S31653	1.4429	5000	15
ASTM A276/A276M Duplex Stainless 2205	S31803 S32205	1.4462	5000	15
*See TR-NAVFAC ESC-CI-1215				
** All other reinforcement not listed require approval of agency's Subject Matter Expert in Concrete Materials				

1.7.6.4 Supplemental Corrosion Protection

If the available materials in the region of the project cannot practically be made to meet the service life based on testing and service life modeling without the use of supplemental corrosion protection, then the Contractor must prepare a recommendation on how to accomplish the service life using imported materials and/or supplemental corrosion protection. With input from the agency's Subject Matter Expert in Concrete Materials, the Contracting Officer must consider approval of the Contractor's recommendation on a case-by-case basis.

1.7.7 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 must 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 must 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 must 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 must 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 must 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 must be less than 20 degrees C 36 degrees F.

(3) Temperature control procedures must 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 must be provided for the Contracting Officer's approval in the event the Contractor fails to control temperatures within the limits listed above. The submittal must 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 must have a minimum dimension of 1.0 m 3.0 feet per side, and must 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 Mass Concrete 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 MNL-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

****
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 must 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 must 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. Adjustments must not be made to the mixture design to facilitate pumping.

b. Submit technical literature for equipment and methods proposed for vibrating and compacting concrete. Submittal must 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 Coatings

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

1.8.2.6 Preconstruction Testing of Materials

All sampling and testing must 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. Material must not 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.

1.8.2.7 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.

1.8.2.8 Mixture Design Report

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. An individual Mixture Design Report must be provided for each concrete mixture.

A cover letter signed and stamped by a registered Professional Engineer must be included certifying compliance with the present specification, including required average compressive strength (f'cr), drying shrinkage, transport properties, and constructability, for mixtures that have the potential to accomplish a structure with the design service life.

1.8.3 Sampling

The Contractor is 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 must 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 must 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 must 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 must 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 must provide/transmit the concrete testing log to the Contracting Officer weekly. The Contractor must 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 must prepare, maintain, and report separate quality control charts illustrating the slump, temperature, air content, compressive strength test results, and transport property results for each lot of each concrete mixture used on the project.

1.8.4.4 Quality Team Meetings

The contractor must 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 must 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 must be with the Contracting Officer's approval.

The Contractor must prepare quality control team meeting minutes for each meeting. The minutes must 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 must be identified and the Contracting Officer and Engineer of Record must 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, transport properties 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 must 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 must be conducted at the Contractor's expense. The Contractor is responsible for the investigation and must 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 must be identified by a sequential report identification code. Each report must 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 must 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.

c. Submit copies of the Durability Modeling Report with laboratory analysis and modeling results indicating contract-goal service life will be met.

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 Slag Cement

Submit test results in accordance with ASTM C989/C989M. 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 must be at least 95 percent of the control.

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

c. The sum SiO_2 plus Al_2O_3 plus Fe_2O_3 must 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 must 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 must be obtained in accordance with ASTM D75/D75M and must 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/C1017M for 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 must 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 must 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[, slag cement,][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 must be no more than one month old, prior to use in the work. No cementitious material must 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 must 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 must be retested at the Contractor's expense and must 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 must 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 must 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 must 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, homogeneity, consolidation, segregation, air void spacing factor, and transport 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 must 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 must 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 must 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, homogeneity, consolidation, segregation, air void spacing factor, and transport 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 must 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

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

2.1 CEMENTITIOUS MATERIALS

****
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 slag cement for partial replacement of portland cement up to 50 percent. Type III cement should not be specified without concurrence of the agency's Subject Matter Expert in Concrete Materials. Laboratory mixtures, proportioning studies, and tests during the design stage of the project should be inclusive of service life modeling.
****

****
NOTE: Supplementary Cementitious Materials (SCM)

When slag cement, 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 must be portland cement or cement blended with supplementary cementing materials. New submittals are required when the cementitious materials change sources or types.

The Contractor must 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

****
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.
****

Provide portland cement conforming to ASTM C150/C150M, Type [I][II][V],[including early stiffening requirements] with tri-calcium aluminates (C3A) content less than 10 percent and a maximum cement-alkali content of 0.80 percent Na_2O_{eq} (sodium oxide) equivalent. Type III cement must 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 encouraged instead of using Type V cement in high-sulfate areas. If the proposed aggregates are found to be expansive, additional requirements to cement in accordance with AASHTO R 80 or ASTM C1778 must be imposed.

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

2.1.2 Blended Cements

Blended cement must conform to ASTM C595/C595M, Type IL, IP, IS, or IT including the optional requirement for sulfate resistance, indicated by MS or HS designations. Any fly ash used in Type IP cement must be ASTM C618 Class F fly ash. A statement from the cement manufacturer, indicating that the finished cement will not vary more than the percentages listed in Table 5 of ASTM C595/C595M with a 99 percent probability of compliance between lots or within a lot, must be included in the Mixture Designs report. The type and percentage of supplementary cementitious materials or limestone used in the blend must not change from that submitted for the aggregate evaluation and mixture proportioning.

2.1.3 Pozzolan

2.1.3.1 Fly Ash

****

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.

****

Fly ash must conform to ASTM C618, Class F, including the optional requirements for uniformity and effectiveness in controlling Alkali-Silica reaction and must have a loss on ignition not exceeding [3][6] percent. Class F fly ash for use in mitigating Alkali-Silica Reactivity must 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 must 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 must have an on ignition loss not exceeding 3 percent. Class N pozzolan for use in mitigating Alkali-Silica Reactivity must 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) must conform to ASTM C618, Class F or N, and the following additional requirements:

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

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

c. The sum of SiO_2 + Al_2O_3 + Fe_2O_3must be greater than 77 percent.

2.1.4 Slag Cement

Slag cement must conform to ASTM C989/C989M[, Grade 100 or Grade 120]. Add with cement.

2.1.5 Silica Fume

****

NOTE: Silica Fume must only be used for OCONUS projects where Class F fly ash and slag cement 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.

****

Silica fume must 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) must 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 must always contain supplementary cementing materials whether or not the aggregates are found to be reactive in accordance with the paragraph AGGREGATES. Concrete mixtures must be designed and proportioned to meet the requirements for strength, constructability, shrinkage, and service life.

****

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 must be used instead of f'c. Maintain required w/cm ratio regardless of strength requirements.

****

2.2 AGGREGATES

****

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.

****

****

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.

****

Comply with ASTM C33/C33M Class 4S, except as modified herein. The maximum aggregate size for each concrete mix must be in accordance with Table 4.

Table 4 - Maximum Aggregate Size	
Concrete Mix Design and Component	Maximum Aggregate Size (mm inches)
[_____]	[_____]
[_____]	[_____]
[_____]	[_____]
[_____]	[_____]

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) must 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 must 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, 25 mm, 19 mm, 12.5 mm, 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 micrometers, 300 micrometers, and 150 micrometers 1-1/2 inches, 1.0 inch, 3/4 inch, 1/2 inch, 3/8 inch, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100.

b. Provide aggregates for exposed concrete from one source. Aggregate reactivity must 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 must be conducted within 6 months from the date of concrete mixture submittal.

e. Provide ASTM C1260 or ASTM C1567 test results conducted within 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. Fine and coarse aggregates to be used in all concrete must be evaluated and tested for alkali-aggregate reactivity.

f. Should the test data indicate a potential for alkali-aggregate reaction, aggregates must be rejected or procedures from AASHTO R 80 or ASTM C1778 must 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 must 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 must not exceed 500 parts per million chloride ion and not more than 1000 parts per million of sulfate ion as SO4. Water must 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 5 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 5. For concrete that may be in contact with prestressing steel tendons, the concentration must not exceed 60 percent of the limits given in Table 5. For the concentration in grout for prestressing ducts, do not exceed 25 percent of the limits in Table 5.

Table 5 - 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 use of anti-washout or viscosity modifying admixture requires approval by the Contracting Officer and a proven record of performance with a minimum of five similar projects must be submitted. Test per COE CRD-C 61 to determine cumulative mass loss must 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 must 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

****

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.

****

ASTM C494/C494M, Type A, E, or F.

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

2.4.5 Corrosion Inhibitors

Corrosion inhibitors are considered "supplemental corrosion protection". 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 must be evaluated. The use of supplemental corrosion protection must not be used in lieu of the fundamental requirement to meet the defined service life using quality concrete with specified concrete cover over the steel reinforcing. Changes to the corrosion propagation period that is calculated for quality concrete due to the use of supplemental corrosion protection materials may be approved by the Contracting Officer based on evidence provided by the Contractor and reviewed by the agency's Subject Matter Expert in Concrete Materials on a case-by-case basis.

2.4.6 Shrinkage-Reducing Admixture

ASTM C494/C494M, Type S.

[2.4.7 Waterproofing/Hydrophobic Admixture

Waterproofing/hydrophobic admixture is considered "supplemental corrosion protection". If used, adjust the quantity of concrete mixing water for the mass of water in the admixture. Concrete setting time and mixture workability must 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 must 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 must 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 must not reduce the effective cover of the reinforcement.

b. Form-facing material must 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

a. Bend reinforcement cold. Fabricate reinforcement in accordance with fabricating tolerances of ACI 117.

b. When handling and storing coated reinforcement, use equipment and methods that do not damage the coating. If stored outdoors for more than 2 months, cover coated reinforcement with opaque protective material.

c. Submit manufacturer's certified test report for reinforcement.

d. Submit placing drawings showing fabrication dimensions and placement locations of reinforcement and reinforcement supports. Placing drawings must indicate locations of splices, lengths of lap splices, and details of mechanical and welded splices.

e. Submit request with locations and details of splices not indicated in Contract Documents.

f. Submit request to place column dowels without using templates.

****
NOTE: Specify if and where (locations) field bending or straightening of reinforcing bars is permitted.
****

[g. Submit request and procedure to field-bend or straighten reinforcing bars partially embedded in concrete at locations not indicated in

Contract Documents. Field bending or straightening of reinforcing bars is permitted[where indicated in the Contract Documents][in the following locations: [_____]].

] h. Submit request for field cutting, including location and type of bar to be cut and reason field cutting is required.

2.7.1 Prestressing Steel

****

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 is 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

****

NOTE: It is intended that plain steel rebar with specified concrete cover of 75 mm 3.0 inches must normally be specified according to applicable codes. Predictive modeling can confirm that the candidate concrete mixture, type of steel and concrete cover will yield the required service life for the particular structural element under consideration. For the purpose of predicting the service life of the concrete, the design must meet the required service life without relying on a barrier such as epoxy or zinc coating of the steel rebar or passive cathodic protection for additional life extension. The use of galvanized rebar and epoxy-coated rebar are acceptable for use, but it is difficult to justify a specific life extension from either without conclusive research data.

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.

****

****

NOTE: Use second recycled content option througout this section if Contractor is choosing recycled content products in accordance with Section 01 33 29

SUSTAINABILITY REQUIREMENTS AND REPORTING.
****

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

a. Reinforcing bars must be deformed, except spirals, load-transfer dowels, and welded wire reinforcement, which may be plain.

b. ASTM A615/A615M with the bars marked S, Grade [420][550][690][60][80][100]; or ASTM A996/A996M with the bars marked R, Grade [350][420][50][60], or marked A, Grade [300][420][40][60].[Cold drawn wire used for spiral reinforcement must conform to ASTM A1064/A1064M.][Provide reinforcing bars that contain a minimum of [100][_____] percent recycled content.][See Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING for cumulative total recycled content requirements.]

c.[Reinforcing bars may contain post-consumer or post-industrial recycled content.][Submit documentation indicating percentage of post-industrial and post-consumer recycled content per unit of product. Indicate relative dollar value of recycled content products to total dollar value of products included in project.]

d. Submit mill certificates for reinforcing bars.

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.

2.7.2.2 Galvanized Reinforcing Bars

****
NOTE: Class 1 has a zinc coating that is thicker than Class 2. For Class 1 bars, fabrication can be performed before or after coating. If fabrication is performed after coating then damage caused by fabrication should be repaired according to ASTM A767/A767M. If needed, add any requirements for bars that require special finished bend diameters and indicate their locations.
****

a. Provide zinc-coated (galvanized) reinforcing bars that conform to ASTM A767/A767M,[Class 1][Class 2][with galvanizing [before][after] fabrication] as required by the contract Documents.

b. Coating damage incurred during shipment, handling, and placing of zinc-coated (galvanized) reinforcing bars must be repaired in accordance with ASTM A780/A780M. Damaged areas must not exceed 2 percent of surface area in each linear foot of each bar or bar must not be used. The 2 percent limit on maximum allowed damaged coating area must include previously repaired areas damaged before shipment as required by ASTM A767/A767M.

2.7.2.3 Epoxy-Coated Reinforcing Bars

****

NOTE: ASTM A775/A775M are coated when straight and then bent as needed and are not allowed while ASTM A934/A934M are bent prior to coating. Bending after coating might result in the epoxy coating to crack or debond from steel.

****

a. Provide epoxy-coated reinforcing bars that conform to ASTM A934/A934M, Grade [60][80][100].

b. Coatings must be applied in plants that are certified in accordance with Concrete Reinforcing Steel Institute (CRSI) Epoxy Coating Plant Certification Program or an equivalent program acceptable to the contracting officer.

c. Coating damage incurred during shipment, storage, handling, and placing of epoxy-coated reinforcing bars must be repaired. Repair damaged coating areas with patching material conforming to ASTM A934/A934M as applicable and in accordance with material manufacturer's written recommendations. Damaged coating area must not exceed 2 percent of surface area in each linear foot of each bar or bar must not be used. The 2 percent limit on damaged coating area must include repaired areas damaged before shipment as required by ASTM A934/A934M as applicable. Fading of coating color is not cause for rejection of epoxy-coated reinforcing bars.

d. [Submit concrete Reinforcing Steel Institute (CRSI) Epoxy Coating Plant Certification][inspection and quality-control program of plant applying epoxy coating if proposed plant is not certified in accordance with CRSI Epoxy Coating Plant Certification Program].

2.7.2.4 Dual-coated Reinforcing Bars

a. Zinc and epoxy dual-coated reinforcing bars must conform to ASTM A1055/A1055M.

b. Coating damage incurred during shipment, storage, handling, and placing of zinc and epoxy dual-coated reinforcing bars must be repaired. Repair damaged coating areas with patching material conforming to ASTM A1055/A1055M and in accordance with material manufacturer's written recommendations. Damaged coating area must not exceed 2 percent of surface area in each linear foot of each bar or bar must not be used. The 2 percent limit on damaged coating area must include repaired areas damaged before shipment as required by ASTM A1055/A1055M. Fading of coating color is not cause for rejection of zinc and epoxy dual-coated reinforcing bars.

2.7.2.5 Low-carbon, Chromium, Steel Bars

Low-carbon, chromium, steel bars must conform to ASTM A1035/A1035M.

2.7.2.6 Stainless Steel Reinforcing Bars

Stainless steel bars must meet the requirements of ASTM A955/A955M.

2.7.2.7   Headed Reinforcing Bars

Headed reinforcing bars must conform to ASTM A970/A970M including Annex A1, and other specified requirements.

2.7.2.8   Bar Mats

a. Bar mats must conform to ASTM A184/A184M.

b. If coated bar mats are required, repair damaged coating as required in paragraphs GALVANIZED REINFORCING BARS, EPOXY-COATED REINFORCING BARS, and DUAL-COATED REINFORCING BARS.

2.7.2.9   Headed Shear Stud Reinforcement

Headed studs and headed stud assemblies must conform to ASTM A1044/A1044M.

[2.7.2.10   Glass Fiber Reinforced Polymer (GFRP) Bars

Glass fiber reinforced polymer (GFRP) bars meeting the requirements of ASTM D7957/D7957M are a permitted alternative. The structure design must consider the use of GFRP bars, noting that GFRP bar is not an in-kind replacement of steel bars.

]2.7.3   Mechanical Reinforcing Bar Connectors

a. Provide 125 percent minimum yield strength of the reinforcement bar being spliced.

b. Mechanical splices for galvanized reinforcing bars must be galvanized or coated with dielectric material.

c. Mechanical splices used with epoxy-coated or dual-coated reinforcing bars must be coated with dielectric material.

d. Mechanical splices for reinforcing bars not indicated in Contract Documents must not be used unless accepted by the Contracting Officer.

e. Remove coating on reinforcing bar in area of mechanical splice if required by splice manufacturer. After installing mechanical splices on zinc-coated (galvanized), epoxy-coated, or zinc and epoxy dual-coated reinforcing bars, repair damaged coating and areas of removed coating in accordance with paragraphs GALVANIZED REINFORCING BARS, EPOXY-COATED REINFORCING BARS, and DUAL-COATED REINFORCING BARS, respectively. Coat exposed parts of mechanical splices used on coated bars with same material used to repair damaged coating.

f. Submit data on mechanical splices demonstrating compliance with this paragraph.

2.7.4   Wire

****

NOTE: Include in your Contract Documents the wire size, yield strength or grade, and any additional requirements not specified here for wires. For more information on wire reinforcement refer to WRI (Wire Reinforcement Institute) documents.

****

a.[Provide wire reinforcement that contains a minimum of [100][_____] percent recycled content.][See Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING for cumulative total recycled content requirements. Wire reinforcement may contain post-consumer or post-industrial recycled content.] Provide flat sheets of welded wire reinforcement for slabs and toppings.

b. Plain or deformed steel wire must conform to ASTM A1064/A1064M.

c. Stainless steel wire must conform to ASTM A1022/A1022M.

d. Epoxy-coated wire must conform to ASTM A884/A884M. Coating damage incurred during shipment, storage, handling, and placing of epoxy-coated wires must be repaired. Repair damaged coating areas with patching material in accordance with material manufacturer's written recommendations. If damaged area exceeds 2 percent of surface area in each linear foot of each wire, wire must not be used. The 2 percent limit on damaged coating area must include repaired areas damaged before shipment as required by ASTM A884/A884M. Fading of coating color must not be cause for rejection of epoxy-coated wire reinforcement.

2.7.5 Welded Wire Reinforcement

****

NOTE: Include in your Contract Documents the welded wire yield strength or grade, size and spacing, and any additional requirements not specified here for wires.

****

a. Use welded wire reinforcement specified in Contract Documents and conforming to one or more of the specifications given herein.

b. Plain welded wire reinforcement must conform to ASTM A1064/A1064M, with welded intersections spaced no greater than 300 mm 12 in. apart in direction of principal reinforcement.

c. Deformed welded wire reinforcement must conform to ASTM A1064/A1064M, with welded intersections spaced no greater than 400 mm 16 in. apart in direction of principal reinforcement.

d. Epoxy-coated welded wire reinforcement must conform to ASTM A884/A884M. Coating damage incurred during shipment, storage, handling, and placing of epoxy-coated welded wire reinforcement must be repaired in accordance with ASTM A884/A884M. Repair damaged coating areas with patching material in accordance with material manufacturer's written recommendations. If damaged area exceeds 2 percent of surface area in each linear foot of each wire or welded wire reinforcement, the sheet containing the damaged area must not be used. The 2 percent limit on damaged coating area must include repaired areas damaged before shipment as required by ASTM A884/A884M. Fading of coating color must not be cause for rejection of epoxy-coated welded wire reinforcement.

e. Stainless steel welded wire reinforcement must conform to ASTM A1022/A1022M.

f. Zinc-coated (galvanized) welded wire reinforcement must conform to

ASTM A1060/A1060M. Coating damage incurred during shipment, storage, handling, and placing of zinc-coated (galvanized) welded wire reinforcement must be repaired in accordance with ASTM A780/A780M. If damaged area exceeds 2 percent of surface area in each linear foot of each wire or welded wire reinforcement, the sheet containing the damaged area must not be used. The 2 percent limit on damaged coating area must include repaired areas damaged before shipment as required by ASTM A1060/A1060M.

2.7.6 Reinforcing Bar Supports

****

NOTE: Include in your Contact Documents the types of reinforcement supports and location used within the structure. Refer to Chapter 3 in CRSI MSP 2.

****

a. Provide reinforcement support types within structure as required by Contract Documents. Reinforcement supports must conform to CRSI RB4.1. Submit description of reinforcement supports and materials for fastening coated reinforcement if not in conformance with CRSI RB4.1.

b.[For epoxy-coated reinforcement, use epoxy-coated or other dielectric-polymer-coated wire bar support.][For zinc-coated reinforcement, use galvanized wire or dielectric-polymer coated wire bar supports.]

****

NOTE: Supports must be coated when using epoxy-coaed reinforcing bars.

****

c. Legs of supports in contact with formwork must be hot-dip galvanized, or plastic coated after fabrication, or stainless-steel bar supports.

d.[Minimum [5][10][_____] percent post-consumer recycled content, or minimum [20][40][_____] percent post-industrial recycled content.][See Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING for cumulative total recycled content requirements. Plastic and steel may contain post-consumer or post-industrial recycled content.]

2.7.7 Welding

a. Provide weldable reinforcing bars that conform to ASTM A706/A706M and ASTM A615/A615M and Supplement S1, Grade 420 60, except that the maximum carbon content must be 0.55 percent.

b. Comply with AWS D1.4/D1.4M unless otherwise specified. Do not tack weld reinforcing bars.

c. Welded assemblies of steel reinforcement produced under factory conditions, such as welded wire reinforcement, bar mats, and deformed bar anchors, are allowed.

d. After completing welds on zinc-coated (galvanized), epoxy-coated, or zinc and epoxy dual-coated reinforcement, coat welds and repair coating damage as previously specified.

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 must 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

****

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 must 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 must 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 must 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 must remain in place for the time periods specified in ACI 347R, except for concrete placed underwater, forms must 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 must 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 must have the same load-carry capabilities as original shoring and must 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

a. Unless otherwise specified, placing reinforcement and miscellaneous materials must be in accordance with ACI 301M ACI 301. Provide bars, welded wire reinforcement, wire ties, supports and other devices necessary to install and secure reinforcement.

b. Reinforcement must not have rust, scale, oil, grease, clay, or foreign substances that would reduce the bond. Rusting of reinforcement is a basis of rejection if the effective cross-sectional area of the nominal weight per unit length has been reduced. Remove loose rust prior to placing steel. Tack welding is prohibited.

c. Inspect and verify proper reinforcement grade, quantity, spacing, and clearance requirements prior to concrete placement. Inspect placed steel reinforcing for coating damage, if applicable, prior to placing concrete. Repair all visible damage.

3.2.1 General

Provide details of reinforcement that are in accordance with the Contract Documents.

3.2.2 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 must 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 must be covered with opaque polyethylene sheeting or other suitable equivalent protective material.

Epoxy Coated Reinforcing must meet the requirements of ASTM A934/A934M including Appendix X2, "Guidelines for Job Site Practices" except as otherwise specified herein.

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

a. Immediately prior to application of the patching material, any rust and debonded coating must be manually removed from the reinforcement by suitable techniques employing devices such as wire brushes and emery paper. Care must be exercised during this surface preparation so that the damaged areas are not enlarged more than necessary to accomplish the repair. Damaged areas must be clean of dirt, debris, oil, and similar materials prior to application of the patching material.

b. Repair and patching must be done in accordance with the patching material manufacturer's recommendations. These recommendations, including cure times, must 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.

3.2.3 Reinforcement Supports

Provide reinforcement support in accordance with CRSI RB4.1 and ACI 301M ACI 301 Section 3 requirements.

Place reinforcement and secure with non-corrodible chairs, spacers, and hangers. Metal hangers may be used, but must 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 must rest on coated wire bar supports, or on bar supports made of dielectric material or other acceptable material. Wire bar supports must 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 must be coated with the same material as the reinforcing. Spreader bars, where used, must be coated. Non-coated combination bar clips and spreaders used in construction with coated reinforcing bars must be made corrosion resistant or coated with dielectric material. Coated bars must be tied with plastic-coated tie wire or other materials acceptable to the Contracting Officer.

3.2.4 Splicing

As indicated in the Contract Drawings. 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 must comply with AWS D1.4/D1.4M and be approved prior to use. Repair the cut ends of Galvanized Reinforcing Bars to completely coat exposed steel, ASTM A780/A780M.

3.2.5 Future Bonding

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

3.2.6   Cover

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

As a minimum, comply with ACI 318M ACI 318 for concrete cover over the steel reinforcement. The cover may be greater than that required by ACI 318M ACI 318 based on the results from service life modeling. Tolerances for the placement of the steel reinforcement must comply with the service life modeling and ACI 117. When predicting service life, the cover thickness must be modelled considering the specified cover and construction tolerances per ACI 117. Steel shapes that are embedded in the concrete must have at least the cover required for concrete reinforcement.

3.2.7   Setting Miscellaneous Material and Prestress Anchorages

Place and secure anchors, bolts, pipe sleeves, conduits, and other such items in position before concrete placement and support against displacement. 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.

3.2.8   Fabrication

Shop fabricate reinforcing bars to conform to shapes and dimensions indicated for reinforcement, and as follows:

a. Provide fabrication tolerances that are in accordance with ACI 117.

b. Provide hooks and bends that are in accordance with the Contract Documents.

Reinforcement must be bent cold to shapes as indicated. Bending must be done in the shop. Rebending of a reinforcing bar that has been bent incorrectly is not to be permitted. Bending must be in accordance with standard approved practice and by approved machine methods.

Deliver reinforcing bars bundled, tagged, and marked. Tags must be metal with bar size, length, mark, and other information pressed in by machine. Marks must correspond with those used on the placing drawings.

Do not use reinforcement that has any of the following defects:

a. Bar lengths, depths, and bends beyond specified fabrication tolerances.

b. Bends or kinks not indicated on drawings or approved shop drawings.

c. Bars with reduced cross-section due to rusting or other cause.

Replace defective reinforcement with new reinforcement having required shape, form, and cross-section area.

3.2.9 Placing Reinforcement

Place reinforcement in accordance with ACI 301M ACI 301.

For slabs on grade (over earth or over capillary water barrier) and for footing reinforcement, support bars or welded wire reinforcement on precast concrete blocks, spaced at intervals required by size of reinforcement, to keep reinforcement the minimum height specified above the underside of slab or footing.

For slabs other than on grade, supports for which any portion is less than 25 mm 1 inch from concrete surfaces that are exposed to view or to be painted must be of precast concrete units, plastic-coated steel, or stainless steel protected bar supports. Precast concrete units must be wedge shaped, not larger than 90 by 90 mm 3-1/2 by 3-1/2 inches, and of thickness equal to that indicated for concrete protection of reinforcement. Provide precast units that have cast-in galvanized tie wire hooked for anchorage and blend with concrete surfaces after finishing is completed.

Provide reinforcement that is supported and secured together to prevent displacement by construction loads or by placing of wet concrete, and as follows:

a. Provide supports for reinforcing bars that are sufficient in number and have sufficient strength to carry the reinforcement they support, and in accordance with ACI 301M ACI 301 and CRSI 10MSP. Do not use supports to support runways for concrete conveying equipment and similar construction loads.

b. Equip supports on ground and similar surfaces with sand-plates.

c. Support welded wire reinforcement as required for reinforcing bars.

d. Secure reinforcements to supports by means of tie wire. Wire must be black, soft iron wire, not less than 1.6 mm 16 gage.

e. Reinforcement must be accurately placed, securely tied at intersections, and held in position during placing of concrete by spacers, chairs, or other approved supports. Point wire-tie ends away from the form. Unless otherwise indicated, numbers, type, and spacing of supports must conform to the Contract Documents.

f. Bending of reinforcing bars partially embedded in concrete is permitted only as specified in the Contract Documents.

3.2.10 Spacing of Reinforcing Bars

a. Spacing must be as indicated in the Contract Documents.

b. Reinforcing bars may be relocated to avoid interference with other reinforcement, or with conduit, pipe, or other embedded items. If any reinforcing bar is moved a distance exceeding one bar diameter or specified placing tolerance, resulting rearrangement of reinforcement is subject to preapproval by the Contracting Officer.

3.2.11 Welding of Reinforcement

Welding of reinforcement, where permitted, must be in accordance with AWS D1.4/D1.4M.

3.2.12 Construction Joints

If construction joints are shown on the plans: Place all concrete between consecutive joints in a continuous operation. Continue reinforcement across joints unless otherwise indicated.

If construction joints are not shown on the plans: Prior to ordering concrete the contractor must locate joints to least impair strength and must provide substantiating calculations for government review and approval.

Construction joints must be oriented normal to the main reinforcement. Construction joint spacing must not exceed 24.4 m 80 feet, unless approved in writing.

Form construction joints using bulkheads with keyways. Locate keyways clear of exposed surfaces by approximately one-third the thickness of the joint-adjacent concrete pour to take place after a minimum of 7 days to allow for initial shrinkage.

Dampen the surface of the concrete to achieve a saturated surface dry condition at the horizontal construction joints immediately before placing adjoining concrete.

Avoid joints in cantilevered members. Where practical, avoid horizontal joints in pile caps, bulkheads, and retaining walls, otherwise locate horizontal joints 600 mm 2 feet or more above the MHHW elevation. If the work is unexpectedly interrupted by breakdowns, storms, or other causes, rearrange the freshly deposited concrete to provide a suitable construction joint. If this joint occurs at a section with shear stress, prevent a plane of weakness by providing an adequate mechanical bond across the joint by forming a keyway, inserting reinforcing steel, or by some other means satisfactory to the Contracting Officer.

3.2.13 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 must be completed within 4 to 12 hours after concrete placement. Protect joints from intrusion of foreign matter.

3.2.14 Waterstop Splices

Fusion weld in the field.

3.2.15 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 must 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 must 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 1.0 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 feet centers maximum for exterior slabs.

3.4.1 Vibration

****

NOTE: The requirement for vibrator spacing must be considered in the reinforcing steel design by the engineer of record. ACI MNL-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 inches 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 must 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 must 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 must 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 must 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 4.1.4, "Effect of Concrete and Air Temperatures, Relative Humidity, and Wind Speeed on the Rate of Evaporation of Surface Moisture From Concrete" in ACI 305R to prevent the evaporation rate from exceeding 1.0 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 4.1.4 of ACI 305R. In addition to the protective measures concrete placement must 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 must be immediately commenced. The methods and materials to remove or repair areas affected by plastic shrinkage cracks must be suggested by the Contractor, reviewed by the agency's Subject Matter Expert in Concrete Materials, and approved by the Contracting Officer. Cracks must never be troweled over or filled with cement slurry.

3.4.5 Mass Concrete

All mass concrete elements must 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 must 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, must 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, bugholes, blisters, pop-outs, and pits greater than 600 square mm 1.0 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 must not vary more than the allowable tolerances of ACI 347R. Exposed surfaces must 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 must 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 must be roughened with stiff brushes or 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, floating must 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 during curing. Protect concrete from injurious action by sun, rain, flowing water, frost, mechanical injury, tire marks, and oil stains during curing.

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. Do not interrupt curing for more than 60 minutes during form removal. Provide moist curing for those areas receiving liquid chemical sealer-hardener or epoxy coating.

Approved equipment and materials for curing must be on-site and available for immediate use before placing concrete.

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

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 must 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 must 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. Anchor the wet sheeting to provide continuous contact with the concrete surface.

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

****

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.

****

Seal or cover joint openings prior to application of curing compound.

Prevent curing compound from entering the joint. The liquid membrane-forming compound must meet the requirements of ASTM C309 Type 1-D or Type 2 Class A. The compound must form a uniform, continuous, coherent film that will not check, crack, or peel during the curing period. It must not peel under traffic after 24 hours drying time. The compound must not react deleteriously with concrete or its constituents. Provide and maintain compound on the concrete surface throughout the curing period. Do not use this method of curing where the use of Figure 4.1.4, "Effect of Concrete and Air Temperatures, Relative Humidity, and Wind Speed on the Rate of Evaporation of Surface Moisture From Concrete" in ACI 305R indicates that hot weather conditions will cause an evaporation rate exceeding 1.0 kg of water per square meter per hour 0.2 pound of water per square foot per hour.

3.7.2.1 Application

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.

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 must 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. 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 Curing Periods

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

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 must be subject to approval by the Contracting Officer.

3.7.4 Protection

3.7.4.1 Thermal Protection Against Cold Weather

Protect concrete against cold weather conditions in accordance with ACI 306R. Concrete must achieve a compressive strength of minimum 24.5 MPa 3500 psi prior to removal of thermal protection in cold weather conditions. Removal of thermal protection must be carried out as to reduce potential crack-inducing differential strains per ACI 306R.

3.7.4.2 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 must 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.

3.8 FIELD QUALITY CONTROL

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

3.8.1 Fresh Concrete Properties

For each concrete mixture, the Contractor must 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 1.0 inch, air content must 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 Mass 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 1.0 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 Contracting Officer 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 casting 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 seven 100 by 200 mm 4 by 8 inch cylinder specimens for transport property testing. Special handling will be necessary for shipments of transport property specimens. These cylinders must be wrapped completely with slightly dampened paper towels with water only. The wrapped cylinders must 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 the results of cylinder tests fail to satisfy transport properties, then an additional pair of specimens must be tested. In the event quality acceptance test results and retest results fail to meet the quality acceptance criteria, the entire lot must be considered non-conforming material, refer to paragraph REPAIR, REHABILITATION AND REMOVAL.

3.8.2.1 Compressive Strength Tests

****

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.

****

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 must 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 must 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 must prepare a remediation strategy for the review by the Contracting Officer.

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

3.8.2.2 Transport Property Tests

The Contractor must monitor the transport properties throughout the duration of the project and prepare an as-built report documenting the transport property test results. The report must include a chart or table of the relevant transport property from the service life modeling tool used in the Durability Modeling Report versus the specified value over the duration of the placement for each concrete, indicate the concrete placed outside of the tolerance limits, describe any mitigation measures taken to ensure the service life specified, and estimate the service life of the various concretes, as placed.

If using STADIUM® software: Test cylinder concrete for porosity and ion diffusion coefficient at 28 days. Calculate the D_{eff} with the determined ionic diffusion coefficient (D_{oh}) and volume of permeable voids (porosity).

If using the time to corrosion model in Appendix B2 of fib Bulletin 34: Test cylinder concrete for chloride migration coefficient at 28 days in accordance with NT Build 492. The tolerance limit for chloride migration coefficient at 28 days is that the three test running average is less than or equal to the specified limit, with no individual test >20% above the specified limit.

Concrete representative of the tested concrete with values non-conforming with the quality acceptance values determined in the service life modeling will require retesting using spare samples. If the retest exceeds the quality acceptance limit, concrete placement must be stopped to review quality control issues.

3.8.2.3 Chloride Ion Content

Comply with Table 2 requirements. Determine acid soluble chloride ion content per ASTM C1152/C1152M. 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 must 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 must 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 Contracting Officer accepts the structure and final payment is made the Contractor must 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 must 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. Costs for repair must be borne by the Contractor.

3.9.1 Crack Repair

Prior to final acceptance, all cracks in excess of 0.25 mm 0.01 inches wide must be documented and repaired. The proposed method and materials to repair the cracks must be submitted to the Contracting Officer for approval. The proposal must address the amount of movement expected in the crack due to temperature changes and loading.

After completing all curing operations and allowing the pier deck to thoroughly dry, the contractor must seal the following areas with a high molecular weight methacrylate (HMWM) sealer, clear color. Flood the cracked areas with the sealer and squeegee off the excess material before opening pier to operation.

a. Transverse joints in the deck.

b. Longitudinal joints in the deck.

c. Longitudinal joints between the deck and safety curb, barriers, and parapets, etc.

d. Cracks discovered in the deck of the top and bottom surfaces before opening the deck to traffic, that are 0.25 mm 0.010 inches or less in width.

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 must be diamond ground to remove the weak surface. Surfaces containing weak surfaces greater than 6 mm 1/4 inch thick must be removed and replaced or mitigated in a manner acceptable to the Contracting Officer.

3.9.3 Failure of Quality Assurance Test Results

****

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.

For those areas adversely affected by substandard concrete new numerical service life modeling simulations can be helpful to evaluate the effectiveness of the proposed remediation strategies.

****

Proposed mitigation efforts by the Contractor to restore the service life must be reviewed by the agency's Subject Matter Expert in Concrete Materials and approved by the Contracting Officer prior to proceeding.

-- End of Section --