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USACE / NAVFAC / AFCEC / NASA	**UFGS-03 30 00 (February 2019)**
	Change 5 - 08/23

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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023

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DIVISION 03 - CONCRETE

SECTION 03 30 00

CAST-IN-PLACE CONCRETE

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SECTION 03 30 00

CAST-IN-PLACE CONCRETE
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NOTE: This guide specification covers the requirements for cast-in-place concrete not exposed to a marine or high chloride environment. For concrete exposed to a marine or high chloride environment, use Section 03 31 30 MARINE CONCRETE.

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

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

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).
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NOTE: Show the following information 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 for each element, f'c.

4. Yield strength of reinforcement required 420 MPa 60,000 psi or other grades available.

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

6. Locations where structural lightweight concrete or lightweight insulation or fill concrete are used.

7. Details which require a depressed structural slab for static-disseminating and spark-resistant tile, terrazzo, or other floor finishes in order to provide finished surfaces at the same elevations.

8. Indicate the locations in the finished structure, when exposed concrete surfaces are specified. Indicate the type and location, if other than cast finish is required.

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PART 1 GENERAL

1.1 REFERENCES

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

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

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

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

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 117	(2010; Errata 2011) Specifications for Tolerances for Concrete Construction and Materials and Commentary

ACI 121R	(2008) Guide for Concrete Construction Quality Systems in Conformance with ISO 9001
ACI 213R	(2014; E2017) Guide for Structural Lightweight-Aggregate Concrete
ACI 301	(2016) Specifications for Structural Concrete
ACI 302.1R	(2015) Guide for Concrete Floor and Slab Construction
ACI 304.2R	(2017) Guide to Placing Concrete by Pumping Methods
ACI 304R	(2000; R 2009) Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 305.1	(2014) Specification for Hot Weather Concreting
ACI 305R	(2020) Guide to Hot Weather Concreting
ACI 306.1	(1990; R 2002) Standard Specification for Cold Weather Concreting
ACI 306R	(2016) Guide to Cold Weather Concreting
ACI 308.1	(2011) Specification for Curing Concrete
ACI 347R	(2014; Errata 1 2017) Guide to Formwork for Concrete
ACI SP-2	(2007; Abstract: 10th Edition) ACI Manual of Concrete Inspection
ACI SP-15	(2011) Field Reference Manual: Standard Specifications for Structural Concrete ACI 301-05 with Selected ACI References

AMERICAN HARDBOARD ASSOCIATION (AHA)

AHA A135.4	(1995; R 2004) Basic Hardboard

AMERICAN WELDING SOCIETY (AWS)

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

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM A53/A53M	(2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM A184/A184M	(2019) Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement
ASTM A615/A615M	(2022) Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A706/A706M	(2022a) Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A767/A767M	(2016) Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
ASTM A775/A775M	(2022) Standard Specification for Epoxy-Coated Steel Reinforcing Bars
ASTM A780/A780M	(2020) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM A820/A820M	(2022) Standard Specification for Steel Fibers for Fiber-Reinforced Concrete
ASTM A884/A884M	(2019) Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement
ASTM A934/A934M	(2022) Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
ASTM A955/A955M	(2020c) Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement
ASTM A970/A970M	(2018) Standard Specification for Headed Steel Bars for Concrete Reinforcement
ASTM A996/A996M	(2016) Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement
ASTM A1022/A1022M	(2016b) Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement
ASTM A1044/A1044M	(2016a) Standard Specification for Steel Stud Assemblies for Shear Reinforcement of Concrete
ASTM A1055/A1055M	(2022) Standard Specification for Zinc and Epoxy Dual Coated Steel Reinforcing Bars
ASTM A1060/A1060M	(2016b) Standard Specification for Zinc-Coated (Galvanized) Steel Welded Wire

	Reinforcement, Plain and Deformed, for Concrete
ASTM A1064/A1064M	(2022) Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
ASTM A1094/A1094M	(2020) Standard Specification for Continuous Hot-Dip Galvanized Steel Bars for Concrete Reinforcement
ASTM C31/C31M	(2022) Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C33/C33M	(2018) Standard Specification for Concrete Aggregates
ASTM C39/C39M	(2021) Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C42/C42M	(2020) Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C78/C78M	(2022) Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C94/C94M	(2022a) Standard Specification for Ready-Mixed Concrete
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C138/C138M	(2017a) Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C143/C143M	(2020) Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C150/C150M	(2022) Standard Specification for Portland Cement
ASTM C172/C172M	(2017) Standard Practice for Sampling Freshly Mixed Concrete
ASTM C173/C173M	(2016) Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C231/C231M	(2022) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C260/C260M	(2010a; R 2016) Standard Specification for Air-Entraining Admixtures for Concrete

ASTM C311/C311M	(2022) Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
ASTM C330/C330M	(2017a) Standard Specification for Lightweight Aggregates for Structural Concrete
ASTM C494/C494M	(2019; E 2022) Standard Specification for Chemical Admixtures for Concrete
ASTM C567/C567M	(2019) Determining Density of Structural Lightweight Concrete
ASTM C595/C595M	(2021) Standard Specification for Blended Hydraulic Cements
ASTM C618	(2023; E 2023) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C803/C803M	(2018) Standard Test Method for Penetration Resistance of Hardened Concrete
ASTM C845/C845M	(2018) Standard Specification for Expansive Hydraulic Cement
ASTM C873/C873M	(2015) Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
ASTM C900	(2015) Standard Test Method for Pullout Strength of Hardened Concrete
ASTM C920	(2018) Standard Specification for Elastomeric Joint Sealants
ASTM C989/C989M	(2022) Standard Specification for Slag Cement for Use in Concrete and Mortars
ASTM C1012/C1012M	(2018b) Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
ASTM C1017/C1017M	(2013; E 2015) Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
ASTM C1074	(2019) Standard Practice for Estimating Concrete Strength by the Maturity Method
ASTM C1077	(2017) Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1107/C1107M	(2020) Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)

ASTM C1116/C1116M	(2010a; R 2015) Standard Specification for Fiber-Reinforced Concrete
ASTM C1157/C1157M	(2020a) Standard Performance Specification for Hydraulic Cement
ASTM C1218/C1218M	(2020c) Standard Test Method for Water-Soluble Chloride in Mortar and Concrete
ASTM C1240	(2020) Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C1260	(2021) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1293	(2008; R 2015) Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
ASTM C1567	(2022) Standard Test Method for Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C1602/C1602M	(2022) Standard Specification for Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM C1778	(2016) Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete
ASTM D412	(2016; R 2021) Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
ASTM D471	(2016a) Standard Test Method for Rubber Property - Effect of Liquids
ASTM D1751	(2018) Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D1752	(2018) Standard Specification for Preformed Sponge Rubber, Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM D2628	(1991; R 2016) Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements
ASTM D2835	(1989; R 2017) Standard Specification for Lubricant for Installation of Preformed

	Compression Seals in Concrete Pavements
ASTM D3042	(2017) Standard Test Method for Insoluble Residue in Carbonate Aggregates
ASTM D5759	(2012; R 2020) Characterization of Coal Fly Ash and Clean Coal Combustion Fly Ash for Potential Uses
ASTM D6690	(2015) Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements
ASTM E96/E96M	(2022a; E 2023) Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials
ASTM E329	(2021) Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection
ASTM E1155	(2020) Standard Test Method for Determining Floor Flatness and Floor Levelness Numbers
ASTM E1643	(2018a) Standard Practice for Selection, Design, Installation, and Inspection of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs
ASTM E1745	(2017; R 2023) Standard Specification for Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs
ASTM E1993/E1993M	(1998; R 2020) Standard Specification for Bituminous Water Vapor Retarders Used in Contact with Soil or Granular Fill Under Concrete Slabs

CONCRETE REINFORCING STEEL INSTITUTE (CRSI)

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

FOREST STEWARDSHIP COUNCIL (FSC)

FSC STD 01 001	(2015) Principles and Criteria for Forest Stewardship

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST PS 1	(2009) DOC Voluntary Product Standard PS 1-07, Structural Plywood

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 104	(1980) Method of Calculation of the

	Fineness Modulus of Aggregate
COE CRD-C 513	(1974) Corps of Engineers Specifications for Rubber Waterstops
COE CRD-C 572	(1974) Corps of Engineers Specifications for Polyvinylchloride Waterstops

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

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

U.S. GREEN BUILDING COUNCIL (USGBC)

LEED NC	(2013) Leadership in Energy and Environmental Design(tm) New Construction Rating System

1.2 DEFINITIONS

a. "Cementitious material" as used herein must include all portland cement, pozzolan, fly ash, slag cement[, and silica fume].

b. "Exposed to public view" means situated so that it can be seen from eye level from a public location after completion of the building. A public location is accessible to persons not responsible for operation or maintenance of the building.

c. "Chemical admixtures" are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes.

d. "Supplementary cementing materials" (SCM) include coal fly ash, [silica fume,]slag cement, natural or calcined pozzolans, and ultra-fine coal ash when used in such proportions to replace the portland cement that result in improvement to sustainability and durability and reduced cost.

e. "Design strength" (f'c) is the specified compressive strength of concrete at time(s) specified in this section to meet structural design criteria.

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

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

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

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

j. "Workability (or consistence)" is the ability of a fresh (plastic) concrete mix to fill the form/mould properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, chemical admixtures, aggregate (shape and size distribution), cementitious content and age (level of hydration).

1.3 SUBMITTALS

****

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

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

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

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

****

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

SD-01 Preconstruction Submittals

[Concrete Curing Plan

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

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

Quality Control Organizational Chart

Laboratory Accreditation; G[, [_____]]

[Form Removal Schedule; G[, [_____]]

] Maturity Method Data

SD-02 Shop Drawings

****
NOTE: Shop drawings for formwork may be required for unusually complicated structures, for structures whose designs were predicted on a particular method of construction, for structures in which the forms impart a desired architectural finish, for folded plates, for thin shells, and for long-span roof structures if required.
****

[Formwork

] Reinforcing Steel; G[, [_____]]

SD-03 Product Data

Joint Sealants; (LEED NC)

Joint Filler; (LEED NC)

Formwork Materials

Recycled Aggregate Materials; (LEED NC)

Cementitious Materials; (LEED NC)

Vapor Retarder [and Vapor Barrier]

Concrete Curing Materials

Reinforcement; (LEED NC)

Liquid Chemical Floor Hardeners and Sealers

Admixtures

Reinforcing Fibers

Mechanical Reinforcing Bar Connectors

Waterstops

Local/Regional Materials; (LEED NC)

Biodegradable Form Release Agent

****
NOTE: Include following submittals when job complexity justifies the additional cost associated with these requirements.
****

[Pumping Concrete

][Finishing Plan

] Nonshrink Grout

SD-04 Samples

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

[Slab Finish Sample

][Surface Finish Samples

] SD-05 Design Data

Concrete Mix Design; G[, [_____]]

****
NOTE: Formwork design calculations only need to be submitted for large complex projects.
****

[Formwork Calculations

] SD-06 Test Reports

Concrete Mix Design; G[, [_____]]

Fly Ash

Pozzolan

Slag Cement

Aggregates

[Fiber-Reinforced Concrete; G[, [_____]]

][Tolerance Report

] Compressive Strength Tests; G[, [_____]]

[Unit Weight of Structural Concrete

][Chloride Ion Concentration

] **********

NOTE: Require air content test results to be submitted when the air percentage is critical to slab finishes such as shake or hardener finishes and the total air content must NOT EXCEED a certain percentage.

Air content should be tested for minimum air entrainment in freeze/thaw areas.

****

[Air Content

] Slump Tests

Water

SD-07 Certificates

Reinforcing Bars

Welder Qualifications

****

NOTE: Include following submittals when job complexity justifies the additional cost associated with these requirements.

****

[Silica Fume Manufacturer's Representative

][VOC Content for Form Release Agents, Curing Compounds, and Concrete Penetrating Sealers

][Safety Data Sheets

] Forest Stewardship Council (FSC) Certification

Field Testing Technician and Testing Agency

SD-08 Manufacturer's Instructions

Liquid Chemical Floor Hardeners and Sealers

Joint Sealants; (LEED NC)

[Curing Compound

]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. Interpret reference to the "Building Official," the "Structural Engineer," and the "Architect/Engineer" to mean the Contracting Officer.

1.5 DELIVERY, STORAGE, AND HANDLING

****

NOTE: Materials which are woven, fibrous, or porous in nature have a high capacity to adsorb VOC emissions; for instance, acoustical ceilings, carpet, textiles, and unprimed gypsum wall board.
****

Follow ACI 301, ACI 304R and ASTM A934/A934M requirements and recommendations. Do not deliver concrete until vapor retarder, [vapor barrier,] forms, reinforcement, embedded items, and chamfer strips are in place and ready for concrete placement. Do not store concrete curing compounds or sealers with materials that have a high capacity to adsorb volatile organic compound (VOC) emissions, including [_____]. Do not store concrete curing compounds or sealers in occupied spaces.

1.5.1 Reinforcement

Store reinforcement of different sizes and shapes in separate piles or racks raised above the ground to avoid excessive rusting. Protect from contaminants such as grease, oil, and dirt. Ensure bar sizes can be accurately identified after bundles are broken and tags removed.

[1.5.1.1 Epoxy Coated Reinforcing Steel

Record coating lot on each shipping notice and carefully identify and re-tag bar bundles from bending plant. Provide systems for handling coated bars which have padded contact areas such as, nylon slings, all free of dirt and grit. Lift bundled coated bars with strong back, multiple supports, or platform bridge to prevent sagging and abrasion. Pad bundling bands 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. Cover bars to be stored longer than 12 hours at the job site with opaque polyethylene sheeting or other suitable equivalent protective material.

]1.6 QUALITY ASSURANCE

1.6.1 Design Data

[1.6.1.1 Formwork Calculations

ACI 347R. Include design calculations indicating arrangement of forms, sizes and grades of supports (lumber), panels, and related components. Furnish drawings and calculations of shoring and re-shoring methods proposed for floor and roof slabs, spandrel beams, and other horizontal concrete members. Calculations must indicate concrete pressure with both live and dead loads, along with material types.

]1.6.1.2 Concrete Mix Design

Sixty days minimum prior to concrete placement, submit a mix design for each strength and type of concrete. Submit a complete list of materials including type; brand; source and amount of cement, supplementary cementitious materials,[fibers,] and admixtures; and applicable reference specifications. Submit mill test and all other test for cement, supplementary cementitious materials, aggregates, and admixtures. Provide

documentation of maximum nominal aggregate size, gradation analysis, percentage retained and passing sieve, and a graph of percentage retained verses sieve size. Provide mix proportion data using at least three different water-cementitious material ratios for each type of mixture, which produce a range of strength encompassing those required for each type of concrete required. If source material changes, resubmit mix proportion data using revised source material. Provide only materials that have been proven by trial mix studies to meet the requirements of this specification, unless otherwise approved in writing by the Contracting Officer. Indicate clearly in the submittal where each mix design is used when more than one mix design is submitted. Resubmit data on concrete components if the qualities or source of components changes. Required average strength can be documented by field experience if field strength test data are available and represent a single group of at least 10 consecutive strength tests for one mixture, using materials and conditions similar to those expected for work, and encompassing a period of not less than 45 days. The average of field strength tests shall equal or exceed fcr'. Changes in materials, conditions, and proportions within the test record shall not have been more closely restricted than those for the proposed work. Test records shall not be more than 24 months old. Obtain mix design approval from the contracting officer prior to concrete placement.

1.6.2 Shop Drawings

[1.6.2.1 Formwork

Drawings showing details of formwork including, but not limited to; joints, supports, studding and shoring, and sequence of form and shoring removal. Indicate placement schedule, construction, location and method of forming control joints. Include locations of inserts, conduit, sleeves and other embedded items. Reproductions of contract drawings are unacceptable. Submit form removal schedule indicating element and minimum length of time for form removal.

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

]1.6.2.2 Reinforcing Steel

Indicate bending diagrams, assembly diagrams, splicing 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. Reproductions of contract drawings are unacceptable.

[1.6.3 Control Submittals

[1.6.3.1 Concrete Curing Plan

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

][1.6.3.2 Pumping Concrete

Submit proposed materials and methods for pumping concrete. Submittal must include mix designs, pumping equipment including type of pump and size and material for pipe, and maximum length and height concrete is to

be pumped.

][1.6.3.3 Silica Fume Manufacturer's Representative

****
NOTE: A pre-construction meeting with the concrete supplier, contractor, finisher, admixture supplier, and Contracting Officer should be required for projects which require silica fume, corrosion inhibitors, or high-range water reducers (superplasticizers). An initial sample pour with the proposed concrete mix and methods of placing, finishing and curing may be beneficial to ensure concrete quality.
****

The manufacturer's representative must be present at mix plant to ensure proper mix, including high range water reducer, and batching methods during the first 3 [_____] days of concrete mix preparation and placement. After which the manufacturer's representative must designate a representative at the concrete producer's plant to ensure the concrete mix procedures meet the silica fume manufacturer's recommendations.[Representative to attend and advise at finishing of sample slab.]

][1.6.3.4 Finishing Plan

****
NOTE: Include when finishing or special flatness are critical.
****

Submit proposed material and procedures to be used in obtaining the finish for the [_____] floors. Include qualification of person to be used for obtaining floor tolerance measurement, description of measuring equipment to be used, and a sketch showing lines and locations the measuring equipment will follow.

][1.6.3.5 VOC Content for form release agents, curing compounds, and concrete penetrating sealers

Submit certification for the form release agent, curing compounds, and concrete penetrating sealers that indicate the VOC content of each product.

]1.6.3.6 Safety Data Sheets

Submit Safety Data Sheets (SDS) for all materials that are regulated for hazardous health effects. SDS must be readily accessible during each work shift to employees when they are at the construction site.

]1.6.4 Test Reports

1.6.4.1 Fly Ash and Pozzolan

Submit test results in accordance with ASTM C618 for fly ash and pozzolan. Submit test results performed within 6 months of submittal date.

1.6.4.2 Slag Cement

Submit test results in accordance with ASTM C989/C989M for slag cement.

Submit test results performed within 6 months of submittal date.

1.6.4.3 Aggregates

Submit test results in accordance with ASTM C33/C33M, or ASTM C330/C330M for lightweight aggregate, and ASTM C1293 or ASTM C1567 as required in the paragraph titled ALKALI-AGGREGATE REACTION.

[1.6.4.4 Fiber-Reinforced Concrete

Test to determine flexural toughness index I5 in accordance with ASTM C1116/C1116M.

]1.6.5 Field Samples

[1.6.5.1 Slab Finish Sample

Install minimum of 3000 mm by 3000 mm 10 foot by 10 foot slab. Slab finish sample must not be part of the final project. Finish as required by specification.[Silica fume manufacturer's representative must attend and advise.]

][1.6.5.2 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, 1 m by 1 m, 75 mm 3 feet 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 must be representative of each of the finishes specified and of the workmanship and finish(es) required. Do not remove or destroy samples until directed by the Contracting Officer.

]1.6.6 Quality Control Program

****
NOTE: The objective of the concrete quality control program is for the Contractor to outline the procedures that will be used to construct a structure that will obtain the design service life.
****

Develop and submit for approval a concrete quality control program in accordance with the guidelines of ACI 121R and as specified herein. The plan must include approved laboratories. Provide direct oversight for the concrete qualification program inclusive of associated sampling and testing. All quality control reports must be provided to the Contracting Officer, Quality Manager and Concrete Supplier. Maintain a copy of ACI SP-15 and CRSI 10MSP at project site.

1.6.7 Quality Control Personnel Certifications

The Contractor must submit for approval the responsibilities of the various quality control personnel, including the names and qualifications

of the individuals in those positions and a quality control organizational chart defining the quality control hierarchy and the responsibility of the various positions. Quality control personnel must be employed by the Contractor.

Submit American Concrete Institute certification for the following:

a. CQC personnel responsible for inspection of concrete operations.

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

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

1.6.7.1 Quality Manager Qualifications

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

1.6.7.2 Field Testing Technician and Testing Agency

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

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

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

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

1.6.8 Laboratory Qualifications for Concrete Qualification Testing

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

1.6.9 Laboratory Accreditation

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

****

NOTE: Use second set of brackets for OCONUS projects to specify alternate licensing requirement

where a registered U.S. professional would not be feasible.
****

a. Aggregate Testing and Mix Proportioning: Aggregate testing and mixture proportioning studies must be performed by an accredited laboratory and under the direction of a [registered professional engineer in a U.S. state or territory competent in concrete materials][_____] who is competent in concrete materials and must sign all reports and designs.

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

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

1.7 ENVIRONMENTAL REQUIREMENTS

****
NOTE: In some regions, designer must choose the most appropriate option(s) for ventilation. For instance, high-humidity regions may generate too much condensate when using 100 percent outside air.
****

Provide space ventilation according to material manufacturer recommendations, at a minimum, during and following installation of concrete curing compound and sealer. Maintain one of the following ventilation conditions during the curing period or for 72 hours after installation:

a. Supply 100 percent outside air 24 hours a day.

b. Supply airflow at a rate of 6 air changes per hour, when outside temperatures are between 13 degrees C 55 degrees F and 29 degrees C 84 degrees F and humidity is between 30 percent and 60 percent.

c. Supply airflow at a rate of 1.5 air changes per hour, when outside air conditions are not within the range stipulated above.

1.7.1 Submittals for Environmental Performance

a. Provide data indication the percentage of post-industrial pozzolan (fly ash, slag cement) cement substitution as a percentage of the full product composite by weight.

b. Provide data indicating the percentage of post-industrial and post-consumer recycled content aggregate.

c. Provide product data indicating the percentage of post-consumer recycled steel content in each type of steel reinforcement as a percentage of the full product composite by weight.

d. Provide product data stating the location where all products were manufactured

e. For projects using FSC certified formwork, provide chain-of-custody documentation for all certified wood products.

f. For projects using reusable formwork, provide data showing how formwork is reused.

g. Provide SDS product information data showing that form release agents meet any environmental performance goals such as using vegetable and soy based products.

h. Provide SDS product information data showing that concrete adhesives meet any environmental performance goals including low emitting, low volatile organic compound products.

1.8 SUSTAINABLE DESIGN REQUIREMENTS

1.8.1 Local/Regional Materials

****

NOTE: Using local materials can help minimize transportation impacts, including fossil fuel consumption, air pollution, and labor. Using materials harvested and manufactured within a 500-mile radius from the project site contributes to the following LEED credit: MR5. Coordinate with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING. Use second option if Contractor is choosing local materials in accordance with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING. Use second option for USACE projects. Army projects must include option only if pursuing this LEED credit.

****

[Use materials or products extracted, harvested, or recovered, as well as manufactured, within a [805][_____] kilometer [500][_____] mile radius from the project site, if available from a minimum of three sources.][See Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING for cumulative total local material requirements. Concrete materials may be locally available.][Submit documentation indicating distance between manufacturing facility and the project site. Indicate distance of raw material origin from the project site. Indicate relative dollar value of local/regional materials to total dollar value of products included in project.]

1.8.2 Forest Stewardship Council (FSC) Certification

Use FSC-certified wood where specified. Provide letter of certification signed by lumber supplier. Indicate compliance with FSC STD 01 001 and identify certifying organization. Submit FSC certification numbers; identify each certified product on a line-item basis. Submit copies of invoices bearing the FSC certification numbers.

1.9 QUALIFICATIONS FOR WELDING WORK

Welding procedures must be in accordance with AWS D1.4/D1.4M.

Verify that Welder qualifications are in accordance with AWS D1.4/D1.4M

for welding of reinforcement or under an equivalent qualification test approved in advance. Welders are permitted to do only the type of welding for which each is specifically qualified.

PART 2 PRODUCTS

2.1 FORMWORK MATERIALS

****

NOTE: Delete the brackets from the requirements below if you do not want to limit options for form-facing materials. In that case the requirement should be: "Form-facing material in contact with concrete must be lumber, plywood, tempered concrete-form-grade hardboard, metal, plastic, or treated paper that creates specified appearance and texture of concrete surface".

****

a. Form-facing material in contact with concrete must be[lumber,][plywood,][tempered concrete-form-grade hardboard,][metal,][plastic,][or][treated paper that creates specified appearance and texture of concrete surface]. Submit product information on proposed form-facing materials if different from that specified herein.

b. Design formwork, shores, reshores, and backshores to support loads transmitted to them and to comply with applicable building code requirements.

c. Design formwork and shoring for load redistribution resulting from stressing of post-tensioned reinforcement. Ensure that formwork allows movement resulting from application of prestressing force.

d. Design formwork to withstand pressure resulting from placement and vibration of concrete and to maintain specified tolerances.

e. Design formwork to accommodate waterstop materials in joints at locations indicated in Contract Documents.

f. Provide temporary openings in formwork if needed to facilitate cleaning and inspection.

g. Design formwork joints to inhibit leakage of mortar.

****

NOTE: Use a 1/240 as a limit for structural concrete and 1/400 for architectural concrete

****

h. Limit deflection of facing materials for concrete surfaces exposed to view to [1/240][1/400][____] of center-to-center spacing of facing supports.

[i. Do not use earth cuts as forms for vertical or sloping surfaces.

] j. Submit product information on proposed form-facing materials if different from that specified herein.

[k. Submit shop drawings for formwork, shoring, reshoring, and

backshoring. Shop drawings must be signed and sealed by a licensed design engineer.

][l. Submit design calculations for formwork, shoring, reshoring, and backshoring. Design calculations must be signed and sealed by a licensed design engineer.

] m. Submit procedure for reshoring and backshoring, including drawings signed and sealed by a licensed design engineer. Include on shop drawings the formwork removal procedure and magnitude of construction loads used for design of reshoring or backshoring system. Indicate in procedure the magnitude of live and dead loads assumed for required capacity of the structure at time of reshoring or backshoring.

n. Submit manufacturer's product data on form liner proposed for use with each formed surface.

2.1.1 Wood Forms

Use lumber as specified in Section 06 10 00 ROUGH CARPENTRY and as follows. Provide lumber that is square edged or tongue-and-groove boards, free of raised grain, knotholes, or other surface defects. Provide plywood that complies with NIST PS 1, B-B concrete form panels or better or AHA A135.4, hardboard for smooth form lining.[Submit data verifying that composite wood products contain no urea formaldehyde resins.][Virgin wood used must be FSC-certified.]

2.1.1.1 Concrete Form Plywood (Standard Rough)

Provide plywood that conforms to NIST PS 1, B-B, concrete form, not less than 16 mm 5/8-inch thick.

2.1.1.2 Overlaid Concrete Form Plywood (Standard Smooth)

Provide plywood that conforms to NIST PS 1, B-B, high density form overlay, not less than 16 mm 5/8-inch thick.

2.1.2 Plastic Forms

Plastic lumber as specified in Section 06 10 00 ROUGH CARPENTRY. Provide plastic forms that contain a minimum of [50] [100] percent post-consumer recycled content, or a minimum of [50] [100] percent post-industrial recycled content.

2.1.3 Carton Forms

Moisture resistant treated paper faces, biodegradable, structurally sufficient to support weight of wet concrete until initial set. Provide carton forms that contain a minimum of [5][10][_____] percent post-consumer recycled content, or a minimum of [20][40][_____] percent post-industrial recycled content.

2.1.4 Steel Forms

Provide steel form surfaces that do not contain irregularities, dents, or sags.

2.2 FORMWORK ACCESSORIES

a. Use commercially manufactured formwork accessories, including ties and hangers.

b. Form ties and accessories must not reduce the effective cover of the reinforcement.

2.2.1 Form Ties

****
NOTE: Form ties: a mechanical connection in tension used to prevent concrete forms from spreading due to the fluid pressure of fresh concrete.
****

a. Use form ties with ends or end fasteners that can be removed without damage to concrete.

b. Where indicated in Contract Documents, use form ties with integral water barrier plates or other acceptable positive water barriers in walls.

****
NOTE: Specify alternative breakback distance for ferrous ties if needed.
****

c. The breakback distance for ferrous ties must be at least [50 mm2 in.][19 mm3/4 in.][_____] for Surface Finish-2.0 or Surface Finish-3.0, as defined in ACI 301.

[d. If the breakback distance is less than 19 mm 3/4 in., use coated or corrosion-resistant ties.

] e. Submit manufacturer's data sheet on form ties.

2.2.2 Waterstops

****
NOTE: waterstop: a thin sheet of metal, rubber, plastic, or other material inserted across a joint, or material adhered within a joint, to obstruct the seepage of water through the joint.
****

Submit manufacturer's data sheet on waterstop materials and splices.

2.2.2.1 PVC Waterstop

Polyvinylchloride waterstops must conform to COE CRD-C 572.

2.2.2.2 Rubber Waterstop

Rubber waterstops must conform to COE CRD-C 513.

2.2.2.3 Thermoplastic Elastomeric Rubber Waterstop

Thermoplastic elastomeric rubber waterstops must conform to ASTM D471.

2.2.2.4 Hydrophilic Waterstop

Swellable strip type compound of polymer modified chloroprene rubber that swells upon contact with water must conform to the following requirements when tested in accordance to ASTM D412: Tensile strength 2.9 MPa 420 psi minimum; ultimate elongation 600 percent minimum. Hardness must be 50 minimum on the type A durometer and the volumetric expansion ratio in distilled water at 20 degrees C 70 degrees F must be 3 to 1 minimum.

2.2.3 Biodegradable Form Release Agent

****

NOTE: The 2002 Farm Bill - Section 9002, Federal Procurement of Biobased Products, requires each Federal Agency to develop a procurement program which ensures that items composed of biobased products are be purchased to the maximum extent practicable and which is consistent with applicable provisions of Federal procurement law.

****

a. Provide form release agent that is colorless, biodegradable, and[rapeseed oil-based][soy oil-based][water-based], with a[low (maximum of 55 grams/liter (g/l))][zero] VOC content.[A minimum of [85][_____] percent of the total product must be biobased material.]

b. Provide product that does not bond with, stain, or adversely affect concrete surfaces and does not impair subsequent treatments of concrete surfaces.

c. Provide form release agent that reduces formwork moisture absorption, and does not contain diesel fuel, petroleum-based lubricating oils, waxes, or kerosene. Submit documentation indicating type of biobased material in product and biobased content. Indicate relative dollar value of biobased content products to total dollar value of products included in project.

d. Submit manufacturer's product data on formwork release agent for use on each form-facing material.

2.2.4 Chamfer Materials

****

NOTE: Chamfer strip: either a triangular or curved insert placed in an inside form corner to produce either a rounded or flat chamfer or to form a rustication. Also called cant strip, fillet, dummy joint, and skew back.

****

Use lumber materials with dimensions of 19 x 19 mm 3/4 x 3/4 in.

2.2.5 Construction and movement joints

****

NOTE: Indicate in Contract Documents the locations of required movement joints, keyways, and the locations where waterstops are required in joints.

****

a. Submit details and locations of construction joints in accordance with the requirements herein.

b. Locate construction joints within middle one-third of spans of slabs, beams, and girders. If a beam intersects a girder within the middle one-third of girder span, the distance between the construction joint in the girder and the edge of the beam must be at least twice the width of the larger member.

c. For members with post-tensioning tendons, locate construction joints where tendons pass through centroid of concrete section.

d. Locate construction joints in walls and columns at underside of slabs, beams, or girders and at tops of footings or slabs.

e. Make construction joints perpendicular to main reinforcement.

f. Provide movement joints where indicated in Contract Documents or in accepted alternate locations.

g. Submit location and detail of movement joints if different from those indicated in Contract Documents.

h. Submit manufacturer's data sheet on expansion joint materials.

i. Provide keyways where indicated in Contract Documents.[Longitudinal keyways indicated in Contract Documents must be at least 37.5 mm 1-1/2 in. deep, measured perpendicular to the plane of the joint.]

2.2.6 Other Embedded items

****

NOTE: Specify materials and design for sleeves, inserts, anchors, and other embedded items if not included in the Contract Documents.

****

Use sleeves, inserts, anchors, and other embedded items of material and design indicated in Contract Documents.

2.3 CONCRETE MATERIALS

2.3.1 Cementitious Materials

****

NOTE: Typical mixtures of concrete contain either an ASTM C150 cement plus one or more supplementary cementitious material (fly ash, slag, silica fume, etc.) or a blended cement that meets ASTM C595/C595M or ASTM C1157/C1157M.

For more information on cements and cementitious materials refer to ACI E3 "Cementitious Materials for Concrete" and ACI 225R "Guide to the Selection and Use of Hydraulic Cements".

****

****

NOTE: Coal fly ash, slag, cenospheres, and silica fumes are EPA designated products to be ingredients in concrete and cement. See Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING and include additive options unless designer determines that justification for non-use exists.

****

2.3.1.1 Portland Cement

****

NOTE: ASTM C150 cements are as follows:
- Type I: For use when the special properties specified for any other type are not required.
- Type II: For general use, more especially when moderate sulfate resistance is desired.
- Type II(MH): For general use, more especially when moderate heat of hydration and moderate sulfate resistance are desired.
- Type III: For use when high early strength is desired.

Type I cement is the default option. Commercially available cements can sometimes meet the requirements of Type I and Type II cements. These cements are labeled as Type I/II cements.

Type III cement is not commonly used for cast-in-place concrete. It is a cement mostly available and used in precast operations. Type III could be used if high early strength is desired but using it will significantly increase the likelihood of thermal cracking. Type III cement should not be specified for flatwork.

Type IV cement (low heat of hydration) is not listed as an option because it is usually not produced by cement plants and is not available in U.S markets. A combination of Type II(MH) and a supplementary cementitious material such as fly ash is typically specified when low heat of hydration is required for a structure/member.

Type V cement is a sulfate resistant cement. Refer to the paragraph on SULFATE RESISTANCE (under durability) for more information on when to specify sulfate resistant cement.

Low-alkali cements are no longer defined in portland cement specifications because specifying low-alkali cement is not necessarily sufficient to mitigate alkali-silica reaction (ASR). To mitigate ASR, refer to paragraph ALKALI-AGGREGATE REACTION.

For more information and options refer to ASTM C150/C150M.

****

a. Unless otherwise specified, provide cement that conforms to ASTM C150/C150M Type [I] [II] [II(MH)] [III] [IV] [V] [_____].

b. Use one brand and type of cement for formed concrete having exposed-to-view finished surfaces.

c. [For portland cement manufactured in a kiln fueled by hazardous waste, maintain a record of source for each batch.] [Supplier must certify that no hazardous waste is used in the fuel mix or raw materials.] [Supplier must certify that the hazardous waste is neutralized by the manufacturing process and that no additional pollutants are discharged.]

d. Submit information along with evidence demonstrating compliance with referenced standards. Submittals must include types of cementitious materials, manufacturing locations, shipping locations, and certificates showing compliance.

e. Cementitious materials must be stored and kept dry and free from contaminants.

[2.3.1.2 Blended Cements

****

NOTE: There are many options to choose from in ASTM C595. Here are some naming designations used:
- IP: portland-pozzolan cement
- IS: portland blast-furnace slag cement
- IL: portland limestone cement
- MS: moderate sulfate resistance
- HS: high sulfate resistance
- MH: moderate heat of hydration
- LH: low heat of hydration

ASTM C1157 blended cements include the following:
- Type GU: Hydraulic cement for general construction
- Type HE: High Early-Strength
- Type MS: Moderate Sulfate Resistance
- Type HS: High Sulfate Resistance
- Type MH: Moderate Heat of Hydration

See ASTM C595/C595M and ASTM C1157/1157M for additional blended cement requirements, special properties, and options.

****

a. Blended cements must conform to ASTM C595/C595M Type [IP][IS][IP(MS)][IS(MS)][IP(MH)][IS(MH)][IP(LH)][IS(LH)][IL][_____] or ASTM C1157/C1157M Type [GU][MS] [MH] [HE].

b. Slag cement added to the Type IS blend must meet ASTM C989/C989M.

c. The pozzolan added to the Type IS blend must meet ASTM C618 [Class F,][Class C,][or][Class N] and must be interground with the cement clinker. The manufacturer must state in writing that the amount of pozzolan in the finished cement will not vary more than plus or minus 5 mass percent of the finished cement from lot-to-lot or within a lot. The percentage and type of pozzolan used in the blend must not change from that submitted for the aggregate evaluation and mixture

proportioning.

]2.3.1.3 Fly Ash

****

NOTE: Fly ash, silica fume, slag, and other SCMs may produce uneven discoloration of the concrete during the early stages of construction, depending upon the type of curing provided. Fly ashes meeting the specified test results, which are more stringent than ASTM C618, should provide acceptable end results. It is suggested that fly ash be used as a replacement for 35 percent of the cement.

Using Class C fly ash is not recommended, Class F fly ash is preferred. The performance of Class C ashes should be evaluated before use because some Class C ashes could help improve performance while others could cause a reduction in concrete quality and durability. For example, some Class C fly ashes may improve sulfate resistance, while others may actually reduce sulfate resistance and accelerate deterioration. Class C should not be used to mitigate ASR unless mortar bars made with the fly ash meet the expansion requirements of ASTM C1567. For more information on the use of fly ash in concrete refer to ACI 232.2R.

****

a. ASTM C618, [Class F] [Class C], except that the maximum allowable loss on ignition must not exceed [3] [6] percent.

****

NOTE: The minimum fly ash content should not be less than 15 percent.

****

b. If fly ash is used it shall range from 15 to [20][30][35][40] percent by weight of cementitious material, provided the fly ash does not reduce the amount of cement in the concrete mix below the minimum requirements of local building codes. Where the use of fly ash cannot meet the minimum level,it shall not be used. Report the chemical analysis of the fly ash in accordance with ASTM C311/C311M. Evaluate and classify fly ash in accordance with ASTM D5759.

2.3.1.4 Slag Cement

ASTM C989/C989M, Grade [100][120].

2.3.1.5 Silica Fume

****

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

****

****

NOTE: The initial cost of the concrete must increase, and supervision at the batch plant, finishing, and curing is necessary. A HRWRA must 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.

****

Silica fume must conform to ASTM C1240, including the optional limits on reactivity with cement alkalis. Silica fume may be furnished as a dry, densified material or as slurry. Proper mixing is essential to accomplish proper distribution of the silica fume and avoid agglomerated silica fume which can react with the alkali in the cement resulting in premature and extensive concrete damage. Supervision at the batch plant, finishing, and curing is essential. Provide at the Contractor's expense the services of a manufacturer's technical representative, experienced in mixing, proportioning, placement procedures, and curing of concrete containing silica fume. This representative must be present on the project prior to and during at least the first 4 days of concrete production and placement using silica fume. A High Range Water Reducing admixture (HRWRA) must be used with silica fume.

2.3.1.6 Other Supplementary Cementitious Materials

Natural pozzolan must be raw or calcined and conform to ASTM C618, Class N, including the optional requirement for uniformity.

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

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

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

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

2.3.2 Water

a. Water or ice must comply with the requirements of ASTM C1602/C1602M.

b. Minimize the amount of water in the mix. Improve workability by adjusting the grading of the aggregate and using admixture rather than by adding water.

c. Water must be[potable][from rainwater collection][from graywater][from recycled water]; free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances deleterious to concrete.

d. Protect mixing water and ice from contamination during storage and delivery.

e. Submit test report showing water complies with ASTM C1602/C1602M.

[f. When nonpotable source is proposed for use, submit documentation on

effects of water on strength and setting time in compliance with ASTM C1602/C1602M.

]2.3.3 Aggregate

2.3.3.1 Normal-Weight Aggregate

****

NOTE: ASTM C33/C33M provides many requirements for concrete aggregates. Requirements such as soundness and the presence of deleterious substances should strictly be adhered to. Grading requirements on the other hand could be evaluated based on the overall mixture design and not based on each individual aggregate source.

Aggregate grading can be evaluated using methods such as 0.45 power chart, the coarseness factor chart, the "percent retained" or "18-8" method, and others. Quality concrete can be produced without meeting the grading requirements of ASTM C33/33M.

****

a. Aggregates must conform to ASTM C33/C33M [unless otherwise specified in the Contract Documents or approved by the contracting officer][_____].

****

NOTE: Specify a nominal maximum size aggregate if needed. Note that the maximum size aggregate can differ for different portions of the structure.

Nominal Maximum Size: the smallest sieve opening through which the entire amount of the aggregate is permitted to pass.

Delete the requirement below if you do not want to specify a maximum size aggregate. Note that the paragraph titled CONCRETE MIX DESIGN limits the nominal maximum size of aggregate based on the dimension of a member and spacing of reinforcement.

****

b. Aggregates used in concrete must be obtained from the same sources and have the same size range as aggregates used in concrete represented by submitted field test records or used in trial mixtures.

****

NOTE: Calcium carbonate sands (limestone or dolomitic limestone) are softer than siliceous sands; when subject to abrasion, limestone sands in concrete polish and cause skid problems. To ensure that soft manufactured calcium carbonate sands are blended with harder sands (such as a natural siliceous sands), a 50 percent acid insoluble sand requirement must be specified when concrete is subject to abrasion (ex: pavements).

Note that for blended sands, the limit is for the blend of sand and not for each individual source of sand. Concrete produced with manufactured sands might require a higher w/c ratio, higher cement content, or higher admixture dosages to obtained the required workability and instability; Most hardened concrete properties (strength and durability) however will not be affected by the usage of 100 percentmanufactured sand. If finishability is an issue, then consider specifying 50 percent natural sand.

****

c. [Provide sand that is at least 50 percent acid insoluble based on ASTM D3042.][Provide sand that is at least 50 percent natural sand.]

d. Store and handle aggregate in a manner that will avoid segregation and prevents contamination by other materials or other sizes of aggregates. Store aggregates in locations that will permit them to drain freely. Do not use aggregates that contain frozen lumps.

e. Submit types, pit or quarry locations, producers' names, aggregate supplier statement of compliance with ASTM C33/C33M, and ASTM C1293 expansion data not more than 18 months old.

2.3.3.2 Lightweight Aggregate

Lightweight aggregate in accordance with ASTM C330/C330M.

2.3.3.3 Recycled Aggregate Materials

****

NOTE: Use of materials with recycled content, calculated based on post-industrial and post-consumer percentage content, contributes to the following LEED credit: MR4. Coordinate with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING.

****

Use a minimum of [25] [_____] percent recycled aggregate, depending on local availability and conforming to requirements of the mix design. Recycled aggregate to include: [recovered glass] [recovered concrete] [recovered porcelain] [recovered stone] [_____] that meets the aggregate requirements specified. Submit recycled material request with the aggregate certification submittals and do not use until approved by the Contracting Officer.

2.3.4 Admixtures

****

NOTE: There are 4 main classes of admixtures for concrete:

- Water Reducers: Used to reduce the quantity of mixing water required to produce concrete of a given consistency.

- Set Control: to retard or accelerate concrete setting time.

- Durability Enhancing: to enhance the durability of concrete. These include air entraining admixture, corrosion inhibitors, ASR inhibitors, Shrinkage reducers, and others.

- Miscellaneous admixtures: these include coloring admixtures, foaming agents, viscosity modifiers, etc.

Specifying water reducers or set control admixtures is not necessary. The contractor should choose the combination of these admixtures as needed and as recommended by the admixture manufacturer. Air-entraining admixture dosage is controlled by the air content requirements specified in the paragraph titled DURABILITY. Thus, the specifier does not need to specify when an air-entraining admixture should be used. Other specialty admixtures however, such as corrosion inhibitors, ASR inhibitors, or shrinkage reducers should be specified in this paragraph if needed.

For more information on concrete admixtures refer to ACI 212.

****

a. Chemical admixtures must conform to ASTM C494/C494M.

b. Air-entraining admixtures must conform to ASTM C260/C260M.

c. Chemical admixtures for use in producing flowing concrete must conform to ASTM C1017/C1017M.

d. Do not use calcium chloride admixtures[.][unless approved by the contracting officer.]

****

NOTE: A corrosion-inhibiting admixture provides supplemental corrosion protection, specify if such an admixture is required under exposure C1 or C2.

An ASR-inhibiting admixture provides supplemental protection to concrete when reactive aggregate is used. Specify if the usage of ASR-inhibiting admixtures is required.

Specify if, when, and where any other specialty admixtures are required. Note that such requirements could also be specified in the paragraph titled CONCRETE MIX DESIGN.

****

e. [Use a corrosion-inhibiting admixture for concrete classified under exposure category [C1][C2].][Use an ASR-inhibiting admixture for concrete containing aggregate susceptible to ASR.] [_____]

f. Admixtures used in concrete must be the same as those used in the concrete represented by submitted field test records or used in trial mixtures.

g. Protect stored admixtures against contamination, evaporation, or damage.

h. To ensure uniform distribution of constituents, provide agitating equipment for admixtures used in the form of suspensions or unstable solutions. Protect liquid admixtures from freezing and from temperature changes that would adversely affect their characteristics.

i. Submit types, brand names, producers' names, manufacturer's technical data sheets, and certificates showing compliance with standards required herein.

2.4 MISCELLANEOUS MATERIALS

2.4.1 Concrete Curing Materials

Provide concrete curing material in accordance with ACI 301 Section 5 and ACI 308.1 Section 2. Submit product data for concrete curing compounds. Submit manufactures instructions for placement of curing compound.

2.4.2 Nonshrink Grout

Nonshrink grout in accordance with ASTM C1107/C1107M.

2.4.3 Floor Finish Materials

2.4.3.1 Liquid Chemical Floor Hardeners and Sealers

a. Hardener must be a colorless aqueous solution containing a blend of inorganic silicate or siliconate material and proprietary components combined with a wetting agent; that penetrates, hardens, and densifies concrete surfaces. Submit manufactures instructions for placement of liquid chemical floor hardener.

b. Use concrete penetrating sealers with a low (maximum 100 grams/liter, less water and less exempt compounds) VOC content. Submit manufactures instructions for placement of sealers.

2.4.3.2 Abrasive Aggregate for Nonslip Aggregate Finish

****

NOTE: When abrasive aggregate is required, delete one of the following two paragraphs as required. Aluminum oxide and emery abrasive grits are blackish-gray and nonsparkling; silicon carbide abrasive grits are black and sparkling.

****

[Aggregate must be packaged, factory-graded fused aluminum oxide grits, or it may be crushed emery containing not less than 40-percent aluminum oxide and not less than 25-percent ferric oxide. Aggregate must be rust proof and nonglazing and must be unaffected by freezing, moisture, and cleaning materials.

][Aggregate must be packaged, factory-graded, silicon carbide grits. Aggregate must be rust proof and must be unaffected by freezing, moisture, and cleaning materials.

][Aggregate must be well-graded in size from particles retained on 600 micrometer sieve No. 30 sieve 0.0236 inch to particles passing 2.36 mm sieve No. 8 sieve 0.0929 inch.

]2.4.3.3 Dry Materials for Colored Wear-Resistant Finish

****

NOTE: When color must be indicated, available colors are natural, bright red, dark red, terra cotta, green, and gray.

****

[Provide materials that are packaged, dry, and a combination of materials formulated for producing colored and wear-resistant monolithic surface treatments; they must include portland cement, graded-quartz aggregate, coloring pigments, and dispersing agents. Provide coloring pigments that are finely ground, nonfacing mineral oxides prepared especially for the purpose and interground with the cement.

]2.4.3.4 Aggregate for Heavy-Duty Wear-Resistant Finish

****

NOTE: When heavy-duty, wear-resistant finish is required, delete first paragraph. Delete following paragraphs when mineral aggregate is not required. Delete second paragraph when iron aggregate is not required.

****

[Provide aggregate that is traprock or emery, as follows:

[Traprock must be packaged, crushed, natural, fine-to-medium-grained, igneous rock, such as diabase, basalt, or black granite. Traprock aggregate must be well-graded in size from particles retained on 4.75 mm sieve No. 4 sieve 0.187 inch to particles passing 9.5 mm 3/8-inch sieve.]

[Emery must be packaged, factory-graded, crushed, natural-emery ore, cubical or polyhedral in form, containing not less than 35-percent aluminum oxide and not less than 24-percent ferric oxide. Emery aggregate must be well graded in size from particles retained on 300 micrometer sieve No. 50 sieve 0.0118 inch to particles passing 2.36 mm sieve No. 8 sieve 0.0929 inch.]

][Provide iron aggregate, as follows:

Iron must be packaged, ground and graded cubicle iron particles with dispersing agents, formulated to blend with portland cement for producing wear-resistant monolithic surface treatments. Provide aggregate that is free of nonferrous metals, oil, grease, soluble alkaline compounds, rust, and impurities and must be well-graded in size from particles retained on 300 micrometer sieve No. 50 sieve 0.0118 inch to particles passing 2.36 mm sieve No. 8 sieve 0.0929 inch.

]2.4.3.5 Aggregate for Heavy-Duty Floor Topping

Provide emery (or may be traprock or traprock-screenings) fine aggregates, as specified.

Provide emery that is packaged, factory-graded, crushed natural emery ore

containing not less than 35-percent aluminum oxide and not less than 24-percent ferric oxide. Provide aggregate that is cubical or polyhedral in form and does not change its physical or chemical nature in the presence of moisture. Grade aggregate to a fineness modulus of 3.9 to 4.0, with 100 percent passing 9.5 mm 3/8-inch sieve and not less than 95 percent retained on 150 micrometer No. 100 sieve. Deliver emery in moisture-resistant bags.

Provide traprock that is packaged, crushed, natural, fine- to medium-grained igneous rock such as diabase, basalt, or black granite. Uniformly grade coarse aggregate with 100 percent passing 12.5 mm 1/2-inch sieve, 30 to 50 percent passing 9.5 mm 3/8-inch sieve, 0 to 15 percent passing 4.75 mm No. 4 sieve, and 0 to 5 percent passing 2.36 mm No. 8 sieve.

Provide fine aggregate using traprock that conforms to ASTM C33/C33M, except gradation. Grade fine aggregate within the following limits:

SIEVE	PERCENT PASSING
9.5 mm 3/8 in.	100
4.75 mm No. 4	95 to 100
2.36 mm No. 8	65 to 80
1.18 mm No. 16	45 to 65
600 micrometer No. 30	25 to 45
300 micrometer No. 50	5 to 15
150 micrometer No. 100	0 to 5

Deliver traprock coarse aggregate and fine aggregate in moisture-resistant bags.

2.4.4 Expansion/Contraction Joint Filler

[ASTM D1751][or][ASTM D1752] [Type I][or][Type II][_____]. Material must be 13 mm 1/2 inch thick[, unless otherwise indicated].

2.4.5 Joint Sealants

****
NOTE: Using low-VOC products contributes to the following LEED credit: EQ4. Include VOC submittal if pursuing this LEED credit, and coordinate with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING.
****

[Submit manufacturer's product data, indicating VOC content.

]2.4.5.1 Horizontal Surfaces, 3 Percent Slope, Maximum

ASTM D6690 or ASTM C920, Type M, Class 25, Use T.

2.4.5.2 Vertical Surfaces Greater Than 3 Percent Slope

****

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

ASTM C920, Type M, Grade NS, Class 25, Use T [NT].[FS SS-S-200, no sag].

2.4.5.3 Preformed Polychloroprene Elastomeric Type

ASTM D2628.

2.4.5.4 Lubricant for Preformed Compression Seals

ASTM D2835.

2.4.6 Vapor Retarder [and Vapor Barrier]

****
NOTE: Edit title to correct choice. Use first paragraph where vapor retarder is required to minimize vapor transmission through the concrete and a permanent vapor barrier is not required. Select second bracketed option where permanent vapor barrier is required. Vapor barriers should only be used where required due to the required moisture content of the slab for floor covering adhesion and as required for quality concrete, see ACI 360R, figure 4.7 for guidance when a vapor retarder is needed. For protection against hydrostatic pressure or conditions of excessive dampness, specify an appropriate waterproofing membrane in Division 7.
****

ASTM E1745 Class C [A] [B] polyethylene sheeting, minimum 0.25 mm 10 mil [0.38 mm15 mil] thickness or other equivalent material with a maximum permeance rating of 0.04 perms per ASTM E96/E96M.

[ASTM E1745 Class C [A] [B] polyethylene sheeting, minimum 0.38 mm 15 mil thickness or ASTM E1993/E1993M bituminous membrane or other equivalent material with a maximum permeance rating of 0.01 perms per ASTM E96/E96M.

] Consider plastic vapor retarders and adhesives with a high recycled content, low toxicity low VOC (Volatile Organic Compounds) levels.

2.4.7 Dovetail Anchor Slot

Preformed metal slot approximately 25 mm by 25 mm 1 inch by 1 inch of not less than 22 gage galvanized steel cast in concrete. Coordinate actual size and throat opening with dovetail anchors and provide with removable filler material.

2.5 CONCRETE MIX DESIGN

2.5.1 Properties and Requirements

****
NOTE: Selecting concrete proportions involves

balance among requirements for placeability, workability, finishability, strength, durability, density, appearance, economy of the resulting mixture, and other desired properties.

Properties specified in this paragraph such as strength, slump, aggregate size, etc. will be used to proportion concrete mixtures and/or order ready-mix concrete. For more on ready-mix concrete see paragraph on READY-MIX CONCRETE and ASTM C94/C94M. Note that the required information for ordering concrete is discussed in section 6 of ASTM C94/C94M.

****

a. Use materials and material combinations listed in this section and the contract documents.

****

NOTE: A minimum cementitious material content limit for concrete is generally not required for most portions of a structure. In the case of floors/slabs, a minimum content of cement could be required to improve the finishability of the surface. A finishing crew might have a hard time finishing a surface made with a lean concrete mixture; in such cases a minimum content of cementitious materials should be required.

****

b. Cementitious material content must be adequate for concrete to satisfy the specified requirements for strength, w/cm, durability, and finishability described in this section and the contract documents.

[The minimum cementitious material content for concrete used in floors must meet the following requirements:

Nominal maximum size of aggregate, mm in.	Minimum cementitious material content, kg per cubic meter pounds per cubic yard
37.5 1-1/2	280 470
25 1	310 520
19 3/4	320 540
9.5 3/8	360 610

]

****

NOTE: This requirement for slump is a general requirement for all concrete members. If specific requirements are needed for a portion of the structure then add those requirements to the table located at the end of this paragraph.

****

c. Selected target slump must meet the requirements this section, the contract documents, and must not exceed 230 mm 9 in. Concrete must

not show visible signs of segregation.

d. The target slump must be enforced for the duration of the project. Determine the slump by ASTM C143/C143M. Slump tolerances must meet the requirements of ACI 117.

e. The nominal maximum size of coarse aggregate for a mixture must not exceed three-fourths of the minimum clear spacing between reinforcement, one-fifth of the narrowest dimension between sides of forms, or one-third of the thickness of slabs or toppings.

****

NOTE: Exposure Class F1, F2, or F3 are defined in the paragraph titled DURABILITY.

****

f. Concrete must be air entrained for members assigned to Exposure Class F1, F2, or F3. The total air content must be in accordance with the requirements of the paragraph titled DURABILITY.

g. Measure air content at the point of delivery in accordance with ASTM C173/C173M or ASTM C231/C231M.

h. Concrete for slabs to receive a hard-troweled finish must not contain an air-entraining admixture or have a total air content greater than 3 percent.

****

NOTE: Specify the properties and requirements needed for each portion of the structure. Note that the values given for the first entry "Footings" is an example to illustrate how this table should be used. Modify this table by adding or deleting information and rows as needed for your project.

- Minimum f'c (compressive strength): Specify the required compressive strength value and age for each portion of the structure. The strength value specified should be based on the value used for structural strengths or durability requirements, whichever controls. The age (7, 28, 56, 90) should be specified based on the needs of the project. 28-day strength is most commonly specified (default age for compressive strength). 7-day strength is specified only when high early strength is required on a project. 56- and 90-day strength requirements are specified for mixtures with relatively higher contents of pozzolanic materials because these mixtures require more time to gain strength. A higher compressive strength may be required for durability considerations. For floors, the specified compressive strength f'c will generally depend upon the intended use and expected wear unless durability considerations dictate higher strengths. If the floor will be exposed to abrasive wear from early construction traffic, consider requiring a minimum compressive strength at 3 days of 1800 psi or higher. Refer to ACI 302.1R for guidance on compressive strengths to specify for

various classes of floors.

- Information on exposure categories can be found in the paragraph titled DURABILITY and Chapter 19 of ACI 318. Choose the exposure categories for each portion of the structure as needed. Note that F0, C0, S0, and W0 are exposure categories that have no additional durability requirements and could be considered as default values.

- Misc. Requirements: Add any requirement or property other than compressive strength, including aggregate size or gradation, w/c ratio and/or air content (if either is different than durability requirements), slump limits, fiber dosages, etc. Note that the default information in this table is given as an example of information that could be added; the table must be modified by the specifier as needed.

-For information on lightweight concrete see ACI 213R.

****

i. Concrete properties and requirements for each portion of the structure are specified in the table below. Refer to the paragraph titled DURABILITY for more details on exposure categories and their requirements.

	Minimum *f'c* MPa psi	**Exposure Categories^**	**Miscellaneous Requirements**
Footings	[35] [19] [_____] [5000] [3000] [_____] at [7] [28] [56] [90] days	[S0] [S1] [S2] [S3]; [C0] [C1] [C2]; [W0] [W1]; [F0] [F1] [F2] [F3]	[Max. slump: [15 cm] [6 in.] [_____]] [Nominal maximum aggregate size must be [12.5 mm][19 mm][25 mm] [1/2 in.][3/4 in.][1 in.] [_____]]
Columns and walls	[35] [19] [_____] [5000] [3000] [_____] at [7] [28] [56] [90] days	[S0] [S1] [S2] [S3]; [C0] [C1] [C2]; [W0] [W1]; [F0] [F1] [F2] [F3]	[Nominal maximum aggregate size must be [12.5 mm][19 mm][25 mm] [1/2 in.][3/4 in.][1 in.] [_____]]

	Minimum *f'c* MPa psi	Exposure Categories^	Miscellaneous Requirements
Beams and elevated slabs	[35] [19] [_____] [5000] [3000] [_____] at [7] [28] [56] [90] days	[S0] [S1] [S2] [S3]; [C0] [C1] [C2]; [W0] [W1]; [F0] [F1] [F2] [F3]	[Nominal maximum aggregate size must be [12.5 mm][19 mm][25 mm] [1/2 in.][3/4 in.][1 in.] [_____]]
Slabs-on-ground	[35] [19] [_____] [5000] [3000] [_____] at [7] [28] [56] [90] days	[S0] [S1] [S2] [S3]; [C0] [C1] [C2]; [W0] [W1]; [F0] [F1] [F2] [F3]	[Min. dosage [0.9] [1.5] [_____] (kg per cubic meter) (pounds per cubic yard) for synthetic micro-fiber] [Min. dosage [2.4][4] [_____] (kg per cubic meter) (pounds per cubic yard) for synthetic macro-fiber] [Min. dosage [30] [50] [_____] (kg per cubic meter) (pounds per cubic yard) for steel fibers]
Lightweight concrete suspended slab	[5000] [3000] [_____] [35] [19] [_____] at [7] [28] [56] [90] days	[S0] [S1] [S2] [S3]; [C0] [C1] [C2]; [W0] [W1]; [F0] [F1] [F2] [F3]	[Max. density of [1840] [115] [1680] [105] [_____] (kg per cubic meter) (pounds per cubic foot)]
Concrete Toppings	[5000] [3000] [_____] [35] [19] [_____] at [7] [28] [56] [90] days	[S0] [S1] [S2] [S3]; [C0] [C1] [C2]; [W0] [W1]; [F0] [F1] [F2] [F3]	[Max. slump: [15 cm] [6 in.] [_____]]

2.5.2 Durability

****

NOTE: Proportions required for durable concrete may take precedence over those for strength. Durability can be more important than strength to the overall performance of the completed work. Concrete should be proportioned to resist the effects of exposures that can deprive it of serviceability. Durability is related to strength, but is also affected by factors which strength alone does not indicate.

Strength tests alone are not a good predictor of durability. Additional durability tests on concrete and its components could be performed to insure that durable concrete is produced.
****

2.5.2.1 Alkali-Aggregate Reaction

Do not use any aggregate susceptible to alkali-carbonate reaction (ACR). Use one of the three options below for qualifying concrete mixtures to reduce the potential of alkali-silica reaction (ASR):

a. For each aggregate used in concrete, the expansion result determined in accordance with ASTM C1293 must not exceed 0.04 percent at one year.

b. For each aggregate used in concrete, the expansion result of the aggregate and cementitious materials combination determined in accordance with ASTM C1567 must not exceed 0.10 percent at an age of 16 days.

****
NOTE: Alkali content in concrete (LBA), which is sometimes referred to as alkali loading in concrete, is a function of how reactive an aggregate is to alkalis. A lower LBA should be used with highly reactive aggregate.

The limit required below was obtained from ACI 301 and should cover most available aggregates. Limits specific to certain aggregates could be obtained by testing a combination of cementitious materials and reactive aggregate being considered. If a highly reactive aggregate is being considered for a project, the value of LBA being specified should be verified or determined for that specific aggregate.
****

c. Alkali content in concrete (LBA) must not exceed [2.4 kg per cubic meter] [4 pounds per cubic yard] [_____] for moderately reactive aggregate or [1.8 kg per cubic meter] [3 pounds per cubic yard] [_____] for highly reactive aggregate. Reactivity must be determined by testing in accordance with ASTM C1293 and categorized in accordance with ASTM C1778. Alkali content is calculated as follows:
LBA = (cement content, kg per cubic meter pounds per cubic yard) × (equivalent alkali content of portland cement in percent/100 percent)

2.5.2.2 Freezing and Thawing Resistance

a. Provide concrete meeting the following requirements based on exposure class assigned to members for freezing-and-thawing exposure in Contract Documents:

Exposure class	**Maximum *w/cm****	**Minimum *f'c*, MPa psi**	**Air content**	**Additional Requirements**
F0	N/A	17 2500	N/A	

Exposure class	Maximum *w/cm**	Minimum *f'c*, MPa psi	Air content	Additional Requirements
F1	0.55	24 3500	Depends on aggregate size	N/A
F2	0.45	31 4500	Depends on aggregate size	See limits on maximum cementitious material by mass
F3	0.40	35 5000	Depends on aggregate size	See limits on maximum cementitious material by mass
F3 plain concrete	0.45	31 4500	Depends on aggregate size	See limits on maximum cementitious material by mass

*The maximum *w/cm* limits do not apply to lightweight concrete.

b. Concrete must be air entrained for members assigned to Exposure Class F1, F2, or F3. The total air content must meet the requirements of the following table:

Nominal maximum aggregate size, mm in.	Total air content, percent*^	
	Exposure Class F2 and F3	Exposure Class F1
9.5 3/8	7.5	6.0
12.5 1/2	7.0	5.5
19.03/4	6.0	5.0
25.0 1	6.0	4.5
37.5 1-1/2	5.5	4.5
50 2	5.0	4.0
75 3	5.5	3.5

*Tolerance on air content as delivered must be plus/minus 1.5 percent.

^For f'c greater than 5000 psi, reducing air content by 1.0 percentage point is acceptable.

c. Submit documentation verifying compliance with specified requirements.

d. For sections of the structure that are assigned Exposure Class F3, submit certification on cement composition verifying that concrete mixture meets the requirements of the following table:

Cementitious material	**Maximum percent of total cementitious material by mass***
Fly ash or other pozzolans conforming to ASTM C618	25
Slag cement conforming to ASTM C989/C989M	50
Silica fume conforming to ASTM C1240	10
Total of fly ash or other pozzolans, slag cement, and silica fume	50^
Total of fly ash or other pozzolans and silica fume	35^

*Total cementitious material also includes ASTM C150/C150M, ASTM C595/C595M, ASTM C845/C845M, and ASTM C1157/C1157M cement. The maximum percentages above must include:

i. Fly ash or other pozzolans present in ASTM C1157/C1157M or ASTM C595/C595M Type IP blended cement.

ii. Slag cement present in ASTM C1157/C1157M or ASTM C595/C595M Type IS blended cement.

iii. Silica fume conforming to ASTM C1240 present in ASTM C1157/C1157M or ASTM C595/C595M Type IP blended cement.

^Fly ash or other pozzolans and silica fume must constitute no more than 25 percent and 10 percent, respectively, of the total mass of the cementitious materials.

2.5.2.3 Corrosion and Chloride Content

a. Provide concrete meeting the requirements of the following table based on the exposure class assigned to members requiring protection against reinforcement corrosion in Contract Documents.

b. Submit documentation verifying compliance with specified requirements.

c. Water-soluble chloride ion content contributed from constituents including water, aggregates, cementitious materials, and admixtures must be determined for the concrete mixture by ASTM C1218/C1218M at age between 28 and 42 days.

d. The maximum water-soluble chloride ion (Cl-) content in concrete, percent by mass of cement is as follows:

Exposure class	Maximum *w/cm**	Minimum f'c, MPa psi	Maximum water-soluble chloride ion (CL-) content in concrete, percent by mass of cement
Reinforced concrete			
C0	N/A	17 2500	1.00
C1	N/A	17 2500	0.30
C2	0.4	35 5000	0.15
Prestressed concrete			
C0	N/A	17 2500	0.06
C1	N/A	17 2500	0.06
C2	0.4	35 5000	0.06

*The maximum w/cm limits do not apply to lightweight concrete.

2.5.2.4 Sulfate Resistance

a. Provide concrete meeting the requirements of the following table based on the exposure class assigned to members for sulfate exposure.

Exposure class	Maximum w/cm	Minimum f'c, MPa psi	Required cementitious materials-types			Calcium chloride admixture
			ASTM C150/C150M	ASTM C595/C595M	ASTM C1157/C1157M	
S0	N/A	17 2500	N/A	N/A	N/A	No restrictions
S1	0.50	28 4000	II*^	Types with (MS) designation	MS	No restrictions
S2	0.45	31 4500	V^	Types with (HS) designation	HS	Not permitted
S3	0.45	31 4500	V + pozzolan or slag cement**	Types with (HS) designation plus pozzolan or slag cement**	HS + pozzolan or slag cement**	Not permitted
S3	0.40	34 5000	V***	Types with (HS) designation	HS	Not permitted

* For seawater exposure, other types of portland cements with tricalcium aluminate (C3A) contents up to 10 percent are acceptable if the w/cm does not exceed 0.40.

** The amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement. Alternatively, the amount of the specific source of the pozzolan or slag used shall not be less than the amount tested in

accordance with ASTM C1012/C1012M and meeting the requirements maximum expansion requirements listed herein.

*** If Type V cement is used as the sole cementitious material, the optional sulfate requirement of 0.040 percent maximum expansion in ASTM C150/C150M shall be required.

^ Other available types of cement, such as Type III or Type I, are acceptable in exposure classes S1 or S2 if the C3A contents are less than 8 or 5 percent, respectively.

b. The maximum w/cm limits for sulfate exposure do not apply to lightweight concrete.

c. Alternative combinations of cementitious materials of those listed in this paragraph are acceptable if they meet the maximum expansion requirements listed in the following table:

Exposure class	**Maximum expansion when tested using ASTM C1012/C1012M**		
	At 6 months	**At 12 months**	**At 18 months**
S1	0.10 percent	N/A	N/A
S2	0.05 percent	0.10 percent^	N/A
S3	N/A	N/A	0.10 percent

^The 12-month expansion limit applies only when the measured expansion exceeds the 6-month maximum expansion limit.

2.5.2.5 Concrete Temperature

****
NOTE: Specify alternative maximum concrete temperature. If concrete delivered in hot weather with a temperature higher than 35°C 95°F has been used successfully in given climates or situations, the higher temperature may be specified in place of the 35°C 95°F limit.
Review ACI 305R for guidance on specifying a higher temperature limit.
****

The temperature of concrete as delivered must not exceed [35°C95°F] [_____].

2.5.2.6 Concrete permeability

a. Provide concrete meeting the requirements of the following table based on exposure class assigned to members requiring low permeability in the Contract Documents.

Exposure class	Maximum *w/cm**	Minimum f'c, MPa psi	Additional minimum requirements
W0	N/A	17 2500	None
W1	0.5	28 4000	None

*The maximum w/cm limits do not apply to lightweight concrete.

b. Submit documentation verifying compliance with specified requirements.

2.5.3 Contractor's Option for Material Only

****
NOTE: Fill in appropriate state and title of referenced specification where work is to be accomplished. If a special class of aggregate and a choice of other materials exists in the state specification, specify that class of aggregate and choice of material. Fill in applicable strength class or other appropriate identification of concrete strength specified in state Department of Transportation specifications. Do not use for NAVFAC LANT projects.
****

At the option of the Contractor, those applicable material sections of [_____] DOT RBS for Class [A] [_____] strength concrete must govern in lieu of this specification for concrete. Do not change the selected option during the course of the work.

2.5.4 Trial Mixtures

Trial mixtures must be in accordance to ACI 301.

2.5.5 Ready-Mix Concrete

****
NOTE: ASTM C94 covers requirements for ready-mix concrete but does not cover requirements for placement, consolidation, curing, or protection of the concrete after delivery to the purchaser.
****

Provide concrete that meets the requirements of ASTM C94/C94M.

Ready-mixed concrete manufacturer must provide duplicate delivery tickets with each load of concrete delivered. Provide delivery tickets with the following information in addition to that required by ASTM C94/C94M:

a. Type and brand cement

b. Cement and supplementary cementitious materials content in 43-kilogram 94-pound bags per cubic meter yard of concrete

c. Maximum size of aggregate

d. Amount and brand name of admixtures

e. Total water content expressed by water cementitious material ratio

2.6 REINFORCEMENT

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

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

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

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

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

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

[f. Submit request and procedure to field-bend or straighten reinforcing bars partially embedded in concrete at locations not indicated in Contract Documents. Field bending or straightening of reinforcing bars is permitted [where indicated in the Contract Documents][in the following locations: [_____]]

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

2.6.1 Reinforcing Bars

****
NOTE: ASTM A706/A706M bars are mainly used in seismic design or for welding. Include ASTM A767/A767M for galvanized reinforcing bars.
****

****
NOTE: Use second recycled content option throughout this section if Contractor is choosing recycled content products in accordance with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING.
****

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

b. ASTM A615/A615M with the bars marked S, Grade [420][550][690] [60][80][100]; or ASTM A996/A996M with the bars marked R, Grade [350][420] [50][60], or marked A, Grade [300][420] [40][60].[Cold drawn wire used for spiral reinforcement must conform to

ASTM A1064/A1064M.][Provide reinforcing bars that contain a minimum of [100][_____] percent recycled content.][See Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING for cumulative total recycled content requirements.]

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

d. Submit mill certificates for reinforcing bars.

2.6.1.1 Galvanized Reinforcing Bars

****

NOTE: Class 1 has a zinc coating that is thicker than Class 2. For Class 1 bars, fabrication can be performed before or after coating. If fabrication is performed after coating then damage caused by fabrication should be repaired according to ASTM A767/767M.

If needed, add any requirements for bars that require special finished bend diameters and indicate their locations.

ASTM A1094 provides 2 mils of coating and can be fabricated after coating. Any damage should be repaired according to ASTM A1094/A1094M. The systems are not equals and the designer should choose based on the requirements of the project.

****

a. Provide zinc-coated (galvanized) reinforcing bars that conform to [ASTM A767/A767M, [Class 1] [Class 2] [with galvanizing [before][after] fabrication] as required by the contract Documents][or][ASTM A1094/A1094M].

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

2.6.1.2 Epoxy-Coated Reinforcing Bars

****

NOTE: ASTM A775/A775M are coated in a straight and then bent as needed while ASTM A934/A934M are bent prior to coating. Bending after coating might result in the epoxy coating to crack or debond from steel.

****

a. Provide epoxy-coated reinforcing bars that conform to[ASTM A775/A775M][ASTM A934/A934M], Grade[60][80][100].

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

c. Coating damage incurred during shipment, storage, handling, and placing of epoxy-coated reinforcing bars must be repaired. Repair damaged coating areas with patching material conforming to ASTM A775/A775M or ASTM A934/A934M as applicable and in accordance with material manufacturer's written recommendations. Damaged coating area must not exceed 2 percent of surface area in each linear foot of each bar or bar must not be used. The 2 percent limit on damaged coating area must include repaired areas damaged before shipment as required by ASTM A775/A775M or ASTM A934/A934M as applicable. Fading of coating color shall not be cause for rejection of epoxy-coated reinforcing bars.

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

e. Epoxy coated reinforcing bars shall be handled and stored in accordance with [ASTM A775/A775M][or][ASTM A934/A934M]. If the manufacturer stores bars outdoors for more than 2 months, cover coated reinforcement with opaque protective material.

2.6.1.3 Dual-coated Reinforcing Bars

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

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

2.6.1.4 Stainless Steel Reinforcing Bars

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

2.6.1.5 Headed Reinforcing Bars

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

2.6.1.6 Bar Mats

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

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

2.6.1.7 Headed Shear Stud Reinforcement

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

2.6.2 Mechanical Reinforcing Bar Connectors

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

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

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

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

2.6.3 Wire

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

For more information on wire reinforcement refer to WRI (Wire Reinforcement Institute) documents.
****

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

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

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

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

2.6.4 Welded wire reinforcement

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

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

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

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

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

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

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

2.6.5 Reinforcing Bar Supports

****

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

****

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

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

****

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

****

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

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

2.6.6 Reinforcing Fibers

****

NOTE: Only use fiber reinforcement when approved by the designer. Drawings should indicate where fiber reinforced concrete is located. Fiber reinforcing is used to help: control cracking due to plastic shrinkage; reduce permeability; and increase impact capacity; shatter resistance, abrasion resistance, and toughness. Fiber reinforcing does 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 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 plastic shrinkage cracking. Include technical representative when warranted by size and importance of job.

For more information on fibers and their use in concrete, refer to ACI 544 documents.

****

2.6.6.1 Synthetic Fibers

In addition to the requirements specified above, provide fiber reinforced concrete in accordance with ASTM C1116/C1116M Type III, synthetic fiber reinforced concrete, and as follows. Synthetic reinforcing fibers must be [100 percent virgin] monofilament polypropylene fibers[, with a minimum of [5] [10] [_____] percent post-consumer recycled content, or a minimum of [20] [40] [_____] percent post-industrial recycled content].[See Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING for cumulative total recycled content requirements. Fibers may contain post-consumer or post-industrial recycled content.]

Provide fibers that 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. Add fibers at the batch plant.[Toughness indices must 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.]

2.6.6.2 Steel Fibers

If steel fiber-reinforced concrete is specified in Contract Documents for providing shear resistance, steel fibers must be deformed and conform to ASTM A820/A820M. Steel fibers must have a length-to-diameter ratio of at least 50 and not exceed 100.

2.6.7 Dowels for Load Transfer in Floors

Provide greased dowels for load transfer in floors of the type, design, weight, and dimensions indicated. Provide dowel bars that are plain-billet steel conforming to ASTM A615/A615M, Grade 40. Provide dowel pipe that is steel conforming to ASTM A53/A53M.

[Plate dowels must conform to ASTM A36/A36M, and must be of size and spacing indicated. Plate dowel system must minimize shrinkage restraint by [using a tapered shape] [or] [formed void] [or] [by having compressible material on the vertical faces with a thin bond breaker on the top and bottom dowel surfaces.]

]2.6.8 Welding

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

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

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

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

PART 3 EXECUTION

3.1 EXAMINATION

a. Do not begin installation until substrates have been properly constructed; verify that substrates are level.

b. If substrate preparation is the responsibility of another installer, notify Contracting Officer of unsatisfactory preparation before processing.

c. Check field dimensions before beginning installation. If dimensions vary too much from design dimensions for proper installation, notify Contracting Officer and wait for instructions before beginning installation.

3.2 PREPARATION

****

NOTE: Options for uses of excess concrete include: additional paving, post footing anchorage, swale riprap reinforcing, mud slab, flowable fill, footing

bottom, retaining wall footing ballast, storm structure covers, underground utility pipe kickers, storm pipe flared end section, toe wash protection, and shoulder and toe outfall restraints for temporary erosion pipes. Diverting waste from the landfill contributes to the following LEED credit: MR2. Coordinate with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING.
****

Determine quantity of concrete needed and minimize the production of excess concrete. Designate locations or uses for potential excess concrete before the concrete is poured.

3.2.1 General

a. Surfaces against which concrete is to be placed must be free of debris, loose material, standing water, snow, ice, and other deleterious substances before start of concrete placing.

b. Remove standing water without washing over freshly deposited concrete. Divert flow of water through side drains provided for such purpose.

3.2.2 Subgrade Under Foundations and Footings

a. When subgrade material is semi-porous and dry, sprinkle subgrade surface with water as required to eliminate suction at the time concrete is deposited, or seal subgrade surface by covering surface with specified vapor retarder.

b. When subgrade material is porous, seal subgrade surface by covering surface with specified vapor retarder.

3.2.3 Subgrade Under Slabs on Ground

a. Before construction of slabs on ground, have underground work on pipes and conduits completed and approved.

b. Previously constructed subgrade or fill must be cleaned of foreign materials

c. Finish surface of capillary water barrier under interior slabs on ground must not show deviation in excess of 6.4 mm 1/4 inch when tested with a 3000 mm 10-foot straightedge parallel with and at right angles to building lines.

d. Finished surface of subgrade or fill under exterior slabs on ground must not be more than 6.10 mm 0.02-foot above or 30.50 mm 0.10-foot below elevation indicated.

3.2.4 Edge Forms and Screed Strips for Slabs

a. Set edge forms or bulkheads and intermediate screed strips for slabs to obtain indicated elevations and contours in finished slab surface and must be strong enough to support vibrating bridge screeds or roller pipe screeds if nature of specified slab finish requires use of such equipment.

b. Align concrete surface to elevation of screed strips by use of

strike-off templates or approved compacting-type screeds.

3.2.5 Reinforcement and Other Embedded Items

a. Secure reinforcement, joint materials, and other embedded materials in position, inspected, and approved before start of concrete placing.

b. When concrete is placed, reinforcement must be free of materials deleterious to bond. Reinforcement with rust, mill scale, or a combination of both will be considered satisfactory, provided minimum nominal dimensions, nominal weight, and minimum average height of deformations of a hand-wire-brushed test specimen are not less than applicable ASTM specification requirements.

3.3 FORMS

****

NOTE: For more information on formwork construction and best practices refer to ACI SP-004 "Formwork for Concrete" or ACI 347R "Guide to Formwork for Concrete".

****

a. Provide forms, shoring, and scaffolding for concrete placement. Set forms mortar-tight and true to line and grade.

b. Chamfer above grade exposed joints, edges, and external corners of concrete [20 mm] [0.75 inch]. Place chamfer strips in corners of formwork to produce beveled edges on permanently exposed surfaces.[Do not bevel reentrant corners or edges of formed joints of concrete.]

c. Provide formwork with clean-out openings to permit inspection and removal of debris.

d. Inspect formwork and remove foreign material before concrete is placed.

e. At construction joints, lap form-facing materials over the concrete of previous placement. Ensure formwork is placed against hardened concrete so offsets at construction joints conform to specified tolerances.

f. Provide positive means of adjustment (such as wedges or jacks) of shores and struts. Do not make adjustments in formwork after concrete has reached initial setting. Brace formwork to resist lateral deflection and lateral instability.

g. Fasten form wedges in place after final adjustment of forms and before concrete placement.

h. Provide anchoring and bracing to control upward and lateral movement of formwork system.

i. Construct formwork for openings to facilitate removal and to produce opening dimensions as specified and within tolerances.

j. Provide runways for moving equipment. Support runways directly on formwork or structural members. Do not support runways on reinforcement. Loading applied by runways must not exceed capacity of formwork or structural members.

k. Position and support expansion joint materials, waterstops, and other embedded items to prevent displacement. Fill voids in sleeves, inserts, and anchor slots temporarily with removable material to prevent concrete entry into voids.

l. Clean surfaces of formwork and embedded materials of mortar, grout, and foreign materials before concrete placement.

3.3.1 Coating

****

NOTE: Coating forms with a film-forming material such as epoxy or polyurethane, along with the use of a proper release agent, will make stripping easier and allow more reuses of the forms. It is important however to not allow the release agent to reach the reinforcement because it would hinder the formation of a bond between concrete and the reinforcement.

****

a. Cover formwork surfaces with an acceptable material that inhibits bond with concrete.

b. If formwork release agent is used, apply to formwork surfaces in accordance with manufacturer's recommendations before placing reinforcement. Remove excess release agent on formwork prior to concrete placement.

c. Do not allow formwork release agent to contact reinforcement or hardened concrete against which fresh concrete is to be placed.

3.3.2 Reshoring

****

NOTE: Reshores, as defined in ACI 347R, are shores placed snugly under a stripped concrete slab or other structural member after the original forms and shores have been removed from a full bay, requiring the new slab or structural member to deflect and support its own weight and existing construction loads applied before installation of the reshores. Such reshores are provided to transfer additional construction loads to other slabs or members and/or to impede deflection due to creep that might otherwise occur.

****

a. Do not allow structural members to be loaded with combined dead and construction loads in excess of loads indicated in the accepted procedure.

b. Install and remove reshores or backshores in accordance with accepted procedure.

c. For floors supporting shores under newly placed concrete, either leave original supporting shores in place, or install reshores or backshores. Shoring system and supporting slabs must resist anticipated loads. Locate reshores and backshores directly under a

shore position or as indicated on formwork shop drawings.

d. In multistory buildings, place reshoring or backshoring over a sufficient number of stories to distribute weight of newly placed concrete, forms, and construction live loads.

3.3.3 Reuse

a. Reuse forms providing the structural integrity of concrete and the aesthetics of exposed concrete are not compromised.

b. Wood forms must not be clogged with paste and must be capable of absorbing high water-cementitious material ratio paste.

c. Remove leaked mortar from formwork joints before reuse.

3.3.4 Forms for Standard Rough Form Finish

****

NOTE: According to ACI 301, surface finish-1.0 (SF-1.0) has the following requirements:
(a) No formwork facing material is specified
(b) Patch voids larger than 1-1/2 in. wide or 1/2 in. deep
(c) Remove projections larger than 1-in.
(d) Tie holes need not be patched
(e) Surface tolerance Class D as specified in ACI 117
(f) Mockup not required

****

Provide formwork in accordance with ACI 301 Section 5 with a surface finish, SF-1.0, for formed surfaces that are to be concealed by other construction.

3.3.5 Forms for Standard Smooth Form Finish

****

NOTE: When exposed to view, formed surfaces require a special architectural finish such as textured form finishes, sculptured inserts, special panel finish, and aggregate transfer finish. Requirements for such formwork must be specified. Select bracketed line for no mockup of the form finish otherwise mockup is required per ACI 301.

According to ACI 301, surface finish-3.0 (SF-3.0) has the following requirements:
(a) Patch voids larger than 3/4 in. wide or 1/2 in. deep
(b) Remove projections larger than 1/8 in.
(c) Patch tie holes
(d) Surface tolerance Class A as specified in ACI 117
(e) Provide mockup of concrete surface appearance and texture

****

Provide formwork in accordance with ACI 301 Section 5 with a surface finish, SF-3.0, for formed surfaces that are exposed to view.[Do not provide mockup of concrete surface appearance and texture.]

3.3.6 Form Ties

a. For post-tensioned structures, do not remove formwork supports until stressing records have been accepted by the Contracting Officer.

b. After ends or end fasteners of form ties have been removed, repair tie holes in accordance with ACI 301 Section 5 requirements.

3.3.7 Forms for Concrete Pan Joist Construction

Pan-form units for one-way or two-way concrete joist and slab construction must be factory-fabricated units of the approximate section indicated. Units must consist of steel or molded fiberglass concrete form pans. Closure units must be furnished as required.

3.3.8 Tolerances for Form Construction

a. Construct formwork so concrete surfaces conform to tolerances in ACI 117.

b. Position and secure sleeves, inserts, anchors, and other embedded items such that embedded items are positioned within ACI 117 tolerances.

c. To maintain specified elevation and thickness within tolerances, install formwork to compensate for deflection and anticipated settlement in formwork during concrete placement. Set formwork and intermediate screed strips for slabs to produce designated elevation, camber, and contour of finished surface before formwork removal. If specified finish requires use of vibrating screeds or roller pipe screeds, ensure that edge forms and screed strips are strong enough to support such equipment.

3.3.9 Removal of Forms and Supports

a. If vertical formed surfaces require finishing, remove forms as soon as removal operations will not damage concrete.

b. Remove top forms on sloping surfaces of concrete as soon as removal will not allow concrete to sag. Perform repairs and finishing operations required. If forms are removed before end of specified curing period, provide curing and protection.

c. Do not damage concrete during removal of vertical formwork for columns, walls, and sides of beams. Perform needed repair and finishing operations required on vertical surfaces. If forms are removed before end of specified curing period, provide curing and protection.

[d. Leave formwork and shoring in place to support construction loads and weight of concrete in beams, slabs, and other structural members until in-place required strength of concrete is reached.

] e. Form-facing material and horizontal facing support members may be removed before in-place concrete reaches specified compressive strength if shores and other supports are designed to allow facing removal without deflection of supported slab or member.

3.3.10 Strength of Concrete Required for Removal of Formwork

****

NOTE: Supporting forms and shores should not be removed from beams, floors, and walls until these structural units are strong enough to carry their own weight and any approved super-imposed load. In no case should supporting forms and shores be removed from horizontal members before the concrete has achieved the specified stripping strength. Shores supporting post-tensioned construction should not be removed until sufficient tensioning force is applied to support the dead load, formwork, and anticipated construction loads.

****

If removal of formwork, reshoring, or backshoring is based on concrete reaching a specified in-place strength, mold and field-cure cylinders in accordance with ASTM C31/C31M. Test cylinders in accordance with ASTM C39/C39M. Alternatively, use one or more of the methods listed herein to evaluate in-place concrete strength for formwork removal.

a. Tests of cast-in-place cylinders in accordance with ASTM C873/C873M. This option is limited to slabs with concrete depths from 12.5 to 30 cm 5 to 12 in.

b. Penetration resistance in accordance with ASTM C803/C803M.

c. Pullout strength in accordance with ASTM C900.

d. Maturity method in accordance with ASTM C1074. Submit maturity method data using project materials and concrete mix proportions used on the project to demonstrate the correlation between maturity and compressive strength of laboratory cured test specimens to the Contracting Officer.

3.4 WATERSTOP INSTALLATION AND SPLICES

a. Provide waterstops in construction joints as indicated.

b. Install formwork to accommodate waterstop materials. Locate waterstops in joints where indicated in Contract Documents. Minimize number of splices in waterstop. Splice waterstops in accordance with manufacturer's written instructions. Install factory-manufactured premolded mitered corners.

c. Install waterstops to form a continuous diaphragm in each joint. Make adequate provisions to support and protect waterstops during progress of work. Protect waterstops protruding from joints from damage.

3.4.1 PVC Waterstop

Make splices by heat sealing the adjacent waterstop edges together using a thermoplastic splicing iron utilizing a non-stick surface specifically designed for waterstop welding. Reform waterstops at splices with a remolding iron with ribs or corrugations to match the pattern of the waterstop. The spliced area, when cooled, must show no signs of separation, holes, or other imperfections when bent by hand in as sharp an angle as possible.

3.4.2 Rubber Waterstop

Rubber waterstops must be spliced using cold bond adhesive as recommended by the manufacturer.

3.4.3 Thermoplastic Elastomeric Rubber Waterstop

Fittings must be shop made using a machine specifically designed to mechanically weld the waterstop. A portable power saw must be used to miter or straight cut the ends to be joined to ensure good alignment and contact between joined surfaces. Maintain continuity of the characteristic features of the cross section of the waterstop (for example ribs, tabular center axis, and protrusions) across the splice.

3.4.4 Hydrophilic Waterstop

Miter cut ends to be joined with sharp knife or shears. The ends must be adhered with adhesive.

3.5 PLACING REINFORCEMENT AND MISCELLANEOUS MATERIALS

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

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

c. Nonprestressed cast-in-place concrete members must have concrete cover for reinforcement given in the following table:

Concrete Exposure	**Member**	**Reinforcement**	**Specified cover, mm in.**
Cast against and permanently in contact with ground	All	All	75 3
Exposed to weather or in contact with ground	All	No. 19 6 through No. 57 18 bars	50 2
		No. 16 5 bar, MW200 W31 or MD200 D31 wire, and smaller	40 1-1/2

Concrete Exposure	Member	Reinforcement	Specified cover, mm in.
Not exposed to weather or in contact with ground	Slabs, joists, and walls	No. 43 14 and No. 57 18 bars	40 1-1/2
		No. 36 11 bar and smaller	20 3/4
	Beams, columns, pedestals, and tension ties	Primary reinforcement, stirrups, ties, spirals, and hoops	40 1-1/2

d. Cast-in-place prestressed concrete members must have concrete cover for reinforcement, ducts, and end fittings given in the following table:

Concrete	Member	Reinforcement	Specified
Cast against and permanently in contact with ground	All	All	75 3
Exposed to weather or in contact with ground	Slabs, joists, and walls	All	25 1
	All other	All	40 1-1/2
Not exposed to weather or in contact with ground	Slabs, joists, and walls	All	20 3/4
	Beams, columns, and tension ties	Primary reinforcement	40 1-1/2
		Stirrups, ties, spirals, and hoops	25 1

e. Precast nonprestressed or prestressed concrete members manufactured under plant conditions must have concrete cover for reinforcement, ducts, and end fittings given in the following table:

Concrete Exposure	Member	Reinforcement	Specified cover, mm in.
Exposed to weather or in contact with ground	Walls	No. 43 14 and No. 57 18 bars; tendons larger than 40 mm 1-1/2 in. diameter	40 1-1/2
		No. 36 11 bars and smaller; MW200 W31 and MD200 D31 wire, and smaller; tendons and strands 40 mm 1-1/2 in.	20 3/4
	All other	No. 43 14 and No. 57 18 bars; tendons larger than 40 mm 1-1/2 in.	50 2
		No. 19 6 through No. 36 11 bars; tendons and strands larger than 16 mm 5/8 in. diameter through 40 mm 1-1/2 in.	40 1-1/2
		No. 16 5 bar, MW200 W31 or MD200 D31 wire, and smaller; tendons and strands 16 mm 5/8 in. diameter and smaller	30 1-1/4

Concrete Exposure	Member	Reinforcement	Specified cover, mm in.
Not exposed to weather or in contact with ground	Slabs, joists, and walls	No. 43 14 and No. 57 18 bars; tendons larger than 40 mm 1-1/2 in. diameter	30 1-1/4
		Tendons and strands 40 mm 1-1/2 in. diameter and smaller	20 3/4
		No. 36 11 bar, MW200 W31 or MD200 D31	16 5/8
	Beams, columns, pedestals, and tension ties	Primary reinforcement	Greater of bar diameter and 16 5/8 and need not exceed 40 1-1/2
		Stirrups, ties, spirals, and hoops	10 3/8

3.5.1 General

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

3.5.2 Vapor Retarder [and Vapor Barrier]

****

NOTE: Locate vapor retarder below the slab-on-grade per ACI 360R, figure 4.7.

****

a. Install in accordance with ASTM E1643. Provide beneath the on-grade concrete floor slab. Use the greatest widths and lengths practicable to eliminate joints wherever possible. Lap joints a minimum of 300 mm 12 inches and tape.

b. Remove torn, punctured, or damaged vapor retarder[and vapor barrier] material and provide with new vapor retarder[and vapor barrier] prior to placing concrete. Concrete placement must not damage vapor retarder[and vapor barrier material].[Place a 50 mm 2 inch layer of clean concrete sand on vapor retarder[and vapor barrier] before placing concrete.][Place vapor barrier directly on underlying subgrade, base course, or capillary water barrier, unless it consists of crushed material or large granular material which could puncture the vapor barrier. In this case, a thin layer of approximately 13 mm

1/2 inch of fine graded material should be rolled or compacted over the fill before installation of the vapor barrier to reduce the possibility of puncture. Control concrete placement so as to prevent damage to the vapor barrier.]

3.5.3 Perimeter Insulation

****

NOTE: When this paragraph is used, ensure that drawings indicate location and extent of perimeter insulation.

****

Install perimeter insulation at locations indicated. Adhesive must be used where insulation is applied to the interior surface of foundation walls and may be used for exterior application.

3.5.4 Reinforcement Supports

****

NOTE: ACI 301 requirements have change for welded wire reinforcement support. If reinforcement less than W4.0 or D4.0 is specified, the continuous support spacing should be less than or equal to 30 cm 12 in.

****

Provide reinforcement support in accordance with CRSI RB4.1 and ACI 301 Section 3 requirements. Supports for coated or galvanized bars must also be coated with electrically compatible material for a distance of at least 50 mm 2 inches beyond the point of contact with the bars.

[3.5.5 Epoxy Coated Reinforcing

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

3.5.5.1 Epoxy Coated Reinforcing Steel Placement and Coating Repair

Carefully handle and install bars to minimize job site patching. Use the same precautions as described in the paragraph titled EPOXY-COATED REINFORCING BARS. 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, are completely free of damaged areas; however, excessive nicks and scrapes which expose steel is 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, manually remove any rust and debonded coating from the reinforcement by suitable techniques employing devices such as wire brushes and emery paper. Exercise cars during this surface preparation so that the damaged areas are not enlarged more than necessary to accomplish the repair. Clean damaged areas of dirt, debris, oil, and similar

materials prior to application of the patching material.

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

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

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

]]3.5.6 Splicing

****
NOTE: When indicated, include ASTM A767/A767M and ASTM A780/A780M for zinc-coated (galvanized) bars.
****

As indicated in the Contract Documents. For splices not indicated follow ACI 301. Do not splice at points of maximum stress. Overlap welded wire reinforcement the spacing of the cross wires, plus 50 mm 2 inches.[AWS D1.4/D1.4M. Approve welded splices prior to use.][Repair the cut ends of hot-dipped galvanized reinforcement steel to completely coat exposed steel, ASTM A780/A780M.]

3.5.7 Future Bonding

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

3.5.8 Setting Miscellaneous Material

Place and secure anchors and bolts, pipe sleeves, conduits, and other such items in position before concrete placement and support against displacement. Plumb anchor bolts and check location and elevation. Temporarily fill voids in sleeves with readily removable material to prevent the entry of concrete.

3.5.9 Fabrication

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

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

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

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

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

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

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

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

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

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

3.5.10 Placing Reinforcement

Place reinforcement in accordance with ACI 301.

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

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

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

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

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

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

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

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

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

3.5.11 Spacing of Reinforcing Bars

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

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

3.5.12 Concrete Protection for Reinforcement

****

NOTE: If the required concrete protection for reinforcement is greater than the thicknesses specified in the ACI building code requirements for reinforced concrete, (such as in extremely corrosive atmospheres or other severe exposures, for fire protection covering, and for concrete surface to receive exposed aggregate or tooled finish), such concrete protection for reinforcement must be indicated in the Contract Documents. ACI 201.2R and ACI 303R require additional concrete protection for severe exposure conditions. Also, refer to ACI 515.2R "Guide to Selecting Protective Treatments for Concrete" for more information about providing additional protection to concrete and reinforcing steel.

****

Additional concrete protection must be in accordance with the Contract Documents.

3.5.13 Welding

Welding must be in accordance with AWS D1.4/D1.4M.

3.6 BATCHING, MEASURING, MIXING, AND TRANSPORTING CONCRETE

In accordance with ASTM C94/C94M, ACI 301, ACI 302.1R and ACI 304R, except as modified herein. Batching equipment must be such that the concrete ingredients are consistently measured within the following tolerances: 1 percent for cement and water, 2 percent for aggregate, and 3 percent for admixtures. Furnish mandatory batch ticket information for each load of ready mix concrete.

3.6.1 Measuring

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

3.6.2 Mixing

a. Mix concrete in accordance with ASTM C94/C94M, ACI 301 and ACI 304R.

****

NOTE: Include optional sentence if greater than 90 minutes will be allowed for concrete placing.

****

b. 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 discharge is acceptable after more than 90 minutes the air content, slump, and concrete temperature shall be tested and shall be within the specified limits.] A retarder shall be used to facilitate placing and finishing when concrete temperature is 30 degrees C 85 degrees F or greater.

c. [If the entrained air content falls below the specified limit, add a sufficient quantity of admixture, within the manufacturer's recommended dosage, 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. Do not reconstitute concrete that has begun to solidify.

d. When fibers are used, add fibers together with the aggregates and never as the first component in the mixer. Fibers must be dispensed into the mixing system using appropriate dispensing equipment and procedure as recommended by the manufacturer.

3.6.3 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.

3.7 PLACING CONCRETE

****
NOTE: When necessary to deposit concrete under water, use specifications 03 31 30 MARINE CONCRETE.
****

Place concrete in accordance with ACI 301 Section 5. Concrete shall be placed within 15 minutes of discharge into non-agitating equipment.

[3.7.1 Footing Placement

Concrete for footings may be placed in excavations without forms upon inspection and approval by the Contracting Officer. Excavation width must be a minimum of 100 mm 4 inches greater than indicated.

][3.7.2 Pumping

****
NOTE: Pumping, especially lightweight concrete, requires careful attention to mix designs and pumping procedures. Allow pumping when other means of placement are impractical or more expensive.
****

ACI 304R and ACI 304.2R. Pumping must 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 must not exceed 50 mm 2 inches at discharge/placement. Do not convey concrete through pipe made of aluminum or aluminum alloy. Avoid rapid changes in

pipe sizes. Limit maximum size of course aggregate to 33 percent of the diameter of the pipe. Limit maximum size of well-rounded aggregate 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.

[3.7.2.1 Pumping Lightweight Concrete

****
NOTE: Specify minimum of 330 kg per cubic meter 564 pounds per cubic yard unless structural considerations require higher cement content. Require field trial run only when justified by job complexities or size.
****

In accordance with ACI 213R unless otherwise specified. Presoak or presaturate aggregates. Cement content must be minimum of [330 kg per cubic meter] [564 pounds per cubic yard] [_____] and be sufficient to accommodate a 100 to 150 mm 4 to 6 inch slump.[Make field trial run in accordance with ACI 213R.]

]]3.7.3 Cold Weather

****
NOTE: The major difference between ACI 301 and ACI 306.1 is that ACI 306.1 requires the contractor to submit detailed procedures (a plan) for cold weather concrete.
****

Cold weather concrete must meet the requirements of [ACI 301][ACI 306.1] unless otherwise specified. Do not allow concrete temperature to decrease below 10 degrees C 50 degrees F. Obtain approval prior to placing concrete when the 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 37 degrees F in any one hour and 10 degrees C 50 degrees F per 24 hours after heat application.

3.7.4 Hot Weather

****
NOTE: The major difference between ACI 301 and ACI 305.1 is that ACI 305.1 requires the contractor to submit detailed procedures (a plan) for hot weather concrete.
****

[Hot weather concrete must meet the requirements of [ACI 301][ACI 305.1] unless otherwise specified.]Maintain required concrete temperature using Figure 4.2 in ACI 305R to prevent the evaporation rate from exceeding 1 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. 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.

3.7.5 Bonding

Surfaces of set concrete at joints, must be roughened and cleaned of laitance, coatings, loose particles, and foreign matter. Roughen surfaces in a manner that exposes the aggregate uniformly and does not leave laitance, loosened particles of aggregate, nor damaged concrete at the surface.

Obtain bonding of fresh concrete that has set as follows:

a. At joints between footings and walls or columns, between walls or columns and the beams or slabs they support, and elsewhere unless otherwise specified; roughened and cleaned surface of set concrete must be dampened, but not saturated, immediately prior to placing of fresh concrete.

b. At joints in exposed-to-view work; at vertical joints in walls; at joints near midpoint of span in girders, beams, supported slabs, other structural members; in work designed to contain liquids; the roughened and cleaned surface of set concrete must be dampened but not saturated and covered with a cement grout coating.

c. Provide cement grout that consists of equal parts of portland cement and fine aggregate by weight with not more than 22.5 liters 6 gallons of water per sack of cement. Apply cement grout with a stiff broom or brush to a minimum thickness of 1.6 mm 1/16 inch. Deposit fresh concrete before cement grout has attained its initial set.

3.8 WASTE MANAGEMENT

Provide as specified in the Waste Management Plan and as follows.

3.8.1 Mixing Equipment

Before concrete pours, designate[Contractor-owned site meeting environmental standards][on-site area to be paved later in project] for cleaning out concrete mixing trucks. Minimize water used to wash equipment.

****

NOTE: The use of crushed waste concrete as an aggregate in the production of new concrete should follow the recommendations of ACI 555R.

****

3.8.2 Hardened, Cured Waste Concrete

[Crush and reuse hardened, cured waste concrete as fill or as a base course for pavement.][Use hardened, cured waste concrete as aggregate in concrete mix if approved by Contracting Officer.]

3.8.3 Reinforcing Steel

Collect reinforcing steel and place in designated area for recycling.

3.8.4 Other Waste

Identify concrete manufacturer's or supplier's policy for collection or return of construction waste, unused material, deconstruction waste, and/or packaging material.[Return excess cement to supplier.][Institute deconstruction and construction waste separation and recycling for use in manufacturer's programs. When such a program is not available, seek local recyclers to reclaim the materials.]

3.9 SURFACE FINISHES EXCEPT FLOOR, SLAB, AND PAVEMENT FINISHES

3.9.1 Defects

Repair surface defects in accordance with ACI 301 Section 5.

3.9.2 Not Against Forms (Top of Walls)

Surfaces not otherwise specified must be finished with wood floats to even surfaces. Finish must match adjacent finishes.

3.9.3 Formed Surfaces

3.9.3.1 Tolerances

Tolerances in accordance with ACI 117 and as indicated.

3.9.3.2 As-Cast Rough Form

Provide for surfaces not exposed to public view a surface finish SF-1.0. Patch holes and defects in accordance with ACI 301.

3.9.3.3 Standard Smooth Finish

Provide for surfaces exposed to public view a surface finish SF-3.0. Patch holes and defects in accordance with ACI 301.

3.9.4 [Smooth-Rubbed][Grout-Cleaned Rubbed][Cork-Floated][Exposed Aggregate] Finish

****
NOTE: Add information where special type of finish is desired. See 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 on the drawings and coordinated with the specifications.
****

[Provide a smooth-rubbed finish per ACI 301 Section 5 in the locations indicated.][Provide a grout-cleaned rubbed finish per ACI 301 Section 5 in the locations indicated.][Provide a cork-floated finish per ACI 301 Section 5 in the locations indicated.][Provide an exposed aggregate finish per ACI 301 Section 5 in the locations indicated.]

3.10 FLOOR, SLAB, AND PAVEMENT FINISHES AND MISCELLANEOUS CONSTRUCTION

****
NOTE: Where floor flatness is critical use paragraph FLAT FLOOR FINISHES. Coordinate concrete finish with applicable architectural finish material to be installed over concrete floor. For thin-set tile, coordinate with Section 09 30 10 CERAMIC, QUARRY, AND GLASS TILING
****

In accordance with ACI 301 and ACI 302.1R, unless otherwise specified. Slope floors uniformly to drains where drains are provided.[Depress the concrete base slab where quarry tile, ceramic tile, [or] [_____] are indicated.][Steel trowel and fine-broom finish concrete slabs that are to receive quarry tile, ceramic tile, or paver tile [_____].] Where straightedge measurements are specified, Contractor must provide straightedge.

3.10.1 Finish

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 the excess water off or remove by absorption with porous materials. Do not use dry cement to absorb bleedwater. Grate tampers ("jitterbugs") shall not be used.

3.10.1.1 Scratched

Use for surfaces intended to receive bonded applied cementitious applications. Finish concrete in accordance with ACI 301 Section 5 for a scratched finish.

3.10.1.2 Floated

Use for [surfaces to receive [roofing,] [waterproofing membranes,] [sand bed terrazzo,]] [_____] [and] [exterior slabs where not otherwise specified.] Finish concrete in accordance with ACI 301 Section 5 for a floated finish.

[3.10.1.3 Concrete Containing Silica Fume

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

]3.10.1.4 Steel Troweled

****
NOTE: ACI 302.1R suggests power troweling three times for Class 5 floors and where increased wear resistance is needed.
****

Use for floors intended as walking surfaces[,] [and] for reception of floor coverings[, and] [_____]. Finish concrete in accordance with ACI 301 Section 5 for a steel troweled finish.

[3.10.1.5 Nonslip Finish

****
NOTE: Include when nonslip finish using dry shake aggregate is desired.
****

Use on surfaces of exterior platforms, steps, and landings; and on exterior and interior pedestrian ramps. Finish concrete in accordance with ACI 301 Section 5 for a dry-shake finish. After the selected material has been embedded by the two floatings, complete the operation with a [broomed] [floated] [troweled] finish.

]3.10.1.6 Broomed

Use on surfaces of exterior walks, platforms, patios, and ramps, unless otherwise indicated. Finish concrete in accordance with ACI 301 Section 5 for a broomed finish.

3.10.1.7 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.

3.10.1.8 Concrete Toppings Placement

The following requirements apply to the placement of toppings of concrete on base slabs that are either freshly placed and still plastic, or on hardened base slabs.

a. Placing on a Fresh Base: Screed and bull float the base slab. As soon as the water sheen has disappeared, lightly rake the surface of the base slab with a stiff bristle broom to produce a bonding surface for the topping. Immediately spread the topping mixture evenly over the roughened base before final set takes place. Give the topping the finish [indicated on the drawings] [specified herein].

b. Bonding to a Hardened Base: When the topping is to be bonded to a floated or troweled hardened base, roughen the base by scarifying, grit-blasting, scabbling, planing, flame cleaning, or acid-etching to lightly expose aggregate and provide a bonding surface. Remove dirt, laitance, and loose aggregate by means of a stiff wire broom. Keep the clean base wet for a period of 12 hours preceding the application of the topping. Remove excess water and apply a 1:1:1/2 cement-sand-water grout, and brush into the surface of the base slab. Do not allow the cement grout to dry, and spread it only short distances ahead of the topping placement. Do not allow the temperature differential between the completed base and the topping mixture to exceed 5 degrees C 41 degrees F at the time of placing.

Place the topping and finish as[indicated][specified herein].

3.10.1.9 Chemical-Hardener Treatment

****

NOTE: Slab surfaces requiring a chemical hardener must be indicated. Such treatment is suitable for surfaces of concrete floors in equipment rooms and on other floor surfaces that are subject to light foot traffic only and must not be covered with resilient flooring, paint, or other finish coating.

****

[Apply liquid-chemical floor hardener where indicated after curing and drying concrete surface. Dilute liquid hardener with water and apply in three coats. First coat must be one-third strength, second coat one-half strength, and third coat two-thirds strength. Apply each coat evenly and allow to dry 24 hours between coats.

Approved proprietary chemical hardeners must be applied in accordance with manufacturer's printed directions.

]3.10.1.10 Colored Wear-Resistant Finish

****

NOTE: Slab surfaces requiring colored, wear-resistant finish must be indicated. Such finish is suitable for exterior and interior slabs that are subject to medium-heavy foot traffic.

****

[a. Give finish to monolithic slab surfaces where indicated.

b. Apply dry shake materials for colored wear-resistant finish at the rate of 29 kilogram per 10 square meter 60 pounds per 100 square feet of surface.

c. Immediately following first floating operation, approximately two-thirds of specified weight of dry shake material must be uniformly distributed over surface and embedded by means of power floating. After first dry-shake application has been embedded, uniformly distribute remainder of dry-shake material over surface at right angles to first dry-shake application and embed by means of power floating. Trueness of surface and other requirements for floating operations not specified in this paragraph must be as specified for float finish.

d. After completion of float finish, apply a trowel finish as specified.

]3.10.1.11 Heavy-Duty Wear-Resistant Finish

****

NOTE: Delete paragraph heading and following paragraphs when not applicable. Slab surfaces requiring heavy-duty wear-resistant finish must be indicated. Traprock and emery aggregate finish are suitable for exterior and interior slabs that are subject to abrasive wear. Iron aggregate finish is suitable for interior slabs that are not subject to

excessive amounts of moisture and are subject to abrasive wear and some impact.
****

a. Give finish to slab surfaces where indicated.

b. Dry-shake material for heavy-duty, wear-resistant finish must consist of a mixture of standard portland cement and aggregate for heavy-duty, wear-resistant finish proportioned by weight as follows:

One part standard portland cement and [two parts traprock aggregate for heavy-duty wear-resistant finish] [four parts emery aggregate for heavy-duty wear-resistant finish] [two parts by weight iron aggregate for heavy-duty, wear-resistant finish].

c. Apply blended dry-shake material as follows:

****
NOTE: Select type of aggregate.
****

Maximum type of aggregate in dry shake	**Amount per 100 square meter feet of Surface**
Traprock	73 kilogram 160 pounds
Emery	59 kilogram 130 pounds
Iron	59 kilogram 130 pounds

d. Immediately following the first floating operation, approximately one-half the specified weight of blended, uniformly distribute dry-shake materials over the surface and embedded by means of power floating. After the first dry-shake application has been embedded, uniformly distribute the remaining one-half of the blended dry-shake material over the surface at right angles to the first dry-shake application and embedded by means of power floating. Trueness of surface and other requirements for floating operations not specified in this paragraph must be as specified for float finish.

e. After completion of the float finish, trowel finish the surface as specified.

[3.10.2 Flat Floor Finishes

****
NOTE: Use these paragraphs where floor flatness is critical. Indicate areas where these requirements apply. Flatness affects the appearance and function of finishes applied to the concrete and in situations such as large or long expanses of glossy floor materials. Low tolerance for product (for example thin set tile and wood gymnasium floors) and equipment dictates to the designer to specify higher than normal flatness requirements. The numbers provided in brackets are typical numbers, but A/E should research and select F numbers high enough to

get desired results but not so high as to cause undue cost increases and construction problems. Ff/FL 20/15 is equivalent to 8 mm in 5.05 mm 5/16 inches in 10 feet. This test method is not suitable for unshored deck. Fitted partitions need FL greater than or equal to 25.

When specifying floors where flatness is important, adhere primarily to good concrete fundamentals, including equalizing hydration on top and bottom, reducing shrinkage prone cement paste content, and paying attention to curing protocol (slower is better).

****

ACI 302.1R. Construct in accordance with one of the methods recommended in Table 10.15.3a, "Slab-on-ground flatness/levelness construction guide" or Table 10.15.3b, "Suspended slab flatness/levelness construction guide" appropriate for the type of construction. ACI 117 for tolerance tested by ASTM E1155.

a. Specified Conventional Value:

Floor Flatness (Ff) [20] [_____] [13] [_____] minimum

Floor Levelness (FL) [15] [_____] [10] [_____] minimum

b. Specified Industrial:

Floor Flatness (Ff) [30] [_____] [15] [_____] minimum

Floor Levelness (FL) [20] [_____] [10] [_____] minimum

3.10.2.1 Measurement of Floor Tolerances

Test slab within 24 hours of the final troweling. Provide tests to Contracting Officer within 12 hours after collecting the data. Floor flatness inspector is required to provide a tolerance report which must include:

a. Key plan showing location of data collected.

b. Results required by ASTM E1155.

3.10.2.2 Remedies for Out of Tolerance Work

Contractor is required to repair and retest any floors not meeting specified tolerances. Prior to repair, Contractor must submit and receive approval for the proposed repair, including product data from any materials proposed. Repairs must not result in damage to structural integrity of the floor. For floors exposed to public view, repairs must prevent any uneven or unusual coloring of the surface.

]3.10.3 Concrete Walks

Provide 100 mm 4 inches thick minimum. Provide contraction joints spaced every 1500 lineal mm 5 linear feet unless otherwise indicated. Cut contraction joints 25 mm 1 inch deep, or one fourth the slab thickness whichever is deeper, with a jointing tool after the surface has been

finished. Provide 13 mm 0.5 inch thick transverse expansion joints at changes in direction where sidewalk abuts curb, steps, rigid pavement, or other similar structures; space expansion joints every 15 m 50 feet maximum. Give walks a broomed finish. Unless indicated otherwise, provide a transverse slope of 1/48. Limit variation in cross section to 6 mm in 1500 mm 1/4 inch in 5 feet.

3.10.4 Pits and Trenches

Place bottoms and walls monolithically or provide waterstops and keys.

3.10.5 Curbs[and Gutters]

Provide contraction joints spaced every 3 m 10 feet maximum unless otherwise indicated. Cut contraction joints 20 mm 3/4 inch deep with a jointing tool after the surface has been finished. Provide expansion joints 13 mm 1/2 inch thick and spaced every 30 m 100 feet maximum unless otherwise indicated. Perform pavement finish.

[3.10.6 Splash Blocks

Provide at outlets of downspouts emptying at grade. Splash blocks may be precast concrete, and must be 600 mm long, 300 mm wide and 100 mm thick 24 inches long, 12 inches wide and 4 inches thick, unless otherwise indicated, with smooth-finished countersunk dishes sloped to drain away from the building.

]3.11 JOINTS

3.11.1 Construction Joints

Make and locate joints not indicated so as not to impair strength and appearance of the structure, as approved. Joints must be perpendicular to main reinforcement. Reinforcement must be continued and developed across construction joints. Locate construction joints as follows:

3.11.1.1 Construction Joints for Constructability Purposes

a. In walls, at top of footing; at top of slabs on ground; at top and bottom of door and window openings or where required to conform to architectural details; and at underside of deepest beam or girder framing into wall.

b. In columns or piers, at top of footing; at top of slabs on ground; and at underside of deepest beam or girder framing into column or pier.

c. Near midpoint of spans for supported slabs, beams, and girders unless a beam intersects a girder at the center, in which case construction joints in girder must offset a distance equal to twice the width of the beam. Make transfer of shear through construction joint by use of inclined reinforcement.

Provide keyways at least 40 mm 1-1/2-inches deep in construction joints in walls and slabs and between walls and footings; approved bulkheads may be used for slabs.

3.11.2 Isolation Joints in Slabs on Ground

****

NOTE: If inserts are to be used for slab on ground contraction joint use bracketed paragraph and remove paragraph related to sawcut joints.
****

a. Provide joints at points of contact between slabs on ground and vertical surfaces, such as column pedestals, foundation walls, grade beams, and elsewhere as indicated.

b. Fill joints with premolded joint filler strips 13 mm 1/2 inch thick, extending full slab depth. Install filler strips at proper level below finish floor elevation with a slightly tapered, dress-and-oiled wood strip temporarily secured to top of filler strip to form a groove not less than 19 mm 3/4 inch in depth where joint is sealed with sealing compound and not less than 6 mm 1/4 inch in depth where joint sealing is not required. Remove wood strip after concrete has set. Contractor must clean groove of foreign matter and loose particles after surface has dried.

3.11.3 Contraction Joints in Slabs on Ground

a. Provide joints to form panels as indicated.

b. Under and on exact line of each control joint, cut 50 percent of welded wire reinforcement before placing concrete.

c. Sawcut contraction joints into slab on ground in accordance with ACI 301 Section 5.

[d. Joints must be 4 mm 1/8-inch wide by 1/5 to 1/4 of slab depth and formed by inserting hand-pressed fiberboard strip into fresh concrete until top surface of strip is flush with slab surface. After concrete has cured for at least 7 days, the Contractor must remove inserts and clean groove of foreign matter and loose particles.

] **********
NOTE: Use the following bracketed sentence for projects in Hawaii.
****

[e. Sawcutting will be limited to within 12 hours after set and at 1/4 slab depth.

]3.11.4 Sealing Joints in Slabs on Ground

a. Contraction and control joints which are to receive finish flooring material must be sealed with joint sealing compound after concrete curing period. Slightly underfill groove with joint sealing compound to prevent extrusion of compound. Remove excess material as soon after sealing as possible.

b. Sealed groove must be left ready to receive filling material that is provided as part of finish floor covering work.

3.12 CONCRETE FLOOR TOPPING

3.12.1 Standard Floor Topping

****

NOTE: When standard floor topping is specifically required, the location of standard floor topping must be indicated.

****

Provide topping for treads and platforms of metal steel stairs and elsewhere as indicated.

3.12.1.1 Preparations Prior to Placing

a. When topping is placed on a green concrete base slab, screed surface of base slab to a level not more than 38 mm 1-1/2 inches nor less than 25 mm 1 inch below required finish surface. Remove water and laitance from surface of base slab before placing topping mixture. As soon as water ceases to rise to surface of base slab, place topping.

b. When topping is placed on a hardened concrete base slab, remove dirt, loose material, oil, grease, asphalt, paint, and other contaminants from base slab surface, leaving a clean surface. Prior to placing topping mixture, 64 mm 2-1/2-inches minimum, slab surface must be dampened and left free of standing water. Immediately before topping mixture is placed, broom a coat of neat cement grout onto surface of slab. Do not allow cement grout to set or dry before topping is placed.

c. When topping is placed on a metal surface, such as metal pans for steel stairs, remove dirt, loose material, oil, grease, asphalt, paint, and other contaminants from metal surface.

3.12.1.2 Placing

Spread standard topping mixture evenly on previously prepared base slab or metal surface, brought to correct level with a straightedge, and struck off. Topping must be consolidated, floated, checked for trueness of surface, and refloated as specified for float finish.

3.12.1.3 Finishing

Give trowel finish standard floor topping surfaces.

****

NOTE: Standard floor topping surfaces requiring an applied finish such as a chemical-hardener, non-slip aggregate finish, colored wear-resistant finish, sealers, or heavy-duty, wear-resistant finish must be indicated.

****

Give other finishes standard floor topping surfaces as indicated.

3.12.2 Heavy-Duty Floor Topping

****

NOTE: Location of heavy-duty floor topping must be

indicated. Heavy-duty floor topping is suitable for an industrial floor subject to continuous severe abrasion and impact such as steel-tire vehicles.

****

Provide topping where indicated.

3.12.2.1 Heavy-duty Topping Mixture

Provide mixture that consists of 1 part portland cement and 2-1/2 parts emery aggregate or 1 part fine aggregate and 1-1/2 parts traprock coarse aggregate, by volume. Exact proportions of mixture must conform to recommendations of aggregate manufacturer. Mixing water must not exceed 14.2 liter per 43 kilogram 3-1/4 gallons per 94-pound sack of cement including unabsorbed moisture in aggregate. Maximum slump must be 25 mm 1 inch.

3.12.2.2 Base Slab

a. Screed surface of slab to a level no more than 38 mm 1-1/2 inches nor less than 25 mm 1 inch below grade of finished floor.

b. Give slab a scratch finish as specified.

c. Preparations prior to placing.

Remove dirt, loose material, oil, grease, asphalt, paint and other contaminants from base slab surface. Prior to placing topping mixture, dampen slab surface and leave free of standing water. Immediately before topping mixture is placed, broom a coat of neat cement grout onto surface of slab. Allow cement grout to set or dry before topping mixture is placed.

3.12.2.3 Placing

Spread heavy-duty topping mixture evenly on previously prepared base slab, and bring to correct level with a straightedge, and strike off. Provide topping that is consolidated, floated, and checked for trueness of surface as specified for float finish, except that power-driven floats is the impact type.

3.12.2.4 Finishing

Give trowel finish heavy-duty floor topping surfaces. Provide trowel finish as specified, except that additional troweling after first power troweling must be not less than three hand-troweling operations.

3.13 CURING AND PROTECTION

****

NOTE: Add to "Curing and Protection" when using silica fume.

Prevent concrete with silica fume from drying by one or more of the following:

1. Misting surface of concrete with fog nozzle;

2. Liquid membrane-forming compound;

3. Pervious or impervious sheeting.

Increase curing time per manufacturer's recommendations.

****

Curing and protection in accordance with ACI 301 Section 5, unless otherwise specified. Begin curing immediately following form removal. Avoid damage to concrete from vibration created by blasting, pile driving, movement of equipment in the vicinity, disturbance of formwork or protruding reinforcement, 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. Allow curing compound/sealer installations to cure prior to the installation of materials that adsorb VOCs, including [_____].

3.13.1 Requirements for Type III, High-Early-Strength Portland Cement

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

3.13.2 Curing Periods

ACI 301 Section 5, except 10 days for retaining walls, pavement or chimneys. Begin curing immediately after placement. Protect concrete from premature drying, excessively hot temperatures, and mechanical injury; and maintain minimal moisture loss at a relatively constant temperature for the period necessary for hydration of the cement and hardening of the concrete. The materials and methods of curing are subject to approval by the Contracting Officer.

3.13.3 Curing Formed Surfaces

Accomplish curing of formed surfaces, including undersurfaces of girders, beams, supported slabs, and other similar surfaces by moist curing with forms in place for full curing period or until forms are removed. If forms are removed before end of curing period, accomplish final curing of formed surfaces by any of the curing methods specified above, as applicable.

3.13.4 Curing Unformed Surfaces

a. Accomplish initial curing of unformed surfaces, such as monolithic slabs, floor topping, and other flat surfaces, by membrane curing.

[b. Accomplish final curing of unformed surfaces by any of curing methods specified, as applicable.

] c. Accomplish final curing of concrete surfaces to receive liquid floor hardener of finish flooring by moisture-retaining cover curing.

3.13.5 Temperature of Concrete During Curing

When temperature of atmosphere is 5 degrees C 41 degrees F and below, maintain temperature of concrete at not less than 13 degrees C 55 degrees F throughout concrete curing period or 7 degrees C 45 degrees F when the curing period is measured by maturity. When necessary, make arrangements before start of concrete placing for heating, covering, insulation, or housing as required to maintain specified temperature and moisture conditions for concrete during curing period.

When the temperature of atmosphere is 27 degrees C 80 degrees F and above or during other climatic conditions which cause too rapid drying of concrete, make arrangements before start of concrete placing for installation of wind breaks, of shading, and for fog spraying, wet sprinkling, or moisture-retaining covering of light color as required to protect concrete during curing period.

Changes in temperature of concrete must be uniform and not exceed 3 degrees C 37 degrees F in any one hour nor 27 degrees C 80 degrees F in any 24-hour period.

3.13.6 Protection from Mechanical Injury

During curing period, protect concrete from damaging mechanical disturbances, particularly load stresses, heavy shock, and excessive vibration and from damage caused by rain or running water.

3.13.7 Protection After Curing

Protect finished concrete surfaces from damage by construction operations.

3.14 FIELD QUALITY CONTROL

3.14.1 Aggregate Testing

3.14.1.1 Fine Aggregate

At least once during each shift when the concrete plant is operating, there shall be one sieve analysis and fineness modulus determination in accordance with ASTM C136/C136M and COE CRD-C 104 for the fine aggregate or for each fine aggregate if it is batched in more than one size or classification. The location at which samples are taken may be selected by the Contractor as the most advantageous for control. However, the Contractor is responsible for delivering fine aggregate to the mixer within specification limits. When the amount passing on any sieve is outside the specification limits, the fine aggregate shall be immediately resampled and retested. If there is another failure on any sieve, the fact shall be immediately reported to the Contracting Officer, concreting shall be stopped, and immediate steps taken to correct the grading.

3.14.1.2 Coarse Aggregate

At least once during each shift in which the concrete plant is operating, there shall be a sieve analysis in accordance with ASTM C136/C136M for each size of coarse aggregate. The location at which samples are taken may be selected by the Contractor as the most advantageous for production control. However, the Contractor shall be responsible for delivering the aggregate to the mixer within specification limits. A test record of

samples of aggregate taken at the same locations shall show the results of the current test as well as the average results of the five most recent tests including the current test. The Contractor may adopt limits for control coarser than the specification limits for samples taken other than as delivered to the mixer to allow for degradation during handling. When the amount passing any sieve is outside the specification limits, the coarse aggregate shall be immediately resampled and retested. If the second sample fails on any sieve, that fact shall be reported to the Contracting Officer. Where two consecutive averages of 5 tests are outside specification limits, the operation shall be considered out of control and reported to the Contracting Officer. Concreting shall be stopped and immediate steps shall be taken to correct the grading.

3.14.2 Concrete Sampling

ASTM C172/C172M. Collect samples of fresh concrete to perform tests specified. ASTM C31/C31M for making test specimens.

3.14.3 Concrete Testing

3.14.3.1 Slump Tests

ASTM C143/C143M. Take concrete samples during concrete placement/discharge. The maximum slump may be increased as specified with the addition of an approved admixture provided that the water-cementitious material ratio is not exceeded. Perform tests at commencement of concrete placement, when test cylinders are made[, and for each [_____] cubic meters cubic yards (maximum) of concrete].

3.14.3.2 Temperature Tests

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 Cbelow 50 degrees F and above 80 degrees F) for each batch (minimum) or every 16 cubic meters 20 cubic yards (maximum) of concrete, until the specified temperature is obtained, and whenever test cylinders and slump tests are made.

3.14.3.3 Compressive Strength Tests

****

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

Use eight cylinders when specifying 56 or 90 day strengths. Use 6x12 cylinders for better prediction of strength and consistency.

****

ASTM C39/C39M. Make [six][eight] 150 mm by 300 mm 6 inch by 12 inch or [nine][12] 100 mm by 200 mm 4 inch by 8 inch test cylinders for each set of tests in accordance with ASTM C31/C31M, ASTM C172/C172M and applicable requirements of ACI 305R and ACI 306R. Take precautions to prevent evaporation and loss of water from the specimen. Test two 150 mm by 300 mm 6 inch by 12 inch or three 100 mm by 200 mm 4 inch by 8 inch cylinders at 7 days, two 150 mm by 300 mm 6 inch by 12 inch or three 100 mm by 200 mm 4

inch by 8 inch cylinders at 28 days,[two 150 mm by 300 mm 6 inch by 12 inch or three 100 mm by 200 mm 4 inch by 8 inch cylinders at 56 days][two 150 mm by 300 mm 6 inch by 12 inch or three 100 mm by 200 mm 4 inch by 8 inch cylinders at 90 days][and hold two 150 mm by 300 mm 6 inch by 12 inch or three 100 mm by 200 mm 4 inch by 8 inch cylinders in reserve]. Take samples for strength tests for each concrete mixture placed each day not less than once a day, nor less than once for each 115 cubic meters 150 cubic yards of concrete, nor less than once for each 450 square meters 5000 square feet of surface area for slabs or walls. For the entire project, take no less than five sets of samples and perform strength tests for each mix design of concrete placed. Each strength test result must be the average of two 150 mm by 300 mm 6 inch by 12 inch or three 100 mm by 200 mm 4 inch by 8 inch cylinders from the same concrete sample tested at 28 days [56 days] [90 days] [_____]. Concrete compressive tests must meet the requirements of this section, the Contract Document, and ACI 301.

[3.14.3.4 Air Content

ASTM C173/C173M or ASTM C231/C231M for normal weight concrete [and ASTM C173/C173M for lightweight concrete]. Test air-entrained concrete for air content at the same frequency as specified for slump tests.

][3.14.3.5 Unit Weight of Structural Concrete

ASTM C567/C567M and ASTM C138/C138M. Determine unit weight of lightweight and normal weight concrete. Perform test for every 15 cubic meters 20 cubic yards maximum.

][3.14.3.6 Chloride Ion Concentration

****

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

****

Chloride ion concentration must meet the requirements of the paragraph titled CORROSION AND CHLORIDE CONTENT. Determine water soluble ion concentration in accordance with ASTM C1218/C1218M. Perform test once for each mix design.

]3.14.3.7 Strength of Concrete Structure

The strength of the concrete structure will be considered to be deficient if any of the following conditions are identified:

a. Failure to meet compressive strength tests as evaluated.

b. Reinforcement not conforming to requirements specified.

c. Concrete which differs from required dimensions or location in such a manner as to reduce strength.

d. Concrete curing and protection of concrete against extremes of temperature during curing, not conforming to requirements specified.

e. Concrete subjected to damaging mechanical disturbances, particularly load stresses, heavy shock, and excessive vibration.

f. Poor workmanship likely to result in deficient strength.

Where the strength of the concrete structure is considered deficient submit a mitigation or remediation plan for review and approval by the contracting officer.

3.14.3.8 Non-Conforming Materials

Factors that indicate that there are non-conforming materials include (but not limited to) excessive compressive strength, inadequate compressive strength, excessive slump, excessive voids and honeycombing, concrete delivery records that indicate excessive time between mixing and placement, or excessive water was added to the mixture during delivery and placement. Any of these indicators alone are sufficient reason for the Contracting Officer to request additional sampling and testing.

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

3.14.3.9 Testing Concrete Structure for Strength

****
NOTE: If the government is going to take cores and test them then include the bracketed paragraph.
****

When there is evidence that strength of concrete structure in place does not meet specification requirements or there are non-conforming materials, make cores drilled from hardened concrete for compressive strength determination in accordance with ASTM C42/C42M, and as follows:

a. Take at least three representative cores from each member or area of concrete-in-place that is considered potentially deficient. Location of cores will be determined by the Contracting Officer.

b. Test cores after moisture conditioning in accordance with ASTM C42/C42M if concrete they represent is more than superficially wet under service.

c. Air dry cores, (16 to 27 degrees C60 to 80 degrees F with relative humidity less than 60 percent) for 7 days before test and test dry if concrete they represent is dry under service conditions.

d. Strength of cores from each member or area are considered satisfactory if their average compressive strength is equal to or greater than 85 percent of the design compressive strength, and if no single core strength is less than 75 percent of the design compressive strength. Additional testing of cores extracted from locations represented by erratic core strength results will be permitted only when approved by the Contracting Officer.

[e. Core specimens will be taken and tested by the Government. If the results of core-boring tests indicate that the concrete as placed does not conform to the drawings and specification, the cost of such tests and restoration required must be borne by the Contractor.

] Fill core holes solid with patching mortar and finished to match adjacent concrete surfaces.

Correct concrete work that is found inadequate by core tests in a manner approved by the Contracting Officer.

3.15 REPAIR, REHABILITATION AND REMOVAL

Before the Contracting Officer accepts the structure the Contractor must inspect the structure for cracks, damage and substandard concrete placements that may adversely affect the service life of the structure. A report documenting these defects must be prepared which includes recommendations for repair, removal or remediation must be submitted to the Contracting Officer for approval before any corrective work is accomplished.

****

NOTE: Include this paragraph if the concrete structure is a water tank designed in accordance with ACI 530.

****

[3.15.1 Crack Repair

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

]3.15.2 Repair of Weak Surfaces

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

3.15.3 Failure of Quality Assurance Test Results

****

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

****

Proposed mitigation efforts by the Contractor must be approved by the Contracting Officer prior to proceeding.

-- End of Section --