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USACE / NAVFAC / AFCESA / NASA **UFGS-03 31 29 (November 2009)**

Preparing Activity: NAVFAC **Superseding UFGS-03 31 29 (August 2009)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2009
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DIVISION 03 - CONCRETE

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MARINE CONCRETE

11/09

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SECTION 03 31 29

MARINE CONCRETE
11/09

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NOTE: This guide specification covers the requirements for cast-in-place new concrete construction subject to exposure in marine environment.

Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

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

This guide specification includes tailoring throughout for STADIUM. If STADIUM is not required for the project, all related STADIUM requirements can be removed by the tailoring option accessed through SpecsIntact's Explorer or SpecsIntact's Editor.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).
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NOTE: For concrete not exposed to marine environment, use Section 03 30 00 CAST-IN-PLACE CONCRETE.
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NOTE: The following information shall be shown on the project drawings:

1. Loading 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 (40,000 and 60,000 psi grades are 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 waterstop locations and splices, keys, and dowels when required, and location of fiber-reinforced concrete elements.

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PART 1 GENERAL

1.1 REFERENCES

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

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

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

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

ACI INTERNATIONAL (ACI)

ACI 117	(2006) Standard Specifications for Tolerances for Concrete Construction and Materials
ACI 121R	(2008) Quality Management System for Concrete Construction

ACI 201.2R	(2008) Guide to Durable Concrete
ACI 211.1	(1991; R 2009) Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 214R	(2002) Recommended Practice for Evaluation of Strength Test Results of Concrete
ACI 301	(2005; Errata 2008) Specifications for Structural Concrete
ACI 304.2R	(1996; R 2008) Placing Concrete by Pumping Methods
ACI 304R	(2000) Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 305R	(1999; Errata 2006) Hot Weather Concreting
ACI 306.1	(1990; R 2002) Standard Specification for Cold Weather Concreting
ACI 308R	(2001; R 2008) Guide to Curing Concrete
ACI 309R	(2005) Guide for Consolidation of Concrete
ACI 311.4R	(2005) Guide for Concrete Inspection
ACI 318M	(2008; Errata 2008; Errata 2009) Metric Building Code Requirements for Structural Concrete and Commentary
ACI 347	(2004) Guide to Formwork for Concrete
ACI SP-15	(2005) Field Reference Manual: Standard Specifications for Structural Concrete with Selected ACI and ASTM References
ACI SP-2	(2007) ACI Manual of Concrete Inspection
ACI SP-66	(2004) ACI Detailing Manual

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

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

AMERICAN WELDING SOCIETY (AWS)

AWS D1.4/D1.4M	(2005; Errata 2005) Structural Welding Code - Reinforcing Steel

ASTM INTERNATIONAL (ASTM)

ASTM A 185/A 185M	(2007) Standard Specification for Steel Welded Wire Reinforcement, Plain, for

	Concrete
ASTM A 416/A 416M	(2006) Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete
ASTM A 496/A 496M	(2007) Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement
ASTM A 497/A 497M	(2007) Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete
ASTM A 615/A 615M	(2009) Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A 706/A 706M	(2009) Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A 82/A 82M	(2007) Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
ASTM A 934/A 934M	(2007) Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
ASTM A 966/A 966M	(2008) Standard Test Method for Magnetic Particle Examination of Steel Forgings Using Alternating Current
ASTM C 1017/C 1017M	(2007) Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
ASTM C 1064/C 1064M	(2008) Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C 1077	(2009b) Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
ASTM C 1107/C 1107M	(2008) Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
ASTM C 1116/C 1116M	(2008a) Standard Specification for Fiber-Reinforced Concrete
ASTM C 1157/C 1157M	(2009) Standard Specification for Hydraulic Cement
ASTM C 1202	(2009) Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
ASTM C 1218/C 1218M	(1999; R 2008) Standard Specification for

	Water-Soluble Chloride in Mortar and Concrete
ASTM C 1240	(2005) Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C 1260	(2007) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C 138/C 138M	(2009) Standard Test Method for Density ("Unit Weight"), Yield, and Air Content (Gravimetric) of Concrete
ASTM C 143/C 143M	(2009) Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C 150/C 150M	(2009) Standard Specification for Portland Cement
ASTM C 1567	(2008) Standard Test Method for Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C 157/C 157M	(2008) Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
ASTM C 171	(2007) Standard Specification for Sheet Materials for Curing Concrete
ASTM C 172	(2008) Standard Practice for Sampling Freshly Mixed Concrete
ASTM C 173/C 173M	(2009) Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C 231	(2009a) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 260	(2006) Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C 295	(2008) Petrographic Examination of Aggregates for Concrete
ASTM C 309	(2007) Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C 31/C 31M	(2009) Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C 33/C 33M	(2008) Standard Specification for Concrete Aggregates

ASTM C 39/C 39M	(2005e1e2) Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 42/C 42M	(2004) Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C 469	(2002e1) Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
ASTM C 494/C 494M	(2008a) Standard Specification for Chemical Admixtures for Concrete
ASTM C 496/C 496M	(2004e1) Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
ASTM C 595/C 595M	(2008a) Standard Specification for Blended Hydraulic Cements
ASTM C 597	(2002) Pulse Velocity Through Concrete
ASTM C 618	(2008a) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C 642	(2006) Density, Absorption, and Voids in Hardened Concrete
ASTM C 805/C 805M	(2008) Rebound Number of Hardened Concrete
ASTM C 881/C 881M	(2002) Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
ASTM C 920	(2008) Standard Specification for Elastomeric Joint Sealants
ASTM C 94/C 94M	(2009) Standard Specification for Ready-Mixed Concrete
ASTM C 989	(2009a) Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
ASTM D 1179	(2004) Fluoride Ion in Water
ASTM D 1190	(1997) Standard Specification for Concrete Joint Sealer, Hot-Applied Elastic Type
ASTM D 1339	(1984) Sulfite Ion in Water
ASTM D 1751	(2004; R 2008) Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)

ASTM D 1752	(2004a; R 2008) Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion
ASTM D 3867	(2009) Nitrite-Nitrate in Water
ASTM D 512	(2004) Chloride Ion in Water
ASTM D 516	(2007) Sulfate Ion in Water
ASTM E 329	(2008) Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 572	(1974) Specifications for Polyvinylchloride Waterstops
COE CRD-C 61	(1989A) Test Method for Determining the Resistance of Freshly Mixed Concrete to Washing Out in Water

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS SS-S-1614	(Rev A; Am 1) Sealants, Joint,Jet-Fuel-Resistant, Hot-Applied, for Portland Cement and Tar Concrete Pavements
FS SS-S-200	(Rev E; Am 2) Sealant, Joint, Two-Component, Jet-Blast-Resistant, Cold-Applied, for Portland Cement Concrete Pavement

1.2 DEFINITIONS

a. "Blending size" is an aggregate that complies with the quality requirements in ASTM C 33/C 33M and paragraph entitled "Aggregates" and as modified herein and can be blended with coarse and fine aggregate to produce a well graded combined grading.

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

c. "Design strength" (f'c) is the specified compressive strength of concrete to meet structural design criteria.

d. "Marine concrete" is that concrete that will be in contact with or subject to submersion, tidal variations, splash, or spray from water in navigable waterways.

e. "Mixture proportioning" is a description of the proportions of a concrete mixture that were selected to enable it to meet the performance durability requirements, constructability requirements, and the initial and life-cycle cost goals.

f. "Mixture proportions" is the concrete supplier's by-mass proportions to replicate the mixture design.

g. "Pozzolan" is a silicious or silicious 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.

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

i. "Service life" is the functional target performance expectation for the various reinforced concrete elements. This has been defined as 75 years before major restoration with minimal maintenance. Major restoration is defined as repairs requiring jack hammering or other destructive means of concrete repair preparation. Service life will be determined by STADIUM® modeling methods described in Section 2.1.3.

j. "Exposure Conditions" is the environmental exposures that will be used in the modeling for each concrete element based on anticipated marine conditions.

k. "Durability Modeling" refers to a methodology using STADIUM® software and analysis that predicts the time before chloride ion contamination will reach a level that is likely to result in the initiation of steel corrosion. From this, certain assumptions are made to predict the time to first major rehabilitation.

l. "Transport property testing or determinations" refer to the four testing procedures that characterize the concrete. These properties are used as input data for STADIUM®. The four tests are: pore solution extraction, porosity, ion migration and moisture transport coefficient (drying test). The first three test method results are combined to develop the Ionic Diffusion Coefficient.

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A “G” following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a “G”. Only delete an existing “G” if the submittal item is not complex and can be reviewed through the Contractor’s Quality Control system. Only add a “G” if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for

Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

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

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Reinforcing steel[; G][; G, [_____]]

Formwork

Construction joints

Reproductions of contract drawings are unacceptable.

SD-03 Product Data

Waterstops

Materials for curing concrete

Joint sealants

Joint filler

Epoxy bonding compound

Synthetic reinforcing fibers

Epoxy coatings

Non-shrink grout

Sealer-hardener

Preformed joint filler

Reinforcement supports

[SD-04 Samples

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

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Slab finish sample]

SD-05 Design Data

Mixture design[; G][; G, [_____]]

Predicted Durability report[; G, [_____]]

SD-06 Test Reports

Durability Modeling (Using STADIUM®)

Concrete mixture proportions

Fly ash

Natural pozzolan

Ground granulated blast-furnace slag

Ultra fine fly ash or pozzolan

[Silica fume]

Aggregates

Admixtures

[Fiber-reinforced concrete]

Cement

Water

Reinforcement and protective coating[; G][; G, [_____]]

SD-07 Certificates

[Curing concrete elements]

[Form removal schedule]

Concrete placement and compaction

[Silica fume manufacturer's supplier representative]

Quality assurance (include durability performance monitoring results

Field testing technician and testing agency

Mixture designs

1.4 MODIFICATION OF REFERENCES

Accomplish work in accordance with ACI publications except as modified herein. Consider the advisory or recommended provisions to be mandatory, as though the word "shall" had been substituted for the words "should" or

"could" or "may," wherever they appear. Interpret reference to the "Building Official," the "Structural Engineer," and the "Architect/Engineer" to mean the Contracting Officer.

1.5 DELIVERY, STORAGE, AND HANDLING

Do not deliver concrete until vapor barrier, forms, reinforcement, embedded items, and chamfer strips are in place and ready for concrete placement. ACI 301 and ASTM A 934/A 934M for job site storage of materials. 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

1.6.1 Concrete Mixture Design

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NOTE: Preference is for concrete mixtures to not include silica fume as a means to achieve durability. However, when deemed necessary by the Engineer and Contracting Officer in order to attain specific strength criteria, it is acceptable. Tailoring throughout specification section is required.

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At least 30 days prior to concrete placement, submit proportions for a concrete mixture for each strength and type of concrete. Submit a complete list of materials including type; brand; source and amount of cement, aggregate, fly ash, (or slag pozzolans), [silica fume,] ground slag, polypropylene fibers, anti-washout and other admixtures for underwater concreting, corrosion inhibitors; and applicable reference specifications. Submit additional data regarding concrete aggregates if the source of aggregate changes. Submittal shall clearly indicate where each mixture will be used when more than one mix design is submitted. An identical concrete mixture previously approved within the past 12 months by the [_____] Division, Naval Facilities Engineering Command, may be used without further approval, if copies of the previous approval and aggregate, fly ash, [silica fume,] and pozzolan test results are submitted. The approval of aggregate, fly ash, [silica fume,] and pozzolan[, and polypropylene fibers] tests results shall have been within 6 months of submittal date. Obtain acknowledgement of receipt prior to concrete placement. The mixture shall be prepared by an accredited laboratory experienced in this field and under the direction of a licensed/registered civil engineer, who shall sign all reports and designs. Refer to Section [01 45 01 USACE QUALITY CONTROL][01 45 02 NAVFAC QUALITY CONTROL][01 45 04 NASA QUALITY CONTROL].

1.6.1.1 Concrete Durability Performance

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NOTE: Predictive durability modeling is not necessarily required. It is the responsibility of the Navy to work with the Engineer of Record to determine if modeling is appropriate for the project. Naval Facilities Engineering Command (NAVFAC ESC) is working with ACI to develop an industry standard for predictive modeling that will

allow other models to perform to the Navy's expectations. Until those standards are delineated, it is the experience of NAVFAC ESC that STADIUM® can provide useful input to the design team regarding the selection of materials and the design mixture with respect to predicting the performance life of the concrete for both cracked and uncracked concrete elements.

Tailoring tags are incorporated throughout. If STADIUM is not required, turn the tailoring off.

****

To ensure durability, include minimum supplementary cementitious materials as indicated in 2.1.2.e. Alternatively, conduct predictive modeling using STADIUM® software for each major concrete element. The STADIUM® results shall show that the concrete mixture design provides a minimum 75-year service life. Submit the STADIUM® report on Predicted Durability with the concrete mixture design.

1.6.2 Drawings

1.6.2.1 Reinforcing Steel

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

1.6.2.2 Formwork

ACI 347. Include design calculations indicating arrangement of forms, sizes 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, pipework, conduit, sleeves, and other embedded items. Furnish drawings and descriptions of shoring and reshoring methods proposed for slabs, beams, and other horizontal concrete members.

1.6.3 Certificates

1.6.3.1 Curing Concrete Elements

Submit proposed materials and methods for curing concrete elements.

1.6.3.2 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.

1.6.3.3 Concrete Placement and Compaction

a. Submit technical literature for equipment and methods proposed for use in placing concrete. Include pumping or conveying equipment including type, size and material for pipe, valve characteristics, and the

maximum length and height concrete will be pumped. No adjustments shall be made to the mixture design to facilitate pumping.

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

[1.6.3.4 Silica Fume Manufacturer's Supplier Representative

Provide statement that the manufacturer's supplier representative will be present at batch plant to ensure proper mixture, including high range water reducer, and batching methods. [Representative to attend and advise at finishing of sample slab.]

]1.6.3.5 Quality Assurance

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NOTE: Coordinate with Section [01 45 01 USACE QUALITY CONTROL][01 45 02 NAVFAC QUALITY CONTROL][01 45 04 NASA QUALITY CONTROL].
****

Develop and submit for approval a quality control plan in accordance with the guidelines of ACI 121R and as specified herein. The plan shall include plans for the concrete supplier, the reinforcing steel supplier, and installer and address aspects of the mix design, materials, and workmanship that may affect the ultimate performance of the structure to meet the operational objectives for the defined service live of 75 years. Maintain a copy of ACI SP-15 and CRSI Manual of Practice at the project site.

1.6.3.6 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 any work.

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

b. Testing agencies that perform testing services on reinforcing steel shall meet the requirements of ASTM E 329.

c. Testing agencies that perform testing services on concrete materials shall meet the requirements of ASTM C 1077.

d. Testing agencies or engineering companies that characterize the transport properties of the concrete or conduct STADIUM® analysis shall be pre-approved by the Contracting Officer and Naval Facilities Engineering Command.

1.6.3.7 Mixture Designs

Provide a detailed report of materials and methods used, test results, and

the field test strength (fcr) for marine concrete required to meetstructural and durability requirements.

1.6.4 Test Reports

1.6.4.1 Concrete Mixture Proportions

a. Submit copies of test reports by independent test labs conforming to ASTM C 1077 showing that the mixture has been successfully tested to produce concrete with the properties specified and that mixture will be suitable for the job conditions. Test reports shall be submitted along with the concrete mixture proportions. Obtain approval before concrete placement.

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

1.6.4.2 Transport Properties

Test specimens for characterizing the transport properties shall be a minimum of 28 days old and samples shall be representative of the concrete for each structural element. The Contracting Officer and Naval Facilities Engineering Command shall approve the proposed method for obtaining representative concrete specimens for testing. A brief description is provided below.

a. Pore Solution Extraction and Chemical Analysis. This method covers the procedure to obtain the pore solution from hardened cementitious materials for use in long-term durability and migration test simulations. The chemical composition of the pore solution is a required parameter to perform multi-ionic simulations using STADIUM®. This test method is not yet adopted by ASTM or AASHTO, as such the methodology is provided in Appendix A.

b. Porosity. Total porosity shall be determined in accordance with ASTM C 642 on concrete.

c. Ion Migration. This test method covers an experimental procedure used to evaluate the diffusion coefficient of ionic species in cementitious materials. This test method is a modified version of the ASTM C 1202 standard test procedures. This test method is not yet adopted by ASTM, as such the methodology is provided in Appendix A.

d. Drying Test. This test method is used to determine the drying rate of cementitious materials by measuring the mass loss due to evaporation and moisture transport in specimens exposed to constant temperature and relative humidity environments. This test method is not yet adopted by ASTM or AASHTO, as such the methodology is provided in Appendix A.

1.6.4.3 Fly Ash and Natural Pozzolan

Submit test results in accordance with ASTM C 618. Submit test results performed within 6 months of submittal date.

1.6.4.4 Ground Granulated Blast-Furnace Slag

Submit test results in accordance with ASTM C 989 for ground granulated

blast-furnace slag. Submit test results performed within 6 months of submittal date.

1.6.4.5 Ultra Fine Fly Ash or Pozzolan

Submit test results in accordance with ASTM C 618 as a Class F fly ash or Class N pozzolan with the following additional requirements:

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

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

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

Submit test results performed within 6 months of submittal date.

[1.6.4.6 Silica Fume

Submit test results in accordance with ASTM C 1240 for silica fume. Data shall be based upon tests performed within 6 months of submittal.]

1.6.4.7 Aggregates

Submit test results for aggregate quality in accordance with ASTM C 33/C 33M, and the combined gradation curve proposed for use in the work and used in the mixture qualification, and ASTM C 295 for results of petrographic examination. Where there is potential for alkali-silica reaction, provide results of tests conducted in accordance with ASTM C 1260. 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.

1.6.4.8 Admixtures

Submit test results in accordance with ASTM C 494/C 494M and ASTM C 1017/C 1017M for concrete admixtures, ASTM C 260 for air-entraining agent, and manufacturer's literature and test reports for corrosion inhibitor and anti-washout admixture. Submitted data shall be based upon tests performed within 6 months of submittal.

[1.6.4.9 Fiber-Reinforced Concrete

Test to determine flexural toughness index is met, in accordance with ASTM C 1116/C 1116M.

]1.6.4.10 Cement

Submit test results in accordance with ASTM C 150/C 150M portland cement and/or ASTM C 595/C 595M and ASTM C 1157/C 1157M for blended cement. Submit current mil data.

1.6.4.11 Water

Submit test results in accordance with ASTM D 512 and ASTM D 516.

[1.6.4.12 Reinforcement and Protective Coating

Provide coating manufacturer's and coating applicator's test data sheets

certifying that applied coating meets the requirements of ASTM A 934/A 934M.

]1.6.5 Field Samples

1.6.5.1 Slab Finish Sample

Install minimum of 3 by 3 m 10 by 10 foot slab. Finish as required by specification. [Silica fume manufacturer's supplier representative will attend and advise.]

[1.6.5.2 Underwater Concrete Sample

Pldays," "14 days," "28 days," and "Extra." Include date and station. .s "7 Provide specimen sets at every 150 lineal feet of seawall [_____] with a minimum of of one set per day of underwater concrete placement. Retrieve specimens at specified intervals. Extract 100 mm diameter by 250 mm 4 inch diameter by 10 inch long core and test in accordance with ASTM C 39/C 39M.

]PART 2 PRODUCTS

2.1 CONCRETE

2.1.1 Strength

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NOTE: Abrasion is defined as an action where concrete surfaces are exposed to wear. This may be due to attrition by sliding, scraping, impact, or cavitation.
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NOTE: Where severe abrasion due to ice, pebbles, sand, or silt is expected, the specified concrete compressive strength shall be at least 42 MPa 6000 psi . Where severe surface degradation of the concrete is expected to occur, additional protection can be achieved by use of concrete aggregates having equal or higher hardness than the abrading material or by the provision of suitable coatings or surface treatments. The specified concrete cover over reinforcement in regions subjected to severe abrasion shall be increased to allow for the anticipation loss of concrete due to abrasion, unless it is documented that adequate protective measures have been taken. The mixture proportioning work shall consider the use of silica fume to enhance abrasion resistance.
****

ACI 201.2R and ACI 211.1. For structural elements to be exposed in a marine environment, adjust the concrete 28-day design strength to produce concrete of minimum design strength (f'c) of 35 MPa 5000 psi. [For elements subject to severe abrasion, the minimum design strength (f'c) shall be adjusted to 42 MPa 6000 psi.]

The minimum required average compressive strength (f'cr) shall exceed the specified design strength (f'c) as per ACI 301.

Special Note: The compressive strength resulting from concrete mixtures meeting the project durability requirements may exceed the required structural compressive strength.

2.1.2 Contractor-Furnished Mixture Proportions

****

NOTE: This specification requires that the structural requirements (f'c) be met. But that, if the prequalified mixture should produce a higher strength (fcr), that strength should govern.

Maintain required w/c and w/cm ratio despite strength requirements.

****

a. Strength. Strength requirements shall be based on 28-day compressive strength determined on 150 by 300 mm 6 by 12 inch cylindrical specimens in accordance with ASTM C 39/C 39M. The specified compressive strength of the concrete (f'c) for each portion of the structure shall meet the requirements in the contract documents.

b. The mixture proportions and Water-Cementitious Materials Ratio for marine concrete shall be developed by the Contractor to produce the design strength (f'c) and to provide durability, workability, and mixture consistency to facilitate placement, compaction into the forms and around reinforcement without segregation or bleeding. The requirements for durability consideration specified in Table 1 and subparagraph "i" below shall be incorporated in the mixture proportions.

Table 1 - Concrete Quality Requirements

Zone	Exposure Condition	Maximum W/CM	Minimum quantity of cementitious material kg/m3	Minimum quantity of portland cement kg/m3
Submerged (1) Tidal (2) Splash (3)	(a) Directly exposed to salt water	0.40	400	300
	(b) Subject to severe abrasion	0.40	400	300
Atmospheric (4)	(a) Directly exposed to marine atmosphere	0.40	400	300
	(b) Protected from direct exposure to marine atmosphere	0.45	360	300

Table 1 - Concrete Quality Requirements

Zone	Exposure Condition	Maximum W/CM	Minimum quantity of cementitious material lb/yd3	Minimum quantity of portland cement lb/yd3
Submerged (1) Tidal (2) Splash (3)	(a) Directly exposed to salt water	0.40	675	505
	(b) Subject to severe abrasion	0.40	675	505
Atmospheric (4)	(a) Directly exposed to marine atmosphere	0.40	675	505
	(b) Protected from direct exposure to marine atmosphere	0.45	607	505

c. One mechanism of material deterioration that results in cracking is the formation of expansive compounds formed either by aggregate reactivity to cement alkali or by chemical reactions between elements of seawater and the hydrated cement paste. As such, the selection of aggregates (coarse and fine) shall present a low risk to producing expansive by-products due to chemical reactions. Maximum allowable expansion is 0.08 percent at 14 days per ASTM C 1260. If this is not met, then maximum allowable expansion for the proposed concrete mixture/s shall be 0.08 percent at 14 days per ASTM C 1567. All aggregate sources shall be tested. Also, provide documentation that the aggregate has no history of chemical deterioration in concrete. All data shall be no more than 90 days old at the time of submittal.

d. Shrinkage Limits of Mixture Designs. Drying shrinkage of concrete for mixture design trial batches at 21 days of age shall not exceed 0.04 percent based on the averaged results from three or more specimens constituting a test set; however, the results from any individual specimen from the trial batches which are less than the shrinkage value obtained by subtracting 0.009 percent shrinkage from the average shall be discarded and a new average established. Test procedures and test specimens shall conform to the following:

The "Drying Shrinkage" specimen shall be fabricated, cured, dried and measured in the manner outlined in ASTM C 157/C 157M and modified as follows:

Specimens shall be removed from molds at an age of 23 hours plus or minus 1 hour after trial batching, shall be placed immediately in lime-saturated water at 23 degrees C 73 degrees F plus or minus 0.5 degrees C 1 degrees F for at least 30 minutes, and shall be measured within 30 minutes thereafter to determine original length, then submerged in lime-saturated water at 23 degrees C 73 degrees F plus or

minus 2 degrees C 3 degrees F.

Measurement to determine expansion expressed as a percentage of original length shall be made at age 7 days. This length at age 7 days shall be the base length for drying shrinkage calculations. Specimens then shall be stored immediately in a humidity control room maintained at 23 degrees C 73 degrees F plus or minus 2 degrees C 3 degrees F and 50 percent plus or minus 4 percent relative humidity for the remainder of the test.

Measurement to determine shrinkage as a percentage of base length shall be made and reported separately for concrete age of 7, 14, 21, and 49 days.

e. Supplemental Cementitious Materials Content. The concrete mixture shall contain one of the supplemental cementitious materials listed below, or a linear combination thereof. Alternatively, conduct predictive modeling using STADIUM® software.

Supplementary Cementitious Material	Minimum Content	Maximum Content
Class N Pozzolan or Class F or C Fly Ash		
$SiO_2 + Al_2O_3 + Fe_2O_3$	30 percent	40 percent
$SiO_2 + Al_2O_3 + Fe_2O_3$	25 percent	40 percent
$SiO_2 + Al_2O_3 + Fe_2O_3$	20 percent	40 percent
$SiO_2 + Al_2O_3 + Fe_2O_3$	15 percent	40 percent
Ultra fine fly ash/Pozzolan	7 percent	16 percent
Ground granulated blast-furnace slag	40 percent	50 percent
Silica fume	7 percent	8 percent

f. The maximum mass of fly ash, natural pozzolans, ground granulated blast-furnace slag, or silica fume that is included in the calculation of water-to-cementitious materials ratio shall not exceed the following limits:

(1) Fly ash shall not be used for more than 40 percent by mass of the cementitious material. The fly ash and other pozzolans present in a Type IP or IPM blended cement, ASTM C 595/C 595M, shall be included in the calculated percentage.

(2) The weight of ground granulated blast-furnace slag conforming to ASTM C 989 shall not exceed 50 percent of the weight of cement. The slag used in manufacture of a Type IS or ISM blended hydraulic cement conforming to ASTM C 595/C 595M shall be included in the calculated percentage. Higher percentage of ground granulated blast-furnace slag may be used if tests are made using actual job materials to ascertain the early and later age strengths and durability performance specified, and the use is approved by the Contracting Officer

[(3) The maximum silica fume content shall not exceed 8 percent by mass of the cementitious material. The silica fume shall originate from the manufacture of silicon metal and ferro-silicon alloys. A high-range water reducer shall be used with silica fume for proper dispersion of the silica fume. Several factors affect the proper dispersion of condensed silica fume. The Contractor is responsible to assure that cured concrete does not contain

undispersed clumps of silica fume that may undergo chemical reaction in the concrete.]

(4) The minimum amount of portland cement is 50 percent of the total mass of cementitious material.

g. Air Content. Concrete that will be subject to destructive exposure (other than loading and wear in a passive environment) such as freezing and thawing, severe weathering, or deicing chemicals shall be air entrained and shall conform to the air limits specified in ACI 301. Variations outside the limits specified shall not be reason to reject the concrete in locations not subject to freeze-thaw conditions.

h. Slump. The concrete mixture shall be proportioned to have, at the point of deposit, a maximum slump of 100 mm 4 inches as determined by ASTM C 143/C 143M. Where an ASTM C 494/C 494M, Type F or G admixture is used, the slump after the addition of the admixture shall be no less than 150 mm 6 inches nor greater than 200 mm 8 inches. Slump tolerances shall comply with the requirements of ACI 117.

i. Chloride Ion Penetration. To ensure the durability of concrete in a marine environment, concrete shall be proportioned to provide a rapid indication of its resistance to the penetration of chloride ions, per ASTM C 1202, of below 3,000 coulombs for concrete specimens tested at 56 days.

j. Representative samples of the concrete mixture shall be tested in the laboratory to characterize the transport properties for predictive modeling using STADIUM® software.

2.1.3 Durability Modeling

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NOTE: Concrete sampling of the completed structure allows the Navy to test the in-place concrete for long-term durability characteristics. Use of numerical modeling predicts the ultimate performance life of the concrete and shall conform to the specified design life. This enhances the Navy's confidence in obtaining durable concrete. As such, it is highly recommended that every significant structure employ this method. The Navy and the Engineer shall determine if this approach is applicable.

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Currently the Navy recognizes only one numerical modeling method for predicting the performance life of marine concrete structures. The software is called STADIUM®. The most current version of STADIUM® shall be used. The use of predictive 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.

a. Scope. Each structural element shall be modeled, such as piles, cast-in-place concrete and prefabricated concrete. Structural elements shall be modeled for the worse case exposure zone, e.g. the inter-tidal zone for piles, splash zone for under deck and atmospheric zone for the top deck.

b. Exposure Conditions. The exposure conditions for the purpose of predictive modeling for this project are divided into two degrees of seawater exposure. There will be a severe and moderate exposure scenario applied to durability modeling of the various concrete elements.

Severe Exposure Condition (immersed and tidal zone):
Temperature: 26 degrees C 79 degrees F Constant
Relative Humidity Combination/variation: 100 percent to 76 percent
Seawater Chemical Content (Salinity = 30 percent):

Moderate Exposure Condition (splash zone):
Temperature: 26 degrees C 79 degrees F Constant
Relative Humidity Combination/variation: 90 percent to 76 percent
Seawater Chemical Content (Salinity = 20 percent):

Low Exposure Condition (airborne seawater):
Temperature: 26 degrees C 79 degrees F Constant
Relative Humidity Combination/variation: 76 percent
Seawater Chemical Content (Salinity = 10 percent)

Seawater Chemical Content:

Salinity:	30 percent	20 percent	10 percent
Na:	9,182 ppm	6,122 ppm	3,060 ppm
K:	253 ppm	169 ppm	84 ppm
So_4:	2,305 ppm	1,537 ppm	768 ppm
Ca:	349 ppm	232 ppm	116 ppm
Mg:	1,106 ppm	739 ppm	369 ppm
Cl:	16,599 ppm	11,072 ppm	5,534 ppm

Exposure Condition by Concrete Element:
Caissons: Severe
Precast Keys: Severe
Precast Cover Slabs: Severe
Precast Caisson Toe Protection Slabs: Severe
CIP Retrofit Overlay Slabs inside Caissons: Severe
CIP Cope Wall and West End Wall: Severe
Utility Trench at Wharf Face/Waterside Crane Beam: Severe
Counterfort Walls and Closure Walls: Moderate
Reinforced Concrete Pavement: Severe
Piles, Pile Caps, and Landside Crane Beams: Moderate
Landside Utility Trenches: Moderate
Wharf Deck: Moderate
Slab on ground: Low

c. Analysis. The STADIUM® software predicts the chloride ion profile as a function of depth, time and exposure. One must then make assumptions as to how long it will take before corrosion of the steel will result in cracks and spalling that requires major repair of the element. These assumptions are a function of several factors, e.g. importance of the element, structural redundancy, type of steel selected and depth of concrete cover. Thus for any given element, exposure condition and concrete mixture, one can predict if the structure will meet the expected 75-year service life.

d. Additional Criteria for Durability Modeling

(1) Concrete Cover. Assume the concrete cover as the design

concrete cover minus the allowable cover tolerance as defined by ACI 117.

(2) Ionic Diffusion Coefficient (IDC) Variation Allowance. The ionic diffusion coefficient is determined by combining the results from the ion migration test, porosity test, and pore solution chemistry results. Modeling for service life will incorporate an inflating factor of 15 percent to the IDC.

(3) Moisture Diffusion Coefficient (MDC) Variance Allowance. Modeling for service life will incorporate an inflating factor of 15 percent to the MDC.

(4) Corrosion Threshold. The assumed chloride ion content, at the reinforcing steel depth, necessary to initiate corrosion is 0.05 percent by mass of concrete for uncoated (black) reinforcing bars.

(5) Propagation Time. The corrosion propagation time is assumed to be 10 years for black steel reinforcement. This requires the concrete system to have a predicted time until breach of corrosion threshold of 65 years for the design 75-year service life requirement.

e. Contact Information. The STADIUM® modeling contact information is:

Naval Facilities Engineering Services Center
1100 23rd Avenue
Port Hueneme, CA 93043
Attention: Douglas Burke, P.E. Code ESC63
Phone: (805) 982-1055
Email: Douglas.burke@navy.mil
NAVFAC ESC approves of transport testing laboratories as indicated in 1.6.3.6

2.2 MATERIALS

2.2.1 Cement

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NOTE: Acceptable types of cement are as follows:

ASTM C 150/C 150M Portland	**ASTM C 595/C 595M Blended**	
Type II	**Type IP(MS) or Type IS(MS) Type II (LA) Type II (LH)**	**For general use in construction where concrete is exposed to moderate sulfate or alkali action or where moderate heat of hydration is required. ASTM C 595/C 595M (blended hydraulic cements): add the suffix MS or MH where either moderate sulfate resistance or moderate heat of hydration, respectively, is required.**
Type III	**None**	**For use when high early strength is required.**

Modify paragraph and specify either 50 percent Type II, IP(MS) or IS(MS) cement with 50 percent ground granulated blast-furnace slag, 75 percent Type II, IP(MS) or IS(MS) cement with 25 percent Class F fly ash. Require cement to meet chemical requirements of ASTM C 150/C 150M, Table 2 for equivalent alkalies when using alkali-reactive aggregates.

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ASTM C 150/C 150M, Type II and/or ASTM C 595/C 595M, Type IP(MS) or IS(MS) and ASTM C 1157/C 1157M, Type MS blended cement except as modified herein. A Type II or blended-hydraulic cement is appropriate for exposure to seawater to resist "moderate sulfate attack" and should have a tricalcium aluminate (C3A) content of 6 to 8 percent. A maximum cement-alkali content of 0.60 percent Na_2O (sodium oxide)equivalent is recommended to avoid deterioration caused by ASR. The use of Type I cement is not acceptable in a marine environment. Cements marked Type I/II may be used provided that they comply with all criteria for ASTM C 150/C 150M Type II or blended-hydraulic cements listed above.Blended cements shall consist of a mixture of ASTM C 150/C 150M cement and one of the following materials: ASTM C 618 pozzolan or fly ash, or ASTM C 989 ground granulated blast-furnace slag. Use one manufacturer for each type of cement, ground slag, fly ash, and pozzolan.

2.2.1.1 Fly Ash and Pozzolan

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NOTE: Fly ash, pozzolan, and slag cement may produce uneven discoloration of the concrete during the early stages of construction, depending upon the type of curing provided. Fly ash or pozzolan meeting the specified test results, which are more stringent than ASTM C 618, should provide acceptable end results. Type F fly ash and slag are replacements for some sand and aggregates also adding to durability.

A maximum loss on ignition of 3 percent is recommended to prevent loss of air entrainment. If Class C is used, it is required that it contains a sum SiO_2 plus Fe_2O_3 plus Al_2O_3 of 65 percent or higher.

****

ASTM C 618, Type N, F, or C, except that the maximum allowable loss on ignition shall be 3[6]percent and total alkalis (sum of sodium and potassium oxides) should not exceed 3 percent. Class C ash should have a sum of silicon dioxide, aluminum oxide and iron oxide equal to or greater than 65 percent. Add with cement.

2.2.1.2 Ground Granulated Blast-Furnace Slag

ASTM C 989, Grade 120.

[2.2.1.3 Silica Fume

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NOTE: Use silica fume concrete for marine

structures where strength requirements can only be attained with its use. The silica fume and high range water reducing admixture should be from the same manufacturer. Select weight percentage based on performance required.

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NOTE: The initial cost of the concrete will increase, and supervision at the batch plant, finishing, and curing is necessary. A HRWR shall be used with silica fume. The slump can be increased 50 to 125 mm 2 to 5 inches without reducing strength. Finishing may be more difficult. Proper curing is essential because there is a tendency for plastic shrinkage cracking.

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ASTM C 1240.]

2.2.2 Water

Water shall comply with the requirements of ASTM C 94/C 94M and the chloride and sulfate limits in accordance with ASTM D 512 and ASTM D 516. Mixing water shall not contain more than 500 parts per million of chlorides as Cl and not more than 1000 parts per million of sulfates as SO_4. Water shall be free from injurious amounts of oils, acids, alkalies, salts, and organic materials. Where water from reprocessed concrete is proposed for use in the work, submit results of tests to verify that the treatment has negated adverse effects of deleterious materials.

2.2.3 Aggregates

ASTM C 33/C 33M, except as modified herein.

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NOTE: 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.

****

a. The combined aggregates in the mixture (coarse, fine, and blending sizes) shall be well graded from the coarsest to the finest with not more than 18[22] percent nor less than 8 percent, unless otherwise permitted, of the combined aggregate retained on any individual sieve with the exceptions that the 300 micrometers No. 50 may have less than 8 percent retained, sieves finer than 300 micrometers No. 50 shall have less than 8 percent retained, and the coarsest sieve may have less than 8 percent retained. Use blending sizes where necessary, to provide a well graded combined aggregate. Reports of individual aggregates shall include standard concrete aggregate sieve sizes including 37.5 mm 1-1/2 inches, 25 mm one inch, 19 mm 3/4 inch, 12.5 mm 1/2 inch, 9.5 mm 3/8

inch, 4.75 mm No. 4, 2.36 mm No. 8, 1.18 mm No. 16, 600 micrometers No. 30, 300 micrometers No. 50, and 150 micrometers No. 100.

b. Provide aggregates for exposed concrete from one source. Aggregate reactivity shall be limited per paragraph 2.1.2. Provide aggregate containing no deleterious material properties as identified by ASTM C 295.

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

d. Current data is required. Current data means data shall be not more than 180 days from the date of concrete mixture submittal.

e. Marine aggregate may be used when conforming to ASTM C 33/C 33M and if it originates from the up-current side of the land mass and it has been washed by the fresh water so that the total chloride and sulfate content of the concrete mixture does not exceed the limits defined herein.

2.2.4 Nonshrink Grout

ASTM C 1107/C 1107M.

2.2.5 Admixtures

a. Provide chemical admixtures that comply with the requirements shown below and in accordance with manufacturer's recommendations, and appropriate for the climatic conditions and the construction needs. Do not use calcium chloride or admixtures containing chlorides from other than impurities from admixture ingredients.

b. Provide maximum concentrations of corrosion-inducing chemicals as shown in Table 2 below. For concrete that may be in contact with prestressing steel tendons, the concentration shall not exceed 60 percent of the limits given in Table 2. For the concentration in grout for prestressing ducts, do not exceed 25 percent of the limits in Table 2.

Table 2 - Limits on Corrosion-Inducing Chemicals

Chemical*	Limits, Percent**	Test Method
Chlorides	0.10	ASTM D 512
Fluorides	0.10	ASTM D 1179
Sulphites	0.13	ASTM D 1339
Nitrates	0.17	ASTM D 3867

* Limits refer to water-soluble chemicals
** Limits are expressed as a percentage of the mass of the total cementitious materials.

c. Provide anti-washout admixtures for underwater placement with a proven record of performance and compatible with the chosen cement.

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

[2.2.5.1 Air Entraining Admixture

Provide air entraining admixtures conforming to ASTM C 260. Provide the admixture of such a type and dosage that the total air content in the hardened concrete can be readily maintained at 5.5 percent plus/minus 1.5 percent unless maximum aggregate size is greater than 37.5 mm 1-1/2 inches. Then the total air content shall be lowered to 4.0 percent plus/minus 1.5 percent. Variation outside these ranges shall not be reason to reject the concrete batch in regions not subject to freeze-thaw conditions.

]2.2.5.2 Accelerating

ASTM C 494/C 494M, Type C.

2.2.5.3 Retarding

ASTM C 494/C 494M, Type B, D, or G.

2.2.5.4 Water Reducing

ASTM C 494/C 494M, Type A, E, or F.

2.2.5.5 High Range Water Reducer (HRWR)

ASTM C 494/C 494M, Type F and ASTM C 1017/C 1017M.

[2.2.5.6 Corrosion Inhibitor Admixture

Corrosion inhibitor shall be 30 percent water solution of calcium nitrite. Allow for the free water in the admixture within the total water in concrete mixture. Accelerating and set adjusted versions are acceptable, however, the concrete set time effects and mixture workability shall be considered. Refer to admixture manufacturer recommendations for dosage for chloride protection levels.]

2.2.6 Materials for Forms

Provide wood, plywood, or steel. Use plywood or steel forms where a smooth form finish is required. Lumber shall be square edged or tongue-and-groove boards, free of raised grain, knotholes, or other surface defects. Plywood: PS-1, B-B concrete form panels or better. Steel form surfaces shall not contain irregularities, dents, or sags.

2.2.6.1 Form Ties and Form-Facing Material

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

b. Form-facing material shall be structural plywood or other material that can absorb air trapped in pockets between the form and the concrete and some of the high water-cementitious materials ratio surface paste. Maximum use is three times. Provide forms with a form treatment to prevent bond of the concrete to the form.

c. As an alternate to using an absorptive wood form contact face as a form liner, use a Controlled Permeability Formliner in strict accordance

with the manufacturer's recommendations.

2.2.7 Reinforcement

2.2.7.1 Prestressing Steel

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NOTE: Use prestressing in fender and bearing piles, deck soffits, and wherever possible. Poststressing of pile caps and decks is recommended where feasible.
****

Use seven-wire stress-relieved or low-relaxation strand conforming to ASTM A 416/A 416M, Grade 270. 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.

2.2.7.2 Reinforcing Bars

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NOTE: ASTM A 706/A 706M bars are mainly used in seismic design or for welding.
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NOTE: Do not mix coated rebar and plain reinforcing bars. This will produce a large corrosion cell between the plain bar and any defect in the coated bar.
****

ACI 301 unless otherwise specified. ASTM A 615/A 615M and ASTM A 966/A 966M with the bars marked A, Grade [40] [60]; or ASTM A 966/A 966M with the bars marked R, Grade [50] [60]. [ASTM A 706/A 706M.] [Prefabricated epoxy coated, ASTM A 934/A 934M. Do not use uncoated reinforcing steel.]

2.2.7.3 Mechanical Reinforcing Bar Connectors

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

2.2.7.4 Welded Wire Fabric

ASTM A 185/A 185M or ASTM A 497/A 497M. Provide flat sheets of welded wire fabric for slabs and toppings.

2.2.7.5 Wire

ASTM A 82/A 82M or ASTM A 496/A 496M.

[2.2.7.6 Fiber-Reinforced Concrete

****
NOTE: Only use fiber reinforcement when approved by the designer. Fiber reinforcing is used to help: control cracking due to drying shrinkage and thermal expansion/contraction; reduce permeability; and increase impact capacity; shatter resistance,

abrasion resistance, and toughness. Fiber reinforcing will not: control cracking due to structural stresses; significantly increase strength; control curling or creeping; justify reducing structural members; eliminate control joints; or replace any moment or structural steel reinforcement. Include flexural toughness tests when synthetic reinforcement fibers are used to increase toughness and when justified by size and importance of job, but not when fibers are used only to control shrinkage cracking. Include technical representative when warranted by size and importance of job.

****

Provide fiber-reinforced concrete in accordance with ASTM C 1116/C 1116M, Type III, synthetic fiber-reinforced concrete, and as follows. Synthetic reinforcing fibers shall be 100 percent virgin polypropylene fibrillated fibers. Fibers shall have a specific gravity of 0.9, a minimum tensile strength of 480 MPa 70 ksi, graded per manufacturer, and specifically manufactured to an optimum gradation for use as concrete secondary reinforcement. A minimum of 2.6 kg of fibers per cubic meter 1.5 pounds of fibers per cubic yard of concrete shall be used. Fibers shall be added at the batch plant. [Toughness indices shall meet requirements for performance Level I.] [Provide the services of a qualified technical representative to instruct the concrete supplier in proper batching and mixing of materials to be provided.]

]2.2.8 Polyvinylchloride Waterstops

COE CRD-C 572.

2.2.9 Materials for Curing Concrete

2.2.9.1 Impervious Sheeting

ASTM C 171; waterproof paper, clear or white polyethylene sheeting, or polyethylene-coated burlap.

2.2.9.2 Pervious Sheeting

AASHTO M 182.

2.2.9.3 Liquid Membrane-Forming Compound

ASTM C 309, white-pigmented, Type 2, Class B.

2.2.10 Liquid Chemical Sealer-Hardener Compound

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

2.2.11 Expansion/Contraction Joint Filler

ASTM D 1751 or ASTM D 1752, 13 mm 1/2 inch thick[, unless otherwise indicated.]

2.2.12 Joint Sealants

2.2.12.1 Horizontal Surfaces, 3 Percent Slope, Maximum

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NOTE: For horizontal surfaces subject to jet fuel, specify FS SS-S-1614.
****

ASTM D 1190 or ASTM C 920, Type M, Class 25, Use T.

2.2.12.2 Vertical Surfaces Greater Than 3 Percent Slope

****
NOTE: Specify ASTM C 920 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.
****

ASTM C 920, Type M, Grade NS, Class 25, Use T. [FS SS-S-1614] [FS SS-S-200, no sag].

2.2.13 Epoxy Bonding Compound

ASTM C 881/C 881M. Provide Type I for bonding hardened concrete to hardened concrete; Type II for bonding freshly mixed concrete to hardened concrete; and Type III as a binder in epoxy mortar or concrete, or for use in bonding skid-resistant materials to hardened concrete. Provide Grade 1 or 2 for horizontal surfaces and Grade 3 for vertical surfaces. Provide Class A if placement temperature is below 4 degrees C 40 degrees F; Class B if placement temperature is between 4 and 16 degrees C 40 and 60 degrees F; or Class C if placement temperature is above 16 degrees C 60 degrees F.

[2.2.14 Dovetail Anchor Slot

Provide preformed metal slot approximately 25 by 25 mm one by one inch minimum 22 gage galvanized steel. Coordinate size and throat opening with dovetail anchors. Provide with removable filler material.]

PART 3 EXECUTION

3.1 FORMS

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

b. Provide formwork with clean-out openings to permit inspection and removal of debris. Formwork shall be gasketed or otherwise rendered sufficiently tight to prevent leakage of paste or grout under heavy, high-frequency vibration. Use a release agent that does not cause surface dusting. Limit reuse of plywood to no more than three times.

Reuse may be further limited by the Contracting Officer if it is found that the pores of the plywood are clogged with paste to the degree that the wood does not absorb the air or the high water-cementitious materials ratio concrete surface.

c. Patch form tie holes with a nonshrink 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 nonstaining mineral oil, nonstaining form coating compound, or two coats of nitrocellulose lacquer. Do not use mineral oil on forms for surfaces to which adhesive, paint, or other finish material is to be applied.

3.1.2 Removal of Forms and Supports

After placing concrete, forms shall remain in place for the time periods specified in ACI 347, except for concrete placed underwater, forms shall remain in place 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 C 39/C 39M 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 which the structural member, with necessary supplemental support, is capable of carrying safely and without damage. Reshore concrete elements where forms are removed prior to the specified time period. Do not permit elements to deflect or accept loads during form stripping or reshoring. Forms on columns, walls, or other load-bearing members may be stripped after 2 days if loads are not applied to the members. After forms are removed, slabs and beams over 3 meters 10 feet in span and cantilevers over 1.2 meters 4 feet shall be reshored for the remainder of the specified time period in accordance wit paragraph entitled "Removal of Forms and Supports." Perform reshoring operations to prevent subjecting concrete members to overloads, eccentric loading, or reverse bending. Reshoring elements shall have the same load-carry capabilities as original shoring and shall be spaced similar to original shoring. Firmly secure and brace reshoring elements to provide solid bearing and support.

3.2 PLACING REINFORCEMENT AND MISCELLANEOUS MATERIALS

ACI 301. Remove rust, scale, oil, grease, clay, or foreign substances from reinforcing that would reduce the epoxy coating bond from reinforcing. Do not tack weld. Inspect placed steel reinforcing for coating damage prior to placing concrete. Repair all visible damage.

[3.2.1 Epoxy Coated Reinforcing

Shall meet the requirements of ASTM A 934/A 934M including Appendix X2, "Guidelines for Job Site Practices" except as otherwise specified herein.

3.2.1.1 Epoxy Coated Reinforcing Steel Delivery, Handling, and Storage

Record coating lot on each shipping notice and carefully identify and retag bar bundles from bending plant. Provide systems for handling coated bars which have padded contact areas, nylon slings, etc., all free of dirt and grit. Lift bundled coated bars with strong back, multiple supports, or platform bridge to prevent sagging and abrasion. Bundling bands shall be padded where in contact with bars. Do not drop or drag bars or bundles. Store coated bars both in shop and in field, aboveground, on wooden or padded cribbing. Space the dunnage close enough to prevent excessive sags. Stack large quantities of straight bars with adequate protective blocking between layers. Schedule deliveries of epoxy coated bars to the job site to avoid the need for long term storage. Protect from direct sunlight and weather. Bars to be stored longer than 12 hours at the job site shall be covered with opaque polyethylene sheeting or other suitable equivalent protective material.

3.2.1.2 Epoxy Coated Steel Reinforcing Steel Placement and Coating Repair

Carefully handle and install bars to minimize job site patching. Use the same precautions as described above for delivery, handling, and storage when placing coated reinforcement. Do not drag bars over other bars or over abrasive surfaces. Keep bar free of dirt and grit. When possible, assemble reinforcement as tied cages prior to final placement into the forms. Support assembled cages on padded supports. It is not expected that coated bars, when in final position ready for concrete placement, will be completely free of damaged areas; however, excessive nicks and scrapes which expose steel will be cause for rejection. Criteria for defects which require repair and for those that do not require repair are as indicated. Inspect for defects and provide required repairs prior to assembly. After assembly, reinspect and provide final repairs.

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

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

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

d. Rinse placed reinforcing bars with fresh water to remove chloride contamination prior to placing concrete.

]

3.2.2 Reinforcement Supports

Place reinforcement and secure with noncorrodible chairs, spacers, or metal hangers. Support reinforcement on the ground with concrete or other noncorrodible material, having a compressive strength equal to or greater than the concrete being placed and having a permeability equal or less than the concrete being placed. [For zinc-coated reinforcement, use galvanized supports or supports coated with dielectric material.]

[ASTM A 934/A 934M. Epoxy-coated reinforcing bars supported from formwork shall rest on coated wire bar supports, or on bar supports made of dielectric material or other acceptable material. Wire bar supports shall be coated with dielectric material, compatible with concrete, for a minimum distance of 50 mm 2 inches from the point of contact with the epoxy-coated reinforcing bars. Reinforcing bars used as support bars shall be epoxy coated. Spreader bars, where used, shall be epoxy coated. Proprietary combination bar clips and spreaders used in construction with epoxy-coated reinforcing bars shall be made corrosion resistant or coated with dielectric material. Epoxy-coated bars shall be tied with plastic-coated tie wire; or other materials acceptable to the Contracting Officer.]

3.2.3 Splicing

As indicated. For splices not indicated, 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. [AWS D1.4/D1.4M. Welded splices shall be approved prior to use.]

[3.2.4 Future Bonding

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

3.2.5 Cover

Uniform, high quality concrete cover over the steel reinforcement is critically important for long-term durability. The cover to the principal reinforcing bars shall be as shown, but not less than 2 times the nominal maximum aggregate size nor less than 1.5 times the effective diameter of the reinforcing bars. ACI 117 shall be used for tolerances of concrete cover.

3.2.6 Setting Miscellaneous Material and Prestress Anchorages

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

3.2.7 Construction Joints

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

3.2.8 Expansion Joints and Contraction Joints

Provide expansion joint at edges of interior floor slabs on grade abutting vertical surfaces, and as indicated. Make expansion joints 13 mm 1/2 inch wide unless indicated otherwise. Fill expansion joints not exposed to weather with preformed joint filler material. Completely fill joints

exposed to weather with joint filler material and joint sealant. Do not extend reinforcement or other embedded metal items bonded to the concrete through any expansion joint unless an expansion sleeve is used. Place contraction joints, either formed or saw cut or cut with a jointing tool, to the indicated depth after the surface has been finished. Sawed joints shall be completed within 4 to 12 hours after concrete placement. Protect joints from intrusion of foreign matter.

3.2.9 Waterstop Splices

Fusion weld in the field.

3.2.10 Pits and Trenches

Place bottoms and walls monolithically or provide waterstops and keys.

3.3 BATCHING, MEASURING, MIXING, AND TRANSPORTING CONCRETE

ASTM C 94/C 94M, ACI 301, and ACI 304R, except as modified herein. Batching equipment shall be such that the concrete ingredients are consistently measured within the following tolerances: 1 percent for cement and water, 2 percent for aggregate, and 3 percent for admixtures. Furnish mandatory batch tickets imprinted with mix identification, batch size, batch design and measured weights, moisture in the aggregates, and time batched for each load of ready mix concrete. When a pozzolan is batched cumulatively with the cement, it shall be batched after the cement has entered the weight hopper.

3.3.1 Measuring

Make measurements at intervals as specified in paragraphs entitled "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

****
NOTE: For SOUTHWESTNAVFACENGCOM projects located a t Marine Corps Base, Camp Pendleton, California, delete the first bracketed sentence.
****

ASTM C 94/C 94M and ACI 301. Machine mix concrete. Begin mixing within 30 minutes after the cement has been added to the aggregates. [Place concrete within 90 minutes of either addition of mixing water to cement and aggregates or addition of cement to aggregates if the air temperature is less than 29 degrees C 85 degrees F.] Reduce mixing time and place concrete within 60 minutes if the air temperature is greater than 29 degrees C 85 degrees F except as follows: if set retarding admixture is used and slump requirements can be met, limit for placing concrete may remain at 90 minutes. [If time of discharge exceeds time required by ASTM C 94/C 94M, submit a request along with description of precautions to be taken.] [If the entrained air content falls below the specified limit, add a sufficient quantity of admixture to bring the entrained air content within the specified limits.] Dissolve admixtures in the mixing water and

mix in the drum to uniformly distribute the admixture throughout the batch.

3.3.3 Transporting

Transport concrete from the mixer to the forms as rapidly as practicable. Prevent segregation or loss of ingredients. Clean transporting equipment thoroughly before each batch. Do not use aluminum pipe or chutes. Remove concrete which has segregated in transporting and dispose of as directed.

3.4 PLACING CONCRETE

****

NOTE: When necessary to deposit concrete under water, add the following paragraph:

"Depositing Concrete Under Water

ACI 301 methods and equipment used shall prevent the washing of the cement from the mixture, minimize the formation of laitance, prevent the flow of water through the concrete before it has hardened, and minimize disturbance to the previously placed concrete. Do not deposit concrete in running water[, seawater,] or in water temperatures below 2 degrees C 35 degrees F. Tremies, if used, shall be watertight and sufficiently large to permit a free flow of concrete. Keep the discharge end continuously submerged in fresh concrete. Keep the shaft full of concrete to a level well above the water surface. Discharge and spread the concrete by raising the tremie to maintain a uniform flow. Place concrete without interruption until the top of the fresh concrete is at the required height."

****

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

3.4.1 Vibration

****

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

****

Comply with the requirements of ACI 309R and ASTM A 934/A 934M using

vibrators with a minimum frequency of 9000 vibrations per minute (VPM). Use only high cycle or high frequency vibrators. Motor-in-head 60 cycle vibrators may not be used. For walls and deep beams, use a minimum of two vibrators with the first to melt down the mixture and the second to thoroughly consolidate the mass. Provide a spare vibrator at the casting site whenever concrete is placed. Place concrete in 500 mm 18 inch maximum vertical lifts. Insert and withdraw vibrators approximately 500 mm18 inches apart. Penetrate at least 200 mm 8 inches into the previously placed lift with the vibrator when more than one lift is required. Extract the vibrator using a series of up and down motions to drive the trapped air out of the concrete and from between the concrete and the forms.

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

[3.4.2 Pumping

****

NOTE: Pumping requires careful attention to mixture designs and pumping procedures. Allow pumping when other means of placement will be impractical or expensive.

****

ACI 304R and ACI 304.2R. Pumping shall not result in separation or loss of materials nor cause interruptions sufficient to permit loss of plasticity between successive increments. Loss of slump in pumping equipment shall not exceed 50 mm 2 inches. Do not use pipe made of aluminum or aluminum alloy. Avoid rapid changes in pipe sizes. Limit maximum size of coarse aggregate to 33 percent of the diameter of the pipe. Maximum size of well rounded aggregate shall be limited to 40 percent of the pipe diameter. Take samples for testing at both the point of delivery to the pump and at the discharge end.

]3.4.3 Cold Weather

ACI 306.1. 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. Cover concrete and provide sufficient heat to maintain 10 degrees C 50 degrees F minimum adjacent to both the formwork and the structure while curing. Limit the rate of cooling to 3 degrees C 5 degrees F in any one hour and 10 degrees C 50 degrees F per 24 hours after heat application.

3.4.4 Hot Weather

ACI 305R. Maintain required concrete temperature using Figure 2.1.5, "Effect of Concrete Temperatures, Relative Humidity, and Wind Velocity on the Rate of Evaporation of Surface Moisture From Concrete" in ACI 305R to prevent the evaporation rate from exceeding one kg per square meter 0.2 pound of water per square foot of exposed concrete per hour. 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.

3.4.5 Depositing Concrete Under Water

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

3.5 SURFACE FINISHES EXCEPT FLOOR, SLAB, AND PAVEMENT

3.5.1 Defects

Repair formed surfaces by removing minor honeycombs, pits greater than 600 square mm one square inch surface area or 6 mm 0.25 inch maximum depth, or otherwise defective areas. Provide edges perpendicular to the surface and patch with nonshrink 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 which affect the serviceability or structural strength will be rejected, unless correction of defects is approved. Obtain approval of corrective action prior to repair. The surface of the concrete shall not vary more than the allowable tolerances of ACI 347. Exposed surfaces shall be uniform in appearance and finished to a smooth form finish unless otherwise indicated.

[3.5.2 Not Against Forms (Top of Walls)

Finish surfaces not otherwise specified with wood floats to even surfaces, and match adjacent finishes.

]3.5.3 Formed Surfaces

3.5.3.1 Tolerances

ACI 117 and as indicated.

3.5.3.2 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.

3.5.3.3 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 which will impair the texture of the concrete surface shall not be used. Patch tie holes and defects and completely remove fins.

3.5.4 [_____] Finish

****
NOTE: Add information where special type of finish is desired. Refer to ACI 301 for information on smooth rubbed finish, grout cleaned finish, cork floated finish, and exposed aggregate. Areas requiring special finish should be clearly indicated. Coordinate with the specifications.
****

Provide concrete indicated with a [_____] finish as follows: [_____].

[3.5.5 Surface Finish Samples

****
NOTE: Include when either job complexity or aesthetics justify the additional cost associated with these requirements.
****

Provide a minimum of three sample concrete panels for each finish for each mix design, one by one m, 75 mm 3 by 3 feet, 3 inches thick. Use the approved concrete mix design(s). Provide sample panels on-site at locations directed. Once approved, each set of panels shall be representative of each of the finishes specified and shall be representative of the workmanship and finish required. Do not remove or destroy samples until directed by the Contracting Officer.

]3.6 FINISHES FOR HORIZONTAL CONCRETE SURFACES

3.6.1 Finish

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

3.6.1.1 Scratched

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

3.6.1.2 Floated

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

[3.6.1.3 Concrete Containing Silica Fume

Finish using magnesium floats or darbies. [Finish using techniques demonstrated in the sample installation.]]

3.6.1.4 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.

3.6.1.5 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 [belting. Lay belt flat on the concrete surface and advance with a sawing motion; continue until a uniform but gritty nonslip surface is obtained.] [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.

3.6.1.6 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 preceeding 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

****

NOTE: When the use of alkali-reactive aggregates is permitted, add paragraph entitled "Additional Curing When Using Alkali-Reactive Aggregates" as follows:

"Furnish ASTM C 39/C 39M 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."

****

a. ACI 301 and ACI 308R unless otherwise specified. Prevent concrete from drying by misting surface of concrete. Begin curing immediately following final set. Avoid damage to concrete from vibration created by blasting, pile driving, movement of equipment in the vicinity, disturbance of formwork or protruding reinforcement, by rain or running water, adverse weather conditions, and any other activity resulting in ground vibrations. Protect concrete from injurious action by sun, rain, flowing water, frost, mechanical injury, tire marks, and oil stains. Do not allow concrete to dry out from time of placement until the expiration of the specified curing period. Do not use membrane-forming compound on surfaces where appearance would be objectionable, on any surface to be painted, where coverings are to be bonded to the concrete , or on concrete to which other concrete is to be bonded. If forms are removed prior to the expiration of the curing period, provide another curing procedure specified herein for the remaining portion of the curing period. Provide moist curing for those areas receiving liquid chemical sealer-hardener or epoxy coating. [For concrete slabs or wide beams containing silica fume, fog spray and install wind breaks to ensure 100 percent relative humidity until wet curing is started.]

b. Wet cure marine concrete using potable water for a minimum of 7 days. Do not allow construction loads to exceed the superimposed load which the structural member, with necessary supplemental support, is capable of carrying safely and without damage.

3.7.1 Moist Curing

Remove water without erosion or damage to the structure.

3.7.1.1 Ponding or Immersion

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

3.7.1.2 Fog Spraying or Sprinkling

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

3.7.1.3 Pervious Sheeting

Completely cover surface and edges of the concrete with two thicknesses of wet sheeting. Overlap sheeting 150 mm 6 inches over adjacent sheeting. Sheeting shall be at least as long as the width of the surface to be cured. During application, do not drag the sheeting over the finished concrete nor over sheeting already placed. Wet sheeting thoroughly and keep continuously wet throughout the curing period.

3.7.1.4 Impervious Sheeting

Wet the entire exposed surface of the concrete thoroughly with a fine spray of water and cover with impervious sheeting throughout the curing period. Lay sheeting directly on the concrete surface and overlap edges 300 mm 12 inches minimum. Provide sheeting not less than 450 mm 18 inches wider than the concrete surface to be cured. Secure edges and transverse laps to form

closed joints. Repair torn or damaged sheeting or provide new sheeting. Cover or wrap columns, walls, and other vertical structural elements from the top down with impervious sheeting; overlap and continuously tape sheeting joints; and introduce sufficient water to soak the entire surface prior to completely enclosing.

[3.7.2 Liquid Membrane-Forming Curing Compound

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NOTE: Moist curing is 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. Apply in accordance with the recommendations of the manufacturer immediately after any water sheen which may develop after finishing has disappeared from the concrete surface. Provide and maintain compound on the concrete surface throughout the curing period. Do not use this method of curing where the use of Figure 2 .1.5, "effect of Concrete Temperatures, Relative Humidity, and Wind Velocity on the Rate of Evaporation of Surface Moisture From Concrete" in ACI 305R indicates that hot weather conditions will cause an evaporation rate exceeding one kg pf water per square meter per hour 0.2 pound of water per square foot per hour.

3.7.2.1 Application

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

3.7.2.2 Protection of Treated Surfaces

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

][3.7.3 Liquid Chemical Sealer-Hardener

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

]3.7.4 Curing Periods

****

NOTE: Add the following if concrete will be under

water: [Cure structures submerged in fresh water for a minimum of 12 hours prior to submerging. Cure structures submerged in seawater for a minimum of 7 days prior to submerging.]

****

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

[3.7.5 Requirements for Type III, High-Early-Strength Portland Cement

The curing periods shall be not less than one-fourth of those specified for portland cement, but in no case less than 72 hours.]

3.8 FIELD QUALITY CONTROL

Field quality control is the responsibility of the Contractor. All plastic concrete properties are to be monitored and controlled to meet the Contractor's constructability demands. There are field quality control requirements for compressive strength and durability. These are also the responsibility of the Contractor.

Acceptance criteria for cylinder compressive strength are provided in 3.8.3.3.

Acceptance criteria for durability are described for evaluated mixes in 3.8.1. Field concrete durability acceptance criteria is provided in 3.8.3.5.

****

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

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3.8.1 Evaluation of Mixture Designs

a. The adequacy of the mixture design to produce the minimum specified strength and durability shall be confirmed by testing field batches, casting concrete in a slab and a wall at the job using job materials, equipment, and personnel, and testing the hardened concrete as described herein. The slab shall be at least 2.5 m 8 feet square and have thickness of at least 200 mm 8 inches. The wall shall be 2.5 m 8 feet long, 1.5 m 4 feet high, and at least 200 mm 8 inches thick. Slump shall not exceed the slump proposed for the work. Moist cure the castings for 7 days.

b. Test the fresh concrete as follows:

(1) Slump in accordance with ASTM C 143/C 143M.

(2) Air content in accordance with ASTM C 231 or ASTM C 173/C 173M.

(3) Unit weight in accordance with ASTM C 138/C 138M.

(4) For strength, cast nineteen 150 by 300 mm 6 by 12 inch cylinders

in accordance with ASTM C 31/C 31M.

(5) For durability and transport property testing, cast ten 100 by 200 mm 4 by 8 inch cylinders in accordance with ASTM C 31/C 31M. Follow closely the making, handling, and curing/storing requirements.

Special handling will be necessary for shipments of transport property specimens. These cylinders shall be wrapped completely with slightly damp paper towels with spring water only. The wrapped cylinders shall be placed in either a vacuum package or double layers of sealed plastic bags. Package cylinders to prevent damage and ship priority mail to an approved testing laboratory as described in 1.6.3.6.d.

c. Test cylinders cast under subparagraph b above as follows:

For unit weight and strength, 150 by 300 mm 6 by 12 inch cylinders:

(1) Measure and weigh each specimen to determine unit weight as they are stripped from the molds.

(2) Two at each age of 24 hours and 3 and 7 days in accordance with ASTM C 39/C 39M.

(3) Three at each age of 28, 56, and 90 days in accordance with ASTM C 39/C 39M.

(4) Two at each age of 28 and 90 days in accordance with ASTM C 496/C 496M.

For durability and transport properties, 100 by 200 mm 4 by 8 inch Cylinders:

(1) Test three cylinders at 28 days of curing for all transport properties as defined in 1.6.4.2. Test all properties in duplicate. These properties will be used as base properties for acceptance of the concrete mixture and for comparison during future quality assurance testing/evaluations on test cylinders.

(2) Test three cylinders at 90 days of curing for all transport properties as defined in 1.6.4.2. Test all properties in duplicate. These properties will be used as base properties for acceptance of the concrete mixture and for comparison during future quality assurance testing/evaluations on test cylinders.

(3) A STADIUM® modeling analysis using the average cylinder transport properties determined at 28 and 90 days of moist curing, in the evaluation of concrete mixtures along with the criteria listed in 2.1.3 will determine the predicted service life performance of the concrete mixture. This will be compared to the 75-year required service life as stated in 1.2. If the cylinder analysis fails to meet the service life requirement of 75 years, the concrete mixture will be rejected.

d. Take 100 mm 4 inch cores from each the wall and the slab in accordance with ASTM C 42/C 42M. Those to be tested at 7 days or earlier age shall be drilled on the test date and tested as cored. Those to be tested at later ages shall be drilled in adequate time for wet curing

before testing.

Special handling will be necessary for shipments of transport property specimens. These cores shall be wrapped completely with slightly damped paper towels with spring water only. The wrapped cores shall be placed in either a vacuum package or double layers of sealed plastic bags. Package cores to prevent damage and ship priority mail to an approved testing company.

Take twenty-two cores from each and test as follows:

(1) Two cores: Static modulus of elasticity in accordance with ASTM C 469 at age 28 days.

(2) Two cores: Specific gravity, absorption, and voids in concrete in accordance with ASTM C 642.

(3) Three cores: Resistance to chloride ion penetration in accordance with ASTM C 1202 at ages 28 and 90 days.

(4) Compressive strength in accordance with ASTM C 39/C 39M.

two cores at 24 hours
one core at 3 days
two cores at 7 days
three cores at 28 days
two cores at 90 days
five spare cores

Take an additional ten cores from each and test as follows:

(1) Three cores: Test concrete cores for all transport property as defined in 1.6.4.2. at 28 days. Test all properties in duplicate. These properties will be used as base properties for acceptance of the concrete mixture and for comparison during future quality assurance testing/evaluations on test cores.

(2) Three cores: Test concrete cores for all transport property as defined in 1.6.4.2. at 90 days. Test all properties in duplicate. These properties will be used as base properties for acceptance of the concrete mixture and for comparison during future quality assurance testing/evaluations on test cores.

(3) A STADIUM® modeling analysis using the average core transport properties determined at 28 and 90 days of moist curing, in the evaluation of concrete mixtures along with the criteria listed in 2.1.3 will determine the predicted service life performance of the concrete mixture. This will be compared to the 75-year required service life as stated in 1.2. If the core analysis fails to meet the service life requirement of 75 years, the concrete mixture will be rejected.

(4) four spare cores

e. Sampling and determination of water soluble chloride ion content in accordance with ASTM C 1218/C 1218M. Maximum water soluble chloride ion concentrations in hardened concrete at ages from 28 to 42 days contributed from the ingredients including water, aggregates, cementitious materials, and admixtures shall not exceed the limits of

Table 3 below.

****

NOTE: For epoxy or zinc-coated reinforcing bars, the limits in Table 3 may be more restrictive than necessary. Where appropriate, submit alternative solutions with supporting technical literature for review.

****

Table 3 - Maximum Chloride Ion Content for Corrosion Protection

Type of Member	Maximum water soluble chloride ion (C1) in concrete, percent by weight of cement
Prestressed concrete	0.06
Reinforced concrete exposed to chloride in service	0.08
Reinforced concrete that will be dry or protected from moisture in service	0.15
Other reinforced concrete construction	0.30

f. Submit test results for evaluation and acceptance.

3.8.2 Sampling

a. ASTM C 172. Collect samples of fresh concrete to perform tests specified. ASTM C 31/C 31M for making test specimens.

b. Sample concrete on a random basis except where a batch appears to be deficient and the test can be used to verify the observed deviation. Identify samples so taken in a manner that they can be distinguished from other samples. Obtain six 150 by 300 mm 6 by 12 inch and six 100 by 200 mm 4 by 8 inch cylinder samples for each 75 cubic meters 100 cubic yards, or fraction thereof, of each design mixture of concrete placed in any one day. When the total quantity of concrete with a given design mixture is less than 38.2 cubic meters 50 cubic yards, the strength tests may be waived by the Contracting Officer, if in his judgment, adequate evidence of satisfactory strength is provided.

Durability performance will be measured constantly throughout the project. Special handling will be necessary for shipments of transport property specimens. These cylinders shall be wrapping completely with slightly damped paper towels with spring water only. The wrapped cylinders shall be placed in either a vacuum package or double layers of sealed plastic bags. Package cylinders to prevent damage and ship priority mail to an approved testing laboratory as described in 1.6.3.6.d.

3.8.3 Testing

3.8.3.1 Slump Tests

ASTM C 143/C 143M. 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 8 cubic meters 10 cubic yards (maximum) of concrete.

3.8.3.2 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 8 cubic meters 10 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 composite sample in accordance with ASTM C 1064/C 1064M. When the average of the highest and lowest temperature during the period from midnight to midnight is expected to drop below 4 degrees C 40 degrees F for more than 3 successive days, concrete shall be delivered to meet the following minimum temperature at the time of placement:

(1) 13 degrees C 55 degrees F for sections less than 300 mm 12 inches in the least dimension

(2) 10 degrees C 50 degrees F for sections 300 to 900 mm 12 to 36 inches in the least dimension

(3) 7 degrees C 45 degrees F for sections 900 to 1800 mm 36 to 72 inches in the least dimension

(4) 4 degrees C 40 degrees F for sections greater than 1800 mm 72 inches in the least dimension

c. The minimum requirements may be terminated when temperatures above 10 degrees C 50 degrees F occur during more than half of any 24 hour duration. The temperature of concrete at time of placement shall not exceed 30 degrees C 90 degrees F.

3.8.3.3 Compressive Strength Tests

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

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

a. Mold and cure six 150 by 300 mm 6 by 12 inch cylinders from each sample taken in accordance with ASTM C 31/C 31M. Prevent evaporation and loss of water from the specimen.

b. Test cylinders in accordance with ASTM C 39/C 39M. Test one cylinder at 3 days, two cylinders at 7 days, two cylinders at 28 days, and hold one cylinder in reserve. The compressive strength test results for acceptance shall be the average of the compressive strengths from the

two specimens tested at 28 days. 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 both specimens in a test show any defects, the Contracting Officer may allow the entire test to be discarded.

c. If the average of any three consecutive strength test results is less than the specified strength (f'c) or the minimum test strength (fcr) for durability, whichever is higher, by more the 3 MPa 500 psi, take a minimum of three core samples in accordance with ASTM C 42/C 42M, from the in-place work represented by the low test results. Locations represented by erratic core strengths shall be retested. Remove concrete not meeting strength criteria and provide new acceptable concrete. Repair core holes with nonshrink grout. Match color and finish of adjacent concrete.

d. Strength test reports shall include location in the work where the batch represented by a test was deposited, batch ticket number, time batched and sampled, slump, air content (where specified), mixture and ambient temperature, unit weight, and water added on the job. Reports of strength tests shall include detailed information of storage and curing of specimens prior to testing.

e. Final reports shall be provided within 7 days of test completion.

[3.8.3.4 Air Content

ASTM C 173/C 173M or ASTM C 231 for normal weight concrete. Make air content tests on samples from the first three batches in the placement and until three consecutive batches have air contents within the range of the specified air content, at which time test every fifth batch. Maintain this test frequency until a batch is not within the specified range at which time resume testing of each batch until three consecutive batches have air contents within the specified range. Perform additional tests as necessary for control. Take air content tests from planned composite samples or from samples taken in accordance with ASTM C 172 at the point of concrete placement.

]3.8.3.5 Durability Tests

Test cylinder concrete for all transport properties as defined in 1.6.4.2. at 28 days. The determined ionic diffusion coefficient (IDC) and the moisture diffusion coefficient (MDC) shall both be within 15 percent of the IDC and MDC values determined in 3.8.1. Concrete representative of the tested concrete with IDC and MDC values greater than those determined in 3.8.1 will require a STADIUM® model analysis. If the modeled service life, as defined in 1.2, is less than the required 75 years, this shall be grounds to stop concrete placement and to review quality control issues.

[3.8.3.6 Chloride Ion Concentration

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NOTE: Include only when justified by size of job or when quality of concrete is questionable.

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ACI 318M. Determine water soluble chloride ion concentration. Perform test once for each mix design. The limits for average chloride ion content are provided in Table 3 in paragraph 3.8.1.

][3.8.3.7 Anti-Washout Admixture

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

]3.8.3.8 Non-Destructive Tests

Non-destructive tests - use of the rebound hammer in accordance with ASTM C 805/C 805M, ASTM C 597, or other non-destructive processes may be permitted by the Contracting Officer in evaluating the uniformity and relative concrete strength in place, or for selecting areas to be cored.

Evaluate and validate test results conducted on properly calibrated equipment in accordance with standard ASTM procedures indicated.

3.8.4 Core Samples and Compressive Strength Testing

Obtain and test cores in accordance with ASTM C 42/C 42M.

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 C 42/C 42M.

Acceptance criteria for cylinder compressive strength are provided in subpart 3.8.5 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, 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 Office will evaluate and validate core tests in accordance with the specified procedures.

3.8.5 Acceptance of Concrete Strength

3.8.5.1 Standard Molded and Cured Strength Specimens

The acceptance of concrete strengths shall be based on averages of results from three consecutive compressive strength tests. When the averages of all sets of three consecutive compressive strength test results, equal or exceed 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.

3.8.5.2 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.

3.8.5.3 Core Tests

When the average compressive strengths of the representative cores are equal to at least 85 percent of the required field test strength (fcr), and if no single core is less than 75 percent of the required field test strength (fcr), the strength of concrete is satisfactory.

3.8.6 Inspection

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

-- End of Section --