
USACE / NAVFAC / AFCEA / NASA UFGS-03 31 01.00 10 (April 2006)

Preparing Activity: USACE (CW) Replacing without change
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UNIFIED FACILITIES GUIDE SPECIFICATIONS

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SECTION TABLE OF CONTENTS

DIVISION 03 - CONCRETE

SECTION 03 31 01.00 10

CAST-IN-PLACE STRUCTURAL CONCRETE FOR CIVIL WORKS

04/06

PART 1 GENERAL

- 1.1 REFERENCES
- 1.2 UNIT PRICES
 - 1.2.1 Structure [_____]
 - 1.2.1.1 Payment
 - 1.2.1.2 Unit of Measure
 - 1.2.2 Concrete for [_____]
 - 1.2.2.1 Payment
 - 1.2.2.2 Measurement
 - 1.2.2.3 Unit of Measure
- 1.3 SUBMITTALS
- 1.4 GOVERNMENT TESTING AND SAMPLING
 - 1.4.1 Preconstruction Sampling and Testing
 - 1.4.1.1 Aggregates
 - 1.4.1.2 Cementitious Materials, Admixtures, and Curing Compound
 - 1.4.2 Construction Testing by the Government
 - 1.4.2.1 Chemical Admixtures Storage
 - 1.4.2.2 Cement and Pozzolan
 - 1.4.2.3 Concrete Strength
- 1.5 DESIGN REQUIREMENTS
 - 1.5.1 Concrete Strength
 - 1.5.2 Maximum Water-Cement (W/C) Ratio
- 1.6 CONSTRUCTION TOLERANCES
 - 1.6.1 Formed Concrete Surfaces
 - 1.6.2 Floor Finish by the F-Number System
 - 1.6.3 Tunnel Linings, Conduits, and Filling and Emptying Culverts
 - 1.6.4 Appearance

PART 2 PRODUCTS

- 2.1 MATERIALS
 - 2.1.1 Cementitious Materials
 - 2.1.1.1 Portland Cement

- 2.1.1.2 High-Early-Strength Portland Cement
- 2.1.1.3 Pozzolan, Other than Silica Fume
- 2.1.1.4 [Ground Granulated Blast-Furnace Slag
- 2.1.1.5 [Silica Fume
- 2.1.1.6 Blended Hydraulic Cement
- 2.1.2 Aggregates
 - 2.1.2.1 General
 - 2.1.2.2 Concrete Aggregate Sources
 - 2.1.2.3 Quality
- 2.1.3 Chemical Admixtures
 - 2.1.3.1 Air-Entraining Admixture
 - 2.1.3.2 Accelerating Admixture
 - 2.1.3.3 Water-Reducing or Retarding Admixture
 - 2.1.3.4 [Other Chemical Admixtures
- 2.1.4 Curing Materials
 - 2.1.4.1 Impervious-Sheet Curing Materials
 - 2.1.4.2 Membrane-Forming Curing Compound
 - 2.1.4.3 Burlap
- 2.1.5 Water
- 2.1.6 Nonshrink Grout
- 2.1.7 Abrasive Aggregates
- 2.1.8 Latex Bonding Compound
- 2.1.9 Epoxy Resin
- 2.2 CONCRETE MIXTURE PROPORTIONING
 - 2.2.1 Quality of Mixture
 - 2.2.2 Nominal Maximum-Size Coarse Aggregate
 - 2.2.3 Air Content
 - 2.2.4 Slump
 - 2.2.5 Concrete Proportioning
 - 2.2.6 Required Average Compressive Strength
 - 2.2.6.1 Average Compressive Strength from Test Records
 - 2.2.6.2 Average Compressive Strength without Previous Test Records

PART 3 EXECUTION

- 3.1 EQUIPMENT
 - 3.1.1 Capacity
 - 3.1.2 Batch Plant
 - 3.1.2.1 Batching Equipment
 - 3.1.2.2 Scales
 - 3.1.2.3 Batching Tolerances
 - 3.1.2.4 Moisture Control
 - 3.1.3 Concrete Mixers
 - 3.1.3.1 Stationary Mixers
 - 3.1.3.2 Truck Mixers
 - 3.1.4 Conveying Equipment
 - 3.1.4.1 Buckets
 - 3.1.4.2 Transfer Hoppers
 - 3.1.4.3 Trucks
 - 3.1.4.4 Chutes
 - 3.1.4.5 Belt Conveyors
 - 3.1.4.6 Concrete Pumps
 - 3.1.5 Vibrators
- 3.2 PREPARATION FOR PLACING
 - 3.2.1 Embedded Items
 - 3.2.2 Concrete on Earth Foundations
 - 3.2.3 Concrete on Rock Foundations
 - 3.2.4 Construction Joint Treatment
 - 3.2.4.1 Joint Preparation

- 3.2.4.2 Air-Water Cutting
 - 3.2.4.3 High-Pressure Water Jet
 - 3.2.4.4 Wet Sandblasting
 - 3.2.4.5 Waste Disposal
- 3.3 PLACING
 - 3.3.1 Placing Procedures
 - 3.3.2 Placement by Pump
 - 3.3.3 Time Interval Between Mixing and Placing
 - 3.3.4 Cold-Weather Placing
 - 3.3.5 Hot-Weather Placing
 - 3.3.6 Consolidation
 - 3.3.7 [Placing Concrete in Ogee Section
 - 3.3.8 [Placing Concrete Underwater
- 3.4 FINISHING
 - 3.4.1 Unformed Surfaces
 - 3.4.1.1 Float Finish
 - 3.4.1.2 Trowel Finish
 - 3.4.1.3 [Abrasive Aggregate Finish
 - 3.4.1.4 [Broom Finish
 - 3.4.1.5 [Bonded Two-Course Floor
 - 3.4.1.6 [Unbonded Two-Course Floor
 - 3.4.2 Formed Surfaces
 - 3.4.2.1 [Grout-Cleaned Finish
 - 3.4.2.2 [Textured Finish
 - 3.4.2.3 [Exposed Coarse-Aggregate Finish
 - 3.4.2.4 [Sand-Blast Finish
 - 3.4.2.5 [Tooled Finish
 - 3.4.3 Formed Surface Repair
 - 3.4.3.1 Classes A, AHV, & B Finishes
 - 3.4.3.2 Class C Finish
 - 3.4.3.3 Class D Finish
 - 3.4.3.4 Material and Procedure for Repairs
- 3.5 CURING AND PROTECTION
 - 3.5.1 Duration
 - 3.5.2 Moist Curing
 - 3.5.3 Membrane-Forming Curing Compound
 - 3.5.3.1 Pigmented Curing Compound
 - 3.5.3.2 Nonpigmented Curing Compound
 - 3.5.3.3 Application
 - 3.5.4 Evaporation Retardant
 - 3.5.5 Cold-Weather Curing and Protection
- 3.6 SETTING OF BASE PLATES AND BEARING PLATES
 - 3.6.1 Setting of Plates
 - 3.6.2 Nonshrink Grout Application
 - 3.6.2.1 Mixing and Placing of Nonshrink Grout
 - 3.6.2.2 Treatment of Exposed Surfaces
 - 3.6.2.3 Curing
- 3.7 TESTS AND INSPECTIONS
 - 3.7.1 General
 - 3.7.2 Testing and Inspection Requirements
 - 3.7.2.1 Fine Aggregate
 - 3.7.2.2 Coarse Aggregate
 - 3.7.2.3 Quality of Aggregates
 - 3.7.2.4 Scales
 - 3.7.2.5 Batch-Plant Control
 - 3.7.2.6 Concrete Mixture
 - 3.7.2.7 Inspection Before Placing
 - 3.7.2.8 Placing
 - 3.7.2.9 Vibrators

- 3.7.2.10 Curing
- 3.7.2.11 Cold-Weather Protection and Sealed Insulation Curing
- 3.7.2.12 Cold-Weather Protection Corrective Action
- 3.7.2.13 Mixer Uniformity
- 3.7.2.14 Mixer Uniformity Corrective Action
- 3.7.3 Reports

-- End of Section Table of Contents --

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CAST-IN-PLACE STRUCTURAL CONCRETE FOR CIVIL WORKS
04/06

NOTE: This guide specification covers the requirements for furnishing, hauling, and placing the cast-in-place structural concrete complete, as specified herein and shown on the contract drawings.

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

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

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

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

PART 1 GENERAL

NOTE: The characteristics that distinguish this specification from UFGS Section 03 70 00 MASS CONCRETE, are:

1. Concrete strengths and maximum permitted water-cement ratios are specified.
2. The proportioning of concrete mixtures is the responsibility of the Contractor.
3. Measurement of concrete is on the basis of the

actual volume of concrete within pay lines of the structure as indicated on the drawings. Payment is made at contract prices per cubic meter (yard) for various items on the schedule. As an option payment may be by lump sum for various items on the schedule.

4. For large complex projects, this specification may be used in conjunction with UFGS Section 03 70 00 MASS CONCRETE. If so used, the portions of the project to be constructed under the respective specifications must be clearly called out in the contract documents.

The content of this specification is such that guidance given in EM 1110-2-2000, "Standard Practice for Concrete", is applicable.

1.1 REFERENCES

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

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

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

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

ACI INTERNATIONAL (ACI)

ACI 117	(2006) Standard Specifications for Tolerances for Concrete Construction and Materials
ACI 211.1	(1991; R 2002) Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 214R	(2002) Recommended Practice for Evaluation of Strength Test Results of Concrete
ACI 303R	(2004) Guide to Cast-In-Place

Architectural Concrete Practice

ACI 305R (1999; Errata 2006) Hot Weather Concreting

ACI 318/318R (2005; Errata 2005) Building Code Requirements for Structural Concrete and Commentary

ACI 318M (2005) Metric Building Code Requirements for Structural Concrete and Commentary

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

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

ASTM INTERNATIONAL (ASTM)

ASTM C 1017/C 1017M (2007) Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete

ASTM C 1059 (1999) Standard Specification for Latex Agents for Bonding Fresh to Hardened Concrete

ASTM C 1064/C 1064M (2005) Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

ASTM C 1077 (2006a) Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

ASTM C 1107/C 1107M (2007a) Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)

ASTM C 117 (2004) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing

ASTM C 123 (2004) Standard Test Method for Lightweight Particles in Aggregate

ASTM C 1240 (2005) Standard Specification for Silica Fume Used in Cementitious Mixtures

ASTM C 1260 (2007) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

ASTM C 127 (2004) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

ASTM C 128	(2007) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
ASTM C 131	(2006) Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C 136	(2006) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 142	(1997; R 2004) Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C 143/C 143M	(2005a) Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C 150	(2007) Standard Specification for Portland Cement
ASTM C 1567	(2004) Standard Test Method for Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C 171	(2003) Standard Specification for Sheet Materials for Curing Concrete
ASTM C 172	(2004) Standard Practice for Sampling Freshly Mixed Concrete
ASTM C 192/C 192M	(2006) Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
ASTM C 231	(2004) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 260	(2006) Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C 295	(2003) Petrographic Examination of Aggregates for Concrete
ASTM C 309	(2007) Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C 31/C 31M	(2006) Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C 33	(2003) Standard Specification for Concrete Aggregates
ASTM C 39/C 39M	(2005e1) Standard Test Method for Compressive Strength of Cylindrical

Concrete Specimens

ASTM C 40	(2004) Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
ASTM C 42/C 42M	(2004) Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C 441	(2005) Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
ASTM C 494/C 494M	(2005a) Standard Specification for Chemical Admixtures for Concrete
ASTM C 535	(2003e1) Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C 566	(1997; R 2004) Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
ASTM C 595	(2007) Standard Specification for Blended Hydraulic Cements
ASTM C 597	(2002) Pulse Velocity Through Concrete
ASTM C 618	(2005) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C 666/C 666M	(2003) Resistance of Concrete to Rapid Freezing and Thawing
ASTM C 803/C 803M	(2003) Penetration Resistance of Hardened Concrete
ASTM C 805	(2002) Rebound Number of Hardened Concrete
ASTM C 87	(2005) Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
ASTM C 881/C 881M	(2002) Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
ASTM C 94/C 94M	(2007) Standard Specification for Ready-Mixed Concrete
ASTM C 989	(2006) Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
ASTM D 75	(2003) Standard Practice for Sampling Aggregates

ASTM E 1155 (1996; R 2001) Standard Test Method for Determining Floor Flatness and Floor Levelness Numbers

ASTM E 1155M (1996; R 2001) Standard Test Method for Determining Floor Flatness and Floor Levelness Numbers (Metric)

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST HB 44 (2007) NIST Handbook 44: Specifications, Tolerances, and other Technical Requirements for Weighing and Measuring Devices

NATIONAL READY MIXED CONCRETE ASSOCIATION (NRMCA)

NRMCA CPMB 100 (2000) Concrete Plant Standards

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 100 (1975) Method of Sampling Concrete Aggregate and Aggregate Sources, and Selection of Material for Testing

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

COE CRD-C 114 (1997) Test Method for Soundness of Aggregates by Freezing and Thawing of Concrete Specimens

COE CRD-C 130 (2001) Standard Recommended Practice for Estimating Scratch Hardness of Coarse Aggregate Particles

COE CRD-C 143 (1962) Specifications for Meters for Automatic Indication of Moisture in Fine Aggregates

COE CRD-C 400 (1963) Requirements for Water for Use in Mixing or Curing Concrete

COE CRD-C 521 (1981) Standard Test Method for Frequency and Amplitude of Vibrators for Concrete

COE CRD-C 94 (1995) Specification for Surface Retarders

1.2 UNIT PRICES

NOTE: If Section 01 22 00.00 10 MEASUREMENT AND PAYMENT is included in the project specifications, this paragraph title (UNIT PRICES) should be deleted from this section and the remaining appropriately edited subparagraphs below should be inserted into Section 01 22 00.00 10.

Consult the concrete materials design memorandum to
choose the appropriate cementitious materials and
admixtures for measurement and payment.

1.2.1 Structure [_____]

NOTE: Repeat this lump sum bid item and its
respective subparagraphs for each structure to be
paid for by lump sum, renumbering the bid items
appropriately. Lump sum bid items should be
inserted in paragraph LUMP SUM BID ITEMS of Section
01 22 00.00 10 MEASUREMENT AND PAYMENT.

1.2.1.1 Payment

Payment will be made for costs associated with operations necessary for
construction of the structure at Station [_____].

1.2.1.2 Unit of Measure

Unit of measure: lump sum.

1.2.2 Concrete for [_____]

NOTE: Repeat this bid item and its respective
subparagraphs for each bid item of concrete,
renumbering the bid items appropriately. Unit price
bid items should be inserted in paragraph UNIT PRICE
BID ITEMS of Section 01 22 0.00 10 MEASUREMENT AND
PAYMENT.

1.2.2.1 Payment

Payment will be made for costs associated with completing the concrete work
for concrete placed in the [_____]. However, these costs will not include
the cost of embedded parts that are specified to be paid for separately.
No payment will be made for concrete, as such, that is placed in structures
of which payment is made as a lump sum.

1.2.2.2 Measurement

Concrete will be measurement for payment based upon the actual volume of
concrete within the pay lines of the structures as indicated on the
drawings. Measurement of concrete placed against the sides of any
excavation without the use of intervening forms shall be made only within
the pay lines of the structure. No deductions shall be made for rounded or
beveled edges, space occupied by metal work, electrical conduits or
reinforcing steel, or for voids or embedded items that are either less than
0.14 cubic meters 5 cubic feet in volume or 0.09 square meter 1 square foot
in cross section.

1.2.2.3 Unit of Measure

Unit of measure: cubic meters yards.

1.3 SUBMITTALS

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

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

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

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

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

SD-03 Product Data

Concrete Mixture Proportioning[; G][; G, [_____]]

Concrete mixture proportions shall be determined by the Contractor and submitted for review. The concrete mixture quantities of all ingredients per cubic meter yard and nominal maximum coarse aggregate size that will be used in the manufacture of each quality of concrete shall be stated. Proportions shall indicate the mass of cement, pozzolan and ground granulated blast-furnace (GGBF) slag when used, and water; the mass of aggregates in a saturated surface-dry condition; and the quantities of admixtures. The submission shall be accompanied by test reports from a laboratory complying with ASTM C 1077 which show that proportions thus selected will produce concrete of the

qualities indicated. No substitution shall be made in the source or type of materials used in the work without additional tests to show that the quality of the new materials and concrete are satisfactory.

Batch Plant[; G][; G, [_____]]

The Contractor shall submit batch plant data to the Contracting Officer for review for conformance with applicable specifications.

Concrete Mixers Capacity

The Contractor shall submit concrete mixer data which includes the make, type, and capacity of concrete mixers proposed for mixing concrete.

Conveying Equipment

Data on the conveying equipment and methods for transporting, handling, and depositing the concrete.

Placing Equipment

Data on placing equipment and methods.

Tests and Inspections Testing Technicians Concrete Transportation Construction Inspector (CTCI) Concrete Construction Inspector (CCI)

Statements that the concrete testing technicians and the concrete inspectors meet the specified requirements.

Construction Joint Treatment[; G][; G, [_____]]

The method and equipment proposed for joint cleanup and waste disposal shall be submitted for review and approval.

Curing and Protection[; G][; G, [_____]]

The curing medium and methods to be used shall be submitted for review and approval.

Cold-Weather Placing[; G][; G, [_____]]

If concrete is to be placed under cold-weather conditions, the proposed materials, methods, and protection shall be submitted for approval.

Hot-Weather Placing[; G][; G, [_____]] Finishing[; G][; G, [_____]]

If concrete is to be placed under hot-weather conditions, the proposed materials and methods shall be submitted for review and approval.

SD-04 Samples

Aggregates[; G][; G, [____]]
Cementitious Materials, Admixtures, and Curing Compound[; G][; G,
[____]]

Samples of materials for government testing and approval.

SD-06 Test Reports

Quality of Aggregates[; G][; G, [____]]

Aggregate quality tests shall be submitted at least 30 days prior to start of concrete placement.

Mixer Uniformity.

The results of the initial mixer uniformity tests shall be submitted at least 5 days prior to the initiation of placing.

Tests and Inspections

Test results and inspection reports shall be submitted daily and weekly.

SD-07 Certificates

NOTE: Delete the requirements for Certificates for
air entrainment admixtures, other chemical
admixtures, curing compounds, portland cement and
pozzolan if the optional parts of paragraph
CEMENTITIOUS MATERIALS, ADMIXTURES, AND CURING
COMPOUND, is used.

[Cementitious Materials[; G][; G, [____]]

Cementitious Materials, including Cement and Pozzolan, [and Ground Granulated Blast-Furnace Slag] will be accepted on the basis of the manufacturer's certification of compliance, accompanied by mill test reports that materials meet the requirements of the specification under which they are furnished. Certification and mill test reports shall be from samples taken from the particular lot furnished. No cementitious materials shall be used until notice of acceptance has been given by the Contracting Officer. Cementitious materials will be subject to check testing from samples obtained at the source, at transfer points, or at the project site, as scheduled by the Contracting Officer, and such sampling will be by or under the supervision of the Government at its expense. Material not meeting specifications shall be promptly removed from the site of work.]

Impervious-Sheet Curing Materials

Impervious-Sheet Curing Materials shall be certified for compliance with all specification requirements.

[Air-Entraining Admixture

Air-Entraining Admixture shall be certified for compliance with

all specification requirements.]

[Other Chemical Admixtures

Other Chemical Admixtures shall be certified for compliance with all specification requirements.]

[Membrane-Forming Curing Compound

Membrane-Forming Curing Compound shall be certified for compliance with all specification requirements.]

Epoxy Resin
Latex Bonding Compound

Epoxy Resin and Latex Bonding Compound shall be certified for compliance with all specification requirements.

Nonshrink Grout

Descriptive literature of the Nonshrink Grout proposed for use shall be furnished together with a certificate from the manufacturer stating that it is suitable for the application or exposure for which it is being considered.

1.4 GOVERNMENT TESTING AND SAMPLING

The Government will sample and test aggregates and concrete to determine compliance with the specifications. The Contractor shall provide facilities and labor as may be necessary for procurement of representative test samples. Samples of aggregates will be obtained at the point of batching in accordance with ASTM D 75. Concrete will be sampled in accordance with ASTM C 172.

1.4.1 Preconstruction Sampling and Testing

1.4.1.1 Aggregates

NOTE: The Designer should consult the appropriate DM, identify the sources for aggregates, and attach them to the end of this section. A Format Template for Aggregate Sources is located in the Template Menu of UFGS. Contact the Director, U.S. Army Corps of Engineers, Engineer Research and Development Center - Structures Laboratory, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199, ATTN: CEERD-SC for information to fill in the blanks below.

The aggregate sources listed at the end of this section for aggregates have been tested and at the time testing was performed were capable of producing materials of a quality required for this project provided suitable processing is performed. The Contractor may furnish materials from a listed source or from a source not listed. Samples from any source of coarse aggregate and any source of fine aggregate selected by the Contractor, consisting of not less than [70] [] kg [150] [] pounds of each size coarse aggregate and [35] [] kg [75] [] pounds of fine aggregate taken under the supervision of the Contracting Officer in

accordance with COE CRD-C 100 shall be delivered to [_____] within 15 days after notice to proceed. Sampling and shipment of samples shall be at the Contractor's expense. [_____] days will be required to complete evaluation of the aggregates. Testing will be performed by and at the expense of the Government in accordance with the applicable COE CRD-C or ASTM test methods. The cost of testing one source for each size of aggregate will be borne by the Government. If the Contractor selects more than one source for each aggregate size or selects a substitute source for any size aggregate after the original source was tested, the cost of that additional testing will be borne by the Contractor. Tests to which aggregate may be subjected are listed in paragraph QUALITY. The material from the proposed source shall meet the quality requirements of this paragraph. The Government's test data and other information on aggregate quality of those sources listed at the end of this section are included in the Design Memorandum and are available for review in the district office. Testing of aggregates by the Government does not relieve the Contractor of the requirements outlined in paragraph TESTS AND INSPECTIONS.

1.4.1.2 Cementitious Materials, Admixtures, and Curing Compound

**NOTE: When the optional sentence below is deleted,
the corresponding manufacturer's certification
described in paragraph SUBMITTALS should be used.
EM 1110-2-2000, "Standard Practice for Concrete,"
provides guidance in selecting the options for
Government or for Contractor testing."**

At least 60 days in advance of concrete placement, the Contractor shall notify the Contracting Officer of the sources for cementitious materials, admixtures, and curing compound, along with sampling location, brand name, type, and quantity to be used in the manufacture and/or curing of the concrete.

1.4.2 Construction Testing by the Government

[Sampling and testing will be performed by and at the expense of the Government except as otherwise specified. No material shall be used until notice has been given by the Contracting Officer that test results are satisfactory.][The Government will sample and test chemical admixtures, curing compounds, and cementitious materials.]

1.4.2.1 Chemical Admixtures Storage

Chemical admixtures that have been in storage at the project site for longer than 6 months or that have been subjected to freezing shall be retested at the expense of the Contractor when directed by the Contracting Officer and shall be rejected if test results are not satisfactory. Chemical admixtures will be accepted based on compliance with the requirements of paragraph CHEMICAL ADMIXTURES.

1.4.2.2 Cement and Pozzolan

**NOTE: Delete this paragraph if materials are to be
accepted on the basis of a manufacturer's
certification of compliance and mill test reports,
and the optional sentence in paragraph SUBMITTALS,**

SD-07 Certificates will be used. See the appropriate DM or consult the Materials Engineer to select prequalified sources, (1) and (2), sealed bins, (3) and (4), or both options, (1), (2), (3) and (4). Selection of the sealed bin method, subparagraphs (3) and (4), must be fully justified in the appropriate DM.

If cement or pozzolan is to be obtained from more than one source, the initial notification shall state the estimated amount to be obtained from each source and the proposed schedule of shipments.

[a. Prequalified Cement Sources - Cement shall be delivered and used directly from a mill of a producer designated as a qualified source. Samples of cement for check testing will be taken at the project site or concrete-producing plant by a representative of the Contracting Officer for testing at the expense of the Government. A list of prequalified cement sources is available from Director, U.S. Army Corps of Engineers, Engineer Research and Development Center - Structures Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, ATTN: CEERD-SC.]

[b. Prequalified Pozzolan Sources - Pozzolan shall be delivered and used directly from a producer designated as a qualified source. Samples of pozzolan for check testing will be taken at the project site by a representative of the Contracting Officer for testing at the expense of the Government. A list of prequalified pozzolan sources is available from the Director, U.S. Army Corps of Engineers, Engineer Research and Development Center - Structures Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, ATTN: CEERD-SC.]

[c. Nonprequalified Cement Sources - Cement, if not from a prequalified source, will be sampled at the source and stored in sealed bins pending completion of testing. Sampling, testing, and the shipping inspection from the point of sampling, when the point is other than at the site of the work, will be made by or under the supervision of the Government and at its expense. No cement shall be used until notice has been given by the Contracting Officer that test results are satisfactory. In the event of failure, the cement may be resampled and tested at the request of the Contractor, at his expense. When the point of sampling is other than at the site of the work, the fill gates of the sampled bin and conveyances used in shipment will be sealed under Government supervision and kept sealed until shipment from the bin has been completed. If tested cement is rehandled at transfer points, the extra cost of inspection shall be at the Contractor's expense. The cost of testing cement excess to project requirements shall also be at the expense of the Contractor. The charges for testing cement at the expense of the Contractor will be deducted from the payments due the Contractor at a rate of [_____] dollars per ton (metric) (2000 lb) of cement represented by the tests.]

NOTE: To fill in the blank for cost of testing excess cement contact the Structures Laboratory, Concrete Division at WES.

[d. Nonprequalified Pozzolan Sources - Pozzolan, if not from a

prequalified source, will be sampled at the source and stored in sealed bins pending completion of certain tests. Pozzolan will also be sampled at the site when determined necessary. All sampling and testing will be by and at the expense of the Government. Release for shipment and approval for use will be based on compliance with 7-day lime-pozzolan strength requirements and other physical and chemical and uniformity requirements for which tests can be completed by the time the 7-day lime-pozzolan strength test is completed. Release for shipment and approval for use on the above basis will be contingent on continuing compliance with the other requirements of the specifications. If a bin fails, the contents may be resampled and tested at the Contractor's expense. In this event the pozzolan may be sampled as it is loaded into cars, trucks, or barges provided they are kept at the source until released for shipment. Unsealing and resealing of bins and sealing of shipping conveyances will be done by or under the supervision of the Government. Shipping conveyances will not be accepted at the site of the work unless received with all seals intact. If pozzolan is damaged in shipment, handling, or storage, it shall be promptly removed from the site of the work. Pozzolan that has not been used within 6 months after testing shall be retested at the expense of the Contractor when directed by the Contracting Officer and shall be rejected if the test results are not satisfactory. If tested pozzolan is rehandled at transfer points, the extra cost of inspection shall be at the Contractor's expense. The cost of testing excess pozzolan shall be at the Contractor's expense at a rate of [_____] cents per ton (metric) (2000 lb). The amount will be deducted from payment to the Contractor.]

1.4.2.3 Concrete Strength

Compressive strength test specimens will be made by the Government and cured in accordance with ASTM C 31/C 31M and tested in accordance with ASTM C 39/C 39M. The strength of the concrete will be considered satisfactory so long as the average of all sets of three consecutive test results equals or exceeds the specified compressive strength f'_c and no individual test result falls below the specified strength f'_c by more than 3.5 MPa 500 psi. A "test" is defined as the average of two companion cylinders, or if only one cylinder is tested, the results of the single cylinder test. Additional analysis or testing, including nondestructive testing, taking cores and/or load tests may be required at the Contractor's expense when the strength of the concrete in the structure is considered potentially deficient.

a. Investigation of Low-Strength Test Results - When any strength test of standard-cured test cylinders falls below the specified strength requirement by more than 3.5 MPa 500 psi or if tests of field-cured cylinders indicate deficiencies in protection and curing, steps shall be taken to assure that the load-carrying capacity of the structure is not jeopardized. Nondestructive testing in accordance with ASTM C 597, ASTM C 803/C 803M, or ASTM C 805 may be permitted by the Contracting Officer to estimate the relative strengths at various locations in the structure as an aid in evaluating concrete strength in place or for selecting areas to be cored. Such tests shall not be used as a basis for acceptance or rejection.

b. Testing of Cores - When the strength of concrete in place is considered potentially deficient, cores shall be obtained and tested in accordance with ASTM C 42/C 42M. At least three representative cores shall be taken from each member or area of concrete in place that is

considered potentially deficient. The location of cores will be determined by the Contracting Officer to least impair the performance of the structure. Concrete in the area represented by the core testing will be considered adequate if the average strength of the cores is equal to at least 85 percent of the specified strength requirement and if no single core is less than 75 percent of the specified strength requirement.

c. Load Tests - If the core tests are inconclusive or impractical to obtain or if structural analysis does not confirm the safety of the structure, load tests may be directed by the Contracting Officer in accordance with the requirements of **ACI 318M ACI 318/318R**. Concrete work evaluated by structural analysis or by results of a load test shall be corrected in a manner satisfactory to the Contracting Officer. All investigations, testing, load tests, and correction of deficiencies will be performed and approved by the Contracting Officer at the expense of the Contractor, except that if all concrete is in compliance with the plans and specifications, the cost of investigations, testing, and load tests will be at the expense of the Government.

1.5 DESIGN REQUIREMENTS

1.5.1 Concrete Strength

NOTE: Consult the Structural Design Engineer and the appropriate DM to fill in the blanks.

Specified compressive strength f'_c shall be as follows:

NOTE: The following compressive strengths are in Metric.

COMPRESSIVE STRENGTH (MPa)	STRUCTURE OR PORTION OF STRUCTURE
[34.5 @ []] days	[]]
[27.6 @ []] days	[]]
[20.7 @ []] days	[]]
[17.2 @ []] days	[]]
[[] @ []] days	[]]

NOTE: The following compressive strengths are in English.

COMPRESSIVE STRENGTH (PSI)	STRUCTURE OR PORTION OF STRUCTURE
[5,000 @ []] days	[]]
[4,000 @ []] days	[]]
[3,000 @ []] days	[]]
[2,500 @ []] days	[]]
[[] @ []] days	[]]

1.5.2 Maximum Water-Cement (W/C) Ratio

NOTE: Consult EM 1110-2-2000 and the appropriate DM to fill in the blanks and to select the appropriate W/C. When cementitious materials other than portland cement are used, see paragraph CONCRETE PROPORTIONING, for definitions of W/C.

Maximum W/C shall be as follows:

WATER-CEMENT RATIO, BY MASS	STRUCTURE OR PORTION OF STRUCTURE
[0.40	[_____]]
[0.45	[_____]]
[0.50	[_____]]
[0.55	[_____]]
[0.60	[_____]]
[0.65	[_____]]

These W/C's may cause higher strengths than that required by paragraph CONCRETE STRENGTH.

1.6 CONSTRUCTION TOLERANCES

NOTE: Finished or formed surfaces subject to high-velocity flow (12 m/s (40 fps) and greater) will meet the tolerances for Class A-HV surfaces specified in paragraph Formed Concrete Surfaces below.

Except as specified otherwise, a plus tolerance increases and a minus tolerance decreases the dimension to which it applies. A tolerance without sign means plus or minus. Where only one sign is specified, there is no limit in the other direction. Tolerances are not cumulative. The most restrictive tolerance will control. Tolerances shall not extend the structure beyond legal boundaries.

a. Level and grade tolerance measurements of slabs shall be made as soon as possible after finishing. When forms or shoring are used, the measurements shall be made prior to removal.

b. Construction tolerances shall meet the requirements of **ACI 117** and any of the following requirements that are applicable.

1.6.1 Formed Concrete Surfaces

For High Velocity flow, Class A-HV-Abrupt variation, a positive offset between concrete surfaces is a raise of elevation in the direction of water flow and a negative offset is a drop of elevation in the direction of the water flow.

Direction of water flow	+0 mm 0 inches -3 mm 1/8 inch
Perpendicular to the	3 mm 1/8 inch

direction of water flow

1.6.2 Floor Finish by the F-Number System

NOTE: Delete this paragraph if floor finish tolerances are not applicable. If surface is subjected to high-velocity flow (12 m/s (40 fps) or greater), the tolerances for Class A-HV surfaces specified under paragraph Formed Concrete Surfaces above, apply. Be aware that the "very flat surface" is difficult to obtain and may require special finishing techniques.

Refer to EM-1110-2-2000 for guidance on the F-Number System. Refer to the appropriate DM for a list of floor locations and F-Numbers to insert in the blanks.

The flatness and levelness of the floors in the following listed areas shall be carefully controlled and the tolerances shall be measured by the F-Number system:

[_____]
[_____]

The Contractor shall furnish a floor profilograph or other equipment capable of measuring the floor flatness (FF) number and the floor levelness (FL) number, in accordance with ASTM E 1155M ASTM E 1155. The Contractor shall perform the tolerance measurements while being observed by the Contracting Officer. The tolerance requirement will be FF[____]/FL[_____]. Special finishing procedures and special care will be required to meet these tolerances.

1.6.3 Tunnel Linings, Conduits, and Filling and Emptying Culverts

Water Conveying:

Lateral alignment

Centerline alignment

Inside dimensions

13 mm 1/2 inch

0.005 times inside dimension

Level alignment

Profile grade

13 mm 1/2 inch

Cross-Sectional dimension

Tunnel and culvert lining

-0 mm 0 inch

1.6.4 Appearance

Permanently exposed surfaces shall be cleaned, if stained or otherwise discolored, by a method that does not harm the concrete and that is approved by the Contracting Officer.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Cementitious Materials

NOTE: See the appropriate DM to select the proper requirements for the Cementitious Materials Options. Other cementitious materials may be added if specifically recommended and approved in the concrete materials DM.

Cementitious materials shall be portland cement, portland-pozzolan cement, portland blast-furnace slag cement, portland cement in combination with pozzolan or GGBF slag [or [____]] [or portland cement in combination with silica fume] and shall conform to appropriate specifications listed below. Use of cementitious materials in architectural concrete shall be restricted to one color, one source, and one type.

2.1.1.1 Portland Cement

ASTM C 150, Type I or II, except that the maximum amount of C3A in Type I cement shall be 15 percent [including the heat of hydration at 7 days] [including false set requirements] [low alkali when used with aggregates listed at the end of this section which require it.] [In lieu of low-alkali cement, the Contractor may use a combination of portland cement that does not meet the low-alkali requirement with a pozzolan or GGBF slag provided the following requirement is met. The expansion of the proposed combination when tested in accordance with **ASTM C 441** shall be equal to or less than the expansion of a low-alkali cement meeting the requirements of **ASTM C 150** when tested in general conformance with **ASTM C 441**. The expansion tests shall be run concurrently at an independent laboratory that is nationally recognized to perform such tests. The Government reserves the right to confirm the test results and to adjust the percentage of pozzolan or slag in the combination to suit other requirements.] [white portland cement shall meet the above requirements except that it may be Type I, Type II, or Type III [low alkali]. White Type III may be used only in specific areas of the structure, when approved in writing by the Contracting Officer.]

2.1.1.2 High-Early-Strength Portland Cement

ASTM C 150, Type III, [with C3A limited to [5] [8] percent] [low alkali when used with aggregates listed at the end of this section which require it] [used only when specifically approved in writing].

2.1.1.3 Pozzolan, Other than Silica Fume

Pozzolan shall conform to **ASTM C 618**, Class [C] [F], with the optional requirements for multiple factor, drying shrinkage, and uniformity of Table 2A. Table 1A requirement for maximum alkalies shall apply when used with aggregates listed at the end of this section to require low-alkali cement.

2.1.1.4 [Ground Granulated Blast-Furnace Slag

Ground Granulated Blast-Furnace Slag shall conform to **ASTM C 989**, Grade [____].]

2.1.1.5 [Silica Fume

NOTE: Optional Table 2 in ASTM C 1240 shall be included when used with aggregates listed to require low-alkali cement. Other requirements in Table 4 may be specified if necessary. Refer to EM 1110-2-2000 for guidance.

Silica fume may be furnished as a dry, densified material or as a slurry. Silica fume, unprocessed, or before processing into a slurry or a densified material, shall conform to **ASTM C 1240** with [Table 2 and]the Specific Surface Area and Uniformity Requirements in Table 4 invoked.

The Contractor shall provide at his expense the services of a manufacturer's technical representative, experienced in mixture proportioning, placement procedures, and curing of concrete containing silica fume. The manufacturer's representative shall be available for consultation by both the Contractor and the Government during mixture proportioning, planning, and production of silica-fume concrete and shall be onsite immediately prior to and during at least the first placement of concrete containing silica fume, and at other times if directed.]

2.1.1.6 Blended Hydraulic Cement

[Portland blast-furnace slag cement shall conform to **ASTM C 595**, Type IS.][
Portland-pozzolan cement shall conform to **ASTM C 595**, Type IP.]

2.1.2 Aggregates

2.1.2.1 General

NOTE: The list of sources and required tests and test limits will be taken from the concrete materials DM; however, if the materials DM will be more than five (5) years old at time of the proposed issuance of the solicitation, then the Designer must update the materials information prior to the issuance of the solicitation.

Concrete aggregates may be furnished from any source capable of meeting the quality requirements as stated in paragraph QUALITY. The sources listed at the end of this section were evaluated during the design phase of the project in [19__][20__] and were found at that time capable of meeting the quality requirements when suitably processed. No guarantee is given or implied that any of the listed sources are currently capable of producing aggregates that meet the required quality stated in paragraph QUALITY. A Design Memorandum containing the results of the government investigation and test results is available for review in the [____] district office. Contact [____] at [____] to arrange for review of the memorandum. The test results and conclusions shall be considered valid only for the sample tested and shall not be taken as an indication of the quality of all material from a source nor for the amount of processing required. Fine and coarse aggregates shall conform to the grading requirements of **ASTM C 33**. The nominal maximum size shall be as listed in paragraph NOMINAL

MAXIMUM-SIZE COARSE AGGREGATE. Where the use of highway department gradations are permitted, proposed gradations shall be submitted for approval.

2.1.2.2 Concrete Aggregate Sources

NOTE: If an aggregate source is provided by the
Government, the appropriate paragraphs from UFGS
Section 03 70 00 MASS CONCRETE should be used.

a. List of Sources - The concrete aggregates sources may be selected from sources listed at the end of this section.

b. Selection of Source - After the award of the contract, the Contractor shall designate in writing only one source or combination of sources from which he proposes to furnish aggregates. If the Contractor proposes to furnish aggregates from a source or from sources not listed at the end of this section, he may designate only a single source or single combination of sources for aggregates. Regardless of the source, selected samples for acceptance testing shall be provided as required by paragraph GOVERNMENT TESTING AND SAMPLING. If a source for coarse or fine aggregates so designated by the Contractor does not meet the quality requirements stated in paragraph QUALITY, the Contractor may not submit for approval other non-listed sources but shall furnish the coarse or fine aggregate, as the case may be, from sources listed at the end of this section at no additional cost to the Government.

2.1.2.3 Quality

NOTES: The tests selected should be those which are
applicable to the concrete to be used in the
project. These tests may include those in the
following list in addition to others not listed.
See EM 1110-2-2000 for schedule of tests.

A list of properties and test values are unique to each project and should be taken from the concrete materials design memorandum. Delete the quality tests not required in the design memorandum.

The petrographic examination shall be used to identify deleterious substances in aggregates. Deleterious substances shall be listed individually with respective limits.

Depending upon the quality of aggregates available, some tests may not be required. Refer to EM 1110-2-2000 for the purpose of each test.

This note may be disregarded for regions where Alkali-Silica Reactivity (ASR) is not a concern. Some aggregate sources may exhibit an ASR potential. ASR is a potentially deleterious reaction between alkalis present in concrete and some siliceous aggregates, reference EM 1110-2-2000 paragraph

2-3b(6) and appendix D. Where ASR is known or suspected to pose a concern for concrete durability, it is recommended that aggregates proposed for use in concrete be evaluated to determine ASR potential and an effective mitigation. EM 1110-2-2000, provides recommendations for evaluating and mitigating ASR in concrete mixtures. Aggregate evaluations may not be practical for projects requiring small quantities of concrete (less than 250 cubic yards).

UFGS Section 32 13 11 CONCRETE PAVEMENT FOR AIRFIELDS AND OTHER HEAVY-DUTY PAVEMENTS MORE THAN 10,000 CUBIC YARDS, paragraph 2.2.1.2 Alkali-Silica Reactivity, provides a specification method for the Contractor to evaluate and mitigate ASR in concrete mixtures. The expansion limits specified in UFGS 02753 are requirements for pavements and exterior slab construction. For structural concrete applications the measured expansion shall be less than 0.10 percent. It may not be economical or practical to specify different test limit requirements for use on the same project. In which case the lower limit required by the application should be used.

The designer may use the specification method in UFGS Section 32 13 11 CONCRETE PAVEMENT FOR AIRFIELDS AND OTHER HEAVY-DUTY PAVEMENTS MORE THAN 10,000 CUBIC YARDS by incorporating the relevant paragraphs into this specification, or may use the following requirements (retain either the 0.10 or the 0.08 percent expansion limits as appropriate) included in the set of brackets highlighted thus "[.]".

Fine and coarse aggregates delivered to the mixer shall "[be tested and evaluated for alkali-aggregate reactivity in accordance with ASTM C 1260. The fine and coarse aggregates shall be evaluated separately and in combination, which matches the Contractor's proposed mix design proportioning. All results of the separate and combination testing shall have a measured expansion less than 0.10 (0.08) percent at 16 days after casting. Should the test data indicate an expansion of 0.10 (0.08) percent or greater, the aggregate(s) shall be rejected or additional testing using ASTM C 1260 and ASTM C 1567 shall be performed. The additional testing using ASTM C 1260 and ASTM C 1567 shall be performed using the low alkali portland cement in combination with ground granulated blast furnace (GGBF) slag, or Class F fly ash. GGBF slag shall be used in the range of 40 to 50 percent of the total cementitious material by mass. Class F fly ash shall be used in the range of 25 to 40 percent of the total cementitious material by mass]".[meet the following requirements:

PROPERTY TEST	TEST LIMITS		
	FINE AGGREGATE	COARSE AGGREGATE	
[Specific Gravity	[_____]	[_____]	ASTM C 127 ASTM C 128]

PROPERTY TEST	TEST LIMITS		
	FINE AGGREGATE	COARSE AGGREGATE	
[Absorption	[_____]	[_____]	ASTM C 127 ASTM C 128]
[Durability Factor using (Procedure A)	[_____]	[_____]	COE CRD-C 114 ASTM C 666/C 666M]
[Clay Lumps and Friable Particles	[_____]	[_____]	ASTM C 142]
[Material Finer than 75-µm (No. 200) Sieve	[_____]	[_____]	ASTM C 117]
[Organic Impurities	Not darker than No. 3 Not less than 95 percent		ASTM C 40 ASTM C 87]
[L.A. Abrasion	[_____]	Test Limits [_____]	ASTM C 131 ASTM C 535]
[Soft Particles	[_____]	[_____]	COE CRD-C 130]
[Chert, less than 2.40 specific gravity	[_____]	[_____]	ASTM C 123]
[Coal and Lignite, less than less than 2.00 specific gravity	[_____]	[_____]	ASTM C 123]
[Petrographic Examination	[List unwanted deleterious materials and their limits]		ASTM C 295]

2.1.1.3 Chemical Admixtures

Chemical admixtures to be used, when required or permitted, shall conform to the appropriate specification listed.

2.1.1.3.1 Air-Entraining Admixture

The air-entraining admixture shall conform to ASTM C 260 and shall consistently cause the concrete to have an air content in the specified ranges under field conditions.

2.1.1.3.2 Accelerating Admixture

Accelerators shall meet the requirements of ASTM C 494/C 494M, Type C or E, except that calcium chloride or admixtures containing calcium chloride shall not be used.

2.1.1.3.3 Water-Reducing or Retarding Admixture

- a. Water-Reducing or Retarding Admixtures: ASTM C 494/C 494M, Type A,

B, or D, except that the 6-month and 1-year compressive strength tests are waived.

b. High-Range Water Reducing Admixture: **ASTM C 494/C 494M**, Type F or G except that the 6-month and 1-year strength requirements shall be waived. The admixture may be used only when approved by the Contracting Officer, such approval being contingent upon particular mixture control as described in the Contractor's Quality Control Plan.

2.1.3.4 [Other Chemical Admixtures]

NOTE: Use this paragraph when the optional sentences in paragraph SLUMP is used.

Other chemical admixtures for use in producing flowing concrete shall comply with **ASTM C 1017/C 1017M**, Type 1 or 2. These admixture shall be used only for concrete listed in paragraph SLUMP.]

2.1.4 Curing Materials

2.1.4.1 Impervious-Sheet Curing Materials

Impervious-sheet curing materials shall conform to **ASTM C 171**, type optional, except polyethylene film shall not be used.

2.1.4.2 Membrane-Forming Curing Compound

The membrane-forming curing compound shall conform to **ASTM C 309**, Type 1-D or 2, except a styrene acrylate or chlorinated rubber compound meeting Class B requirements shall be used for surfaces that are to be painted or are to receive bituminous roofing, or waterproofing, or floors that are to receive adhesive applications of resilient flooring. The curing compound selected shall be compatible with any subsequent paint, roofing, coating, or flooring specified. Nonpigmented compound shall contain a fugitive dye and shall have the reflective requirements in **ASTM C 309** waived.

2.1.4.3 Burlap

Burlap used for curing shall conform to **AASHTO M 182**

2.1.5 Water

Water for mixing and curing shall be fresh, clean, potable, and free of injurious amounts of oil, acid, salt, or alkali, except that nonpotable water may be used if it meets the requirements of **COE CRD-C 400**.

2.1.6 Nonshrink Grout

Nonshrink grout shall conform to **ASTM C 1107/C 1107M** and shall be a commercial formulation suitable for the application proposed.

2.1.7 Abrasive Aggregates

Fifty-five percent, minimum, aluminum oxide or silicon-dioxide abrasive ceramically bonded together to form a homogeneous material sufficiently porous to provide a good bond with portland paste; or factory-graded emery aggregate consisting of not less than 45 percent aluminum oxide and 25

percent ferric oxide. The aggregate shall be well graded from particles retained on the 600- μ m (No. 30) sieve to particles passing the 2.36-mm (No. 8) sieve.

2.1.8 Latex Bonding Compound

Latex bonding compound agents for bonding fresh to hardened concrete shall conform to [ASTM C 1059](#).

2.1.9 Epoxy Resin

Epoxy resin for use in repairs shall conform to [ASTM C 881/C 881M](#), Type III, Grade I or II.

2.2 CONCRETE MIXTURE PROPORTIONING

2.2.1 Quality of Mixture

For each portion of the structure, mixture proportions shall be selected so that the strength and W/C requirements listed in paragraph DESIGN REQUIREMENTS are met.

2.2.2 Nominal Maximum-Size Coarse Aggregate

NOTE: Consult the appropriate DM for the nominal maximum-size aggregate.

Nominal maximum-size coarse aggregate shall be [37.5 mm 1-1/2 inch] [25.0 mm 1 inch] inches except 19.0 mm 3/4 inch nominal maximum-size coarse aggregate shall be used when any of the following conditions exist: the narrowest dimension between sides of forms is less than 190 mm 7-1/2 inches, the depth of the slab is less than 100 mm 4 inches, or the minimum clear spacing between reinforcing is less than 55 mm 2-1/4 inches.

2.2.3 Air Content

NOTE: For a specified compressive strength (f'c) of 34.5 MPa (5,000 psi) or greater the air content may be reduced by 1.0 percent.

Air content as delivered to the forms and as determined by [ASTM C 231](#) shall be between 4 and 7 percent except that when the nominal maximum-size coarse aggregate is 19.0 mm 3/4 inch, it shall be between 4.5 and 7.5 percent.

2.2.4 Slump

NOTE: Consult the appropriate DM and or the Materials Engineer to fill in the blank and to use the optional sentence.

The slump shall be determined in accordance with [ASTM C 143/C 143M](#) and shall be within the range of 25 to 100 mm 1 to 4 inches. Where placement by pump is approved, the slump shall not exceed 150 mm 6 inches. [Concrete

to be placed in [_____] may contain a chemical admixture for use in producing flowing concrete in accordance with ASTM C 1017/C 1017M, and the slump of the concrete shall not exceed 200 mm 8 inches].

2.2.5 Concrete Proportioning

Trial batches and testing requirements for various qualities of concrete specified shall be the responsibility of the Contractor. Samples of aggregates shall be obtained in accordance with the requirements of ASTM D 75. Samples of materials other than aggregate shall be representative of those proposed for the project and shall be accompanied by the manufacturer's test reports indicating compliance with applicable specified requirements. Trial mixtures having proportions, consistencies, and air content suitable for the work shall be made based on methodology described in ACI 211.1, using at least three different water-cement ratios, which will produce a range of strength encompassing those required for the work. The maximum water-cement ratios required in paragraph MAXIMUM WATER-CEMENT RATIO will be converted to a weight ratio of water to cement plus pozzolan by mass, silica fume, or GGBF slag by mass equivalency as described in ACI 211.1. In the case where GGBF slag is used, the weight of the slag shall be included in the equations for the term P, which is used to denote the mass of pozzolan. If pozzolan is used in the concrete mixture, the minimum pozzolan content shall be 15 percent of the total cementitious material. Trial mixtures shall be proportioned for maximum permitted slump and air content with due consideration to the approved conveying and placement method. The temperature of concrete in each trial batch shall be reported. For each water-cement ratio, at least three test cylinders for each test age shall be made and cured in accordance with ASTM C 192/C 192M. They shall be tested at 7 days and at the design age specified in paragraph DESIGN REQUIREMENTS in accordance with ASTM C 39/C 39M. From these test results, a curve will be plotted showing the relationship between water-cement ratio and strength.

2.2.6 Required Average Compressive Strength

In meeting the strength requirements specified in paragraph CONCRETE STRENGTH, the selected mixture proportion shall produce a required average compressive strength f'_{cr} exceeding the specified strength f'_c by the amount indicated below.

2.2.6.1 Average Compressive Strength from Test Records

Where a concrete production facility has test records, a standard deviation shall be established in accordance with the applicable provisions of ACI 214R. Test records from which a standard deviation is calculated shall represent materials, quality control procedures, and conditions similar to those expected, shall represent concrete produced to meet a specified strength or strengths (f'_c) within 6.89 MPa 1,000 psi of that specified for proposed work, and shall consist of at least 30 consecutive tests. A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days or at another test age designated for determination of f'_c .

Required average compressive strength f'_{cr} used as the basis for selection of concrete proportions shall be the larger of the equations that follow using the standard deviation as determined above:

$$f'_{cr} = f'_c + 1.34S$$

$$f'_{cr} = f'_c + 2.33S - 3.45 \text{ 500}$$

Where S = standard deviation

Where a concrete production facility does not have test records meeting the requirements above but does have a record based on 15 to 29 consecutive tests, a standard deviation shall be established as the product of the calculated standard deviation and a modification factor from the following table:

NUMBER OF TESTS*	MODIFICATION FACTOR FOR STANDARD DEVIATION	
	Use tabulation in paragraph DETERMINING REQUIRED AVERAGE STRENGTH	
less than 15		
15		1.16
20		1.08
25		1.03
30 or more		1.00

*Interpolate for intermediate numbers of tests.

2.2.6.2 Average Compressive Strength without Previous Test Records

When a concrete production facility does not have sufficient field strength test records for calculation of the standard deviation, the required average strength f'_{cr} shall be determined as follows:

If the specified compressive strength f'_c is less than 20.7 MPa 3,000 psi,

$$f'_{cr} = f'_c + 6.89 \text{ 1,000}$$

If the specified compressive strength f'_c is 20.7 to 34.5 MPa 3,000 to 5,000 psi,

$$f'_{cr} = f'_c + 8.27 \text{ 1,200}$$

If the specified compressive strength f'_c is over 34.5 MPa 5,000 psi,

$$f'_{cr} = f'_c + 9.65 \text{ 1,400.}$$

PART 3 EXECUTION

3.1 EQUIPMENT

3.1.1 Capacity

NOTE: Refer to the appropriate DM for the capacity.
Guidance is also found in EM 1110-2-2000.

The batching, mixing, conveying, and placing equipment shall have a capacity of at least [_____] cubic meters yards per hour.

3.1.2 Batch Plant

Batch plant shall conform to the requirements of NRMCA CPMB 100 and as specified; however, rating plates attached to batch plant equipment are not required.

3.1.2.1 Batching Equipment

NOTE: Refer to the appropriate DM to choose the appropriate alternates.

The batching controls shall be [partially automatic], [semiautomatic], [or] [automatic]. [The semiautomatic batching system shall be provided with interlocks such that the discharge device cannot be actuated until the indicated material is within the applicable tolerance.] The batching system shall be equipped with an accurate recorder or recorders that meet the requirements of **NRMCA CPMB 100**. Separate bins or compartments shall be provided for each size group of aggregate and cement, pozzolan, and GGBF slag. Aggregates shall be weighed either in separate weigh batchers with individual scales or cumulatively in one weigh batcher on one scale. Aggregate shall not be weighed in the same batcher with cement, pozzolan, or GGBF slag. If both cement and pozzolan or GGBF slag are used, they may be batched cumulatively provided that the portland cement is batched first.

If measured by mass, the mass of the water shall not be weighed cumulatively with another ingredient. Water batcher filling and discharging valves shall be so interlocked that the discharge valve cannot be opened before the filling valve is fully closed. An accurate mechanical device for measuring and dispensing each admixture shall be provided. Each dispenser shall be interlocked with the batching and discharging operation of the water so that each admixture is separately batched and discharged automatically in a manner to obtain uniform distribution throughout the batch in the specified mixing period. Admixtures shall not be combined prior to introduction in water. The plant shall be arranged so as to facilitate the inspection of all operations at all times. Suitable facilities shall be provided for obtaining representative samples of aggregates from each bin or compartment. All filling ports for cementitious materials bins or silos shall be clearly marked with a permanent sign stating the contents.

3.1.2.2 Scales

The equipment for batching by mass shall conform to the applicable requirements of **NIST HB 44**, except that the accuracy shall be plus or minus 0.2 percent of scale capacity. The Contractor shall provide standard test weights and any other auxiliary equipment required for checking the operating performance of each scale or other measuring devices. Tests shall be made at the frequency required in paragraph TESTS AND INSPECTIONS, and in the presence of a government inspector.

3.1.2.3 Batching Tolerances

a. Weighing Tolerances

MATERIAL	PERCENT OF REQUIRED MASS
Cementitious materials	0 to plus 2
Aggregate	plus or minus 2
Water	plus or minus 1
Chemical admixture	0 to plus 6

b. Volumetric Tolerances - For volumetric batching equipment, the

following tolerances shall apply to the required volume of material being batched:

Water: Plus or minus 1 percent.

Chemical admixtures: Zero to plus 6 percent.

3.1.2.4 Moisture Control

The plant shall be capable of ready adjustment to compensate for the varying moisture content of the aggregates and to change the masses of the materials being batched. [An electric moisture meter complying with the provisions of COE CRD-C 143 shall be provided for measuring moisture in the fine aggregate. The sensing element shall be arranged so that the measurement is made near the batcher charging gate of the sand bin or in the sand batcher.]

3.1.3 Concrete Mixers

The concrete mixers shall not be charged in excess of the capacity recommended by the manufacturer. The mixers shall be operated at the drum or mixing blade speed designated by the manufacturer. The mixers shall be maintained in satisfactory operating condition, and the mixer drums shall be kept free of hardened concrete. Should any mixer at any time produce unsatisfactory results, its use shall be promptly discontinued until it is repaired.

3.1.3.1 Stationary Mixers

Concrete plant mixers shall be tilting, nontilting, horizontal-shaft, vertical-shaft, or pugmill and shall be provided with an acceptable device to lock the discharge mechanism until the required mixing time has elapsed.

The mixing time and uniformity shall conform to all the requirements in ASTM C 94/C 94M applicable to central-mixed concrete.

3.1.3.2 Truck Mixers

Truck mixers, the mixing of concrete therein, and concrete uniformity shall conform to the requirements of ASTM C 94/C 94M. A truck mixer may be used either for complete mixing (transit-mixed) or to finish the partial mixing done in a stationary mixer (shrink-mixed). Each truck shall be equipped with two counters from which it will be possible to determine the number of revolutions at mixing speed and the number of revolutions at agitating speed.

3.1.4 Conveying Equipment

The conveying equipment shall conform to the following requirements.

3.1.4.1 Buckets

The interior hopper slope shall be not less than 58 degrees from the horizontal, the minimum dimension of the clear gate opening shall be at least five times the nominal maximum-size aggregate, and the area of the gate opening shall not be less than 0.2 square meters 2 square feet. The maximum dimension of the gate opening shall not be greater than twice the minimum dimension. The bucket gates shall be essentially grout tight when closed and may be manually, pneumatically, or hydraulically operated except that buckets larger than 1.5 cubic meters 2 cubic yards shall not be manually operated. The design of the bucket shall provide means for

positive regulation of the amount and rate of deposit of concrete in each dumping position.

3.1.4.2 Transfer Hoppers

Concrete may be charged into nonagitating hoppers for transfer to other conveying devices. Transfer hoppers shall be capable of receiving concrete directly from delivery vehicles and have conical-shaped discharge features.

The transfer hopper shall be equipped with a hydraulically operated gate and with a means of external vibration to effect complete discharge. Concrete shall not be held in nonagitating transfer hoppers more than 30 minutes.

3.1.4.3 Trucks

Truck mixers operating at agitating speed or truck agitators used for transporting plant-mixed concrete shall conform to the requirements of **ASTM C 94/C 94M**. Nonagitating equipment may be used for transporting plant-mixed concrete over a smooth road when the hauling time is less than 15 minutes. Bodies of nonagitating equipment shall be smooth, watertight, metal containers specifically designed to transport concrete, shaped with rounded corners to minimize segregation, and equipped with gates that will permit positive control of the discharge of the concrete.

3.1.4.4 Chutes

When concrete can be placed directly from a truck mixer, agitator, or nonagitating equipment, the chutes attached to this equipment by the manufacturer may be used. A discharge deflector shall be used when required by the Contracting Officer. Separate chutes and other similar equipment will not be permitted for conveying concrete.

3.1.4.5 Belt Conveyors

Belt conveyors shall be designed and operated to assure a uniform flow of concrete from mixer to final place of deposit without segregation of ingredients or loss of mortar and shall be provided with positive means for preventing segregation of the concrete at the transfer points and the point of placing. Belt conveyors shall be constructed such that the idler spacing shall not exceed **900 mm 36 inches**. The belt speed shall be a minimum of **90 m 300 feet** per minute and a maximum of **230 m 750 feet** per minute. If concrete is to be placed through installed horizontal or sloping reinforcing bars, the conveyor shall discharge concrete into a pipe or elephant trunk that is long enough to extend through the reinforcing bars.

3.1.4.6 Concrete Pumps

Concrete may be conveyed by positive displacement pump when approved. The pumping equipment shall be piston or squeeze pressure. The pipeline shall be rigid steel pipe or heavy-duty flexible hose. The inside diameter of the pipe shall be at least three times the nominal maximum-size coarse aggregate in the concrete mixture to be pumped but not less than **100 mm 4 inches**. Aluminum pipe shall not be used.

3.1.5 Vibrators

Vibrators of the proper size, frequency, and amplitude shall be used for the type of work being performed in conformance with the following

requirements:

APPLICATION	HEAD DIAMETER mm	FREQUENCY VPM	AMPLITUDE mm
Thin walls, beams, etc.	32 to 64	9,000 to 13,500	0.5 to 1.0
General construction	50 to 88	8,000 to 12,000	0.6 to 1.2

APPLICATION	HEAD DIAMETER INCHES	FREQUENCY VPM	AMPLITUDE INCHES
Thin walls, beams, etc.	1-1/4 to 2-1/2	9,000 to 13,500	0.02 to 0.04
General construction	2 to 3-1/2	8,000 to 12,000	0.025 to 0.05

The frequency and amplitude shall be determined in accordance with
COE CRD-C 521.

3.2 PREPARATION FOR PLACING

3.2.1 Embedded Items

Before placement of concrete, care shall be taken to determine that all embedded items are firmly and securely fastened in place as indicated on the drawings, or required. Embedded items shall be free of oil and other foreign matter such as loose coatings or rust, paint, and scale. The embedding of wood in concrete will be permitted only when specifically authorized or directed. Voids in sleeves, inserts, and anchor slots shall be filled temporarily with readily removable materials to prevent the entry of concrete into voids. Welding, including tack welding, will not be permitted on embedded metals within 600 mm 2 feet of the surface of the concrete.

3.2.2 Concrete on Earth Foundations

Earth surfaces upon which concrete is to be placed shall be clean, damp, and free from debris, frost, ice, and standing or running water. Prior to placement of concrete, the earth foundation shall have been satisfactorily compacted in accordance with Section [_____].

3.2.3 Concrete on Rock Foundations

Rock surfaces upon which concrete is to be placed shall be clean, free from oil, standing or running water, ice, mud, drummy rock, coating, debris, and loose, semidetached, or unsound fragments. Joints in rock shall be cleaned to a satisfactory depth, as determined by the Contracting Officer, and to firm rock on the sides. Immediately before the concrete is placed, all rock surfaces shall be cleaned thoroughly by the use of air-water jets or sandblasting as described in paragraph CONSTRUCTION JOINT TREATMENT. All rock surfaces shall be kept continuously wet for at least 24 hours immediately prior to placing concrete thereon. All approximately horizontal surfaces shall be covered, immediately before the concrete is placed, with a layer of mortar proportioned similar to that in the concrete mixture. The mortar shall be covered with concrete before the time of initial setting of the mortar.

3.2.4 Construction Joint Treatment

Construction joint treatment shall conform to the following requirements.

3.2.4.1 Joint Preparation

Concrete surfaces to which additional concrete is to be bonded shall be prepared for receiving the next lift or adjacent concrete by cleaning with either air-water cutting, sandblasting, high-pressure water jet, or other approved method. Air-water cutting will not be permitted on formed surfaces or surfaces congested with reinforcing steel. Regardless of the method used, the resulting surfaces shall be free from all laitance and inferior concrete so that clean, well bonded coarse aggregate is exposed uniformly throughout the lift surface. The edges of the coarse aggregate shall not be undercut. The surface shall be washed clean again as the last operation prior to placing the next lift. There shall be no standing water on the surface upon which concrete is placed.

3.2.4.2 Air-Water Cutting

Air-water cutting of a construction joint shall be performed at the proper time and only on horizontal construction joints. The air pressure used in the jet shall be 620 to 760 kPa 90 to 110 psi, and the water pressure shall be just sufficient to bring the water into effective influence of the air pressure. When approved by the Contracting Officer, a retarder complying with the requirements of COE CRD-C 94 may be applied to the surface of the lift to prolong the period of time during which air-water cutting is effective. Prior to receiving approval, the Contractor shall furnish samples of the material to be used and shall demonstrate the method to be used in applications. After cutting, the surface shall be washed and rinsed as long as there is any trace of cloudiness of the wash water. Where necessary to remove accumulated laitance, coatings, stains, debris, and other foreign material, high-pressure water jet or sandblasting will be required as the last operation before placing the next lift.

3.2.4.3 High-Pressure Water Jet

A stream of water under a pressure of not less than 20.7 MPa 3,000 psi may be used for cleaning. Its use shall be delayed until the concrete is sufficiently hard so that only the surface skin or mortar is removed and there is no undercutting of coarse-aggregate particles. If the water jet is incapable of a satisfactory cleaning, the surface shall be cleaned by sandblasting.

3.2.4.4 Wet Sandblasting

This method may be used when the concrete has reached sufficient strength to prevent undercutting of the coarse aggregate particles. The surface of the concrete shall then be washed thoroughly to remove all loose materials.

3.2.4.5 Waste Disposal

The method used in disposing of waste water employed in cutting, washing, and rinsing of concrete surfaces shall be such that the waste water does not stain, discolor, or affect exposed surfaces of the structures, or damage the environment of the project area. The method of disposal shall be subject to approval.

3.3 PLACING

3.3.1 Placing Procedures

The surfaces of horizontal construction joints shall be kept continuously wet for the first 12 hours during the 24-hour period prior to placing concrete. Surfaces may be dampened immediately before placement if necessary. Concrete placement will not be permitted when, in the opinion of the Contracting Officer, weather conditions prevent proper placement and consolidation. Concrete shall be deposited as close as possible to its final position in the forms and, in so depositing, there shall be no vertical drop greater than 1.5 m 5 feet except where suitable equipment is provided to prevent segregation and where specifically authorized. Depositing of the concrete shall be so regulated that it may be effectively consolidated in horizontal layers 600 mm 2.0 feet or less in thickness with a minimum of lateral movement. The amount deposited in each location shall be that which can be readily and thoroughly consolidated. Sufficient placing capacity shall be provided so that concrete placement can be kept plastic and free of cold joints while concrete is being placed. Concrete shall be placed by methods that will prevent segregation or loss of ingredients. Any concrete transferred from one conveying device to another shall be passed through a hopper that is conical in shape. The concrete shall not be dropped vertically more than 1.5 m 5 feet, except where a properly designed and sized elephant truck with rigid drop chute bottom section is provided to prevent segregation and where specifically authorized. In no case will concrete be discharged to free-fall through reinforcing bars.

3.3.2 Placement by Pump

When concrete is to be placed by pump, the nominal maximum-size coarse aggregate shall not be reduced to accommodate the pumps. The distance to be pumped shall not exceed limits recommended by the pump manufacturer. The concrete shall be supplied to the concrete pump continuously. When pumping is completed, concrete remaining in the pipeline shall be ejected without contamination of concrete in place. After each operation, equipment shall be thoroughly cleaned, and flushing water shall be wasted outside of the forms. Grout used to lubricate the pumping equipment at the beginning of the placement will not be incorporated into the placement.

3.3.3 Time Interval Between Mixing and Placing

Concrete shall be placed within 30 minutes after discharge into nonagitating equipment. When concrete is truck-mixed or when a truck mixer or agitator is used for transporting concrete mixed by a concrete plant mixer, the concrete shall be delivered to the site of the work, and discharge shall be completed within 1-1/2 hours after introduction of the cement to the aggregates. When the length of haul makes it impossible to deliver truck-mixed concrete within these time limits, batching of cement and a portion of the mixing water shall be delayed until the truck mixer is at or near the construction site.

3.3.4 Cold-Weather Placing

When cold-weather placing of concrete is likely to be subjected to freezing temperatures before the expiration of the curing period, it shall be placed in accordance with procedures previously submitted in accordance with paragraph SUBMITTALS. The ambient temperature of the space adjacent to the concrete placement and surfaces to receive concrete shall be above 0

degrees C 32 degrees F. The placing temperature of the concrete having a minimum dimension less than 300 mm 12 inches shall be between 12 and 24 degrees C 55 and 75 degrees F when measured in accordance with ASTM C 1064/C 1064M. The placing temperature of the concrete having a minimum dimension greater than 300 mm 12 inches shall be between 10 and 20 degrees C 50 and 70 degrees F. Heating of the mixing water or aggregates will be required to regulate the concrete-placing temperatures. Materials entering the mixer shall be free from ice, snow, or frozen lumps. Salt, chemicals, or other materials shall not be mixed with the concrete to prevent freezing.

3.3.5 Hot-Weather Placing

NOTE: See the appropriate DM for the proper placing temperature.

Concrete shall be properly placed and finished with procedures previously submitted in accordance with paragraph SUBMITTALS. The concrete-placing temperature shall not exceed [_____] degrees C F when measured in accordance with ASTM C 1064/C 1064M. Cooling of the mixing water and aggregates, or both, may be required to obtain an adequate placing temperature. A retarder meeting the requirements of paragraph WATER-REDUCING OR RETARDING ADMIXTURES may be used to facilitate placing and finishing. Steel forms and reinforcement shall be cooled prior to concrete placement when steel temperatures are greater than 50 degrees C 120 degrees F. Conveying and placing equipment shall be cooled if necessary to maintain proper concrete-placing temperature.

3.3.6 Consolidation

Immediately after placement, each layer of concrete, including flowing concrete, shall be consolidated by internal vibrating equipment. Vibrators shall not be used to transport concrete within the forms. Hand spading may be required, if necessary, with internal vibrating along formed surfaces permanently exposed to view. Form or surface vibrators shall not be used unless specifically approved. The vibrator shall be inserted vertically at uniform spacing over the entire area of placement. The distance between insertions shall be approximately 1-1/2 times the radius of action of the vibrator. The vibrator shall penetrate rapidly to the bottom of the layer and at least 150 mm 6 inches into the preceding unhardened layer if such exists. It shall be held stationary until the concrete is consolidated and then withdrawn slowly.

3.3.7 [Placing Concrete in Ogee Section

The unformed portion of the ogee section shall be finished by placing concrete slightly above grade and striking off to grade by accurate screeding. Screeding may be accomplished by semimechanical devices or by a mechanical screed that consolidates and screeds the surface in one operation. Ribs embedded in the fresh concrete as guides for screeds will not be permitted.]

3.3.8 [Placing Concrete Underwater

Concrete, described in Bid Item [____], shall be deposited in water by a tremie or concrete pump. The methods and equipment used shall be subject to approval. Concrete buckets will not be permitted for underwater

placement of concrete except to deliver concrete to the tremie. The tremie shall be watertight and sufficiently large to permit a free flow of concrete. The discharge end of the pump line or tremie shaft shall be kept continuously submerged in the concrete. The underwater seal shall be effected in a manner that will not produce undue turbulence in the water. The tremie shaft shall be kept full of concrete to a point well above the water surface. Placement shall proceed without interruption until the concrete has been brought to the required height. The tremie shall not be moved horizontally during a placing operation, and a sufficient number of tremies shall be provided so that the maximum horizontal flow will be limited to 5 m 15 feet.]

3.4 FINISHING

NOTE: Consult the appropriate DM for those surfaces to receive a trowel finish, abrasive aggregate finish or broom finish. Be sure those special finishes are shown in the drawings.

The ambient temperature of spaces adjacent to surfaces being finished shall be not less than 5 degrees C 40 degrees F. In hot weather when the rate of evaporation of surface moisture, as determined by use of Figure 2.1.5 of ACI 305R, may reasonably be expected to exceed 1.0 kg/square meter 0.2 pounds per square foot per hour. Provisions for windbreaks, shading, fog spraying, or wet covering with a light-colored material shall be made in advance of placement, and such protective measures shall be taken as quickly as finishing operations will allow. All unformed surfaces that are not to be covered by additional concrete or backfill shall have a float finish. Additional finishing shall be as specified below and shall be true to the elevation shown in the drawings. Surfaces to receive additional concrete or backfill shall be brought to the elevation shown on the drawings and left true and regular. Exterior surfaces shall be sloped for drainage unless otherwise shown in the drawing or as directed. Joints shall be carefully made with a jointing or edging tool. The finished surfaces shall be protected from stains or abrasions. Grate tampers or jitterbugs shall not be used.

3.4.1 Unformed Surfaces

3.4.1.1 Float Finish

Surfaces shall be screeded and darried or bullfloated to bring the surface to the required finish level with no coarse aggregate visible. No water, cement, or mortar shall be added to the surface during the finishing operation. The concrete, while still green but sufficiently hardened to bear a man's weight without deep imprint, shall be floated to a true and even plane. Floating may be performed by use of suitable hand floats or power-driven equipment. Hand floats shall be made of magnesium or aluminum.

3.4.1.2 Trowel Finish

A trowel finish shall be applied to the following surfaces: [_____] [_____]. Concrete surfaces shall be finished with a float finish, and after surface moisture has disappeared, the surface shall be troweled to a smooth, even, dense finish free from blemishes including trowel marks.

3.4.1.3 [Abrasive Aggregate Finish]

An abrasive aggregate finish shall be applied to the following surfaces: [_____] [_____]. The concrete surface shall be finished with a float finish. Abrasive aggregate shall be uniformly sprinkled over the floated surface at a rate of not less than 1.22 kg/square meter 1/4 pounds per square foot. The surface shall be troweled to a smooth, even finish that is uniform in texture and appearance and free from blemishes including trowels marks. Immediately after curing, cement coating or laitance covering the abrasive aggregate shall be removed by steel brushing, rubbing with abrasive stone, or sandblasting to expose the abrasive particles.]

3.4.1.4 [Broom Finish]

A broom finish shall be applied to the following surfaces: [_____] [_____]. The concrete surface shall be finished with a float finish. The floated surface shall be broomed with a fiber-bristle brush in a direction transverse to that of the main traffic.]

3.4.1.5 [Bonded Two-Course Floor]

NOTE: Consult the appropriate DM or the Design Engineer to choose from the optional paragraphs below.

A bonded two-course floor shall be constructed by placing a bonded topping on the thoroughly hardened concrete slab left a distance below final grade as shown in the drawings. The floor topping mixture shall have a specified compressive strength of 41.4 MPa 6,000 psi at 28 days, a 50 mm 2 inch maximum slump, 13 mm 1/2 inch maximum-size coarse aggregate and shall be proportioned to obtain required finishability. Materials shall meet the requirements of paragraph MATERIALS. The surface of the base slab shall be thoroughly cleaned by sandblasting or high pressure water jet in accordance with paragraph PREPARATION FOR PLACING. The base slab shall be kept continuously wet for the first 12 hours during the 24-hour period immediately prior to placing the finished floor. After all free water has evaporated or has been removed from the surface, a grout shall be scrubbed in. The grout shall be a 1:1 mixture of portland cement and sand passing the 2.36 mm No. 8 sieve mixed to a creamlike consistency. The grout shall be applied just ahead of the concrete-placing operation. While the grout is still damp, the top course shall be spread and screeded. The surface shall then be floated with a disc power float or equivalent, followed by a minimum of two power trowelings. Trowel marks left by the machine shall be removed by final, hard steel troweling by hand. The finished floor shall be moist cured in accordance with paragraph CURING AND PROTECTION, subparagraph MOIST CURING.]

3.4.1.6 [Unbonded Two-Course Floor]

An unbonded two-course floor shall be constructed by placing a bond-breaker on the thoroughly hardened concrete slab left a distance below final grade as shown in the drawings. The floor topping mixture shall have a specified compressive strength of 41.4 MPa 6,000 psi 28 days, a 50 mm 2 inch maximum slump, 13 mm 1/2 inch nominal maximum-size coarse aggregate, and shall be proportioned to obtain required finishability. Materials shall meet the requirements of paragraph MATERIALS. The base (bottom) course shall be screeded and bull-floated. The bond-breaker shall consist of plastic

sheeting, felt paper, a bond-breaking compound or a sand cushion. The topping shall be floated with a disc power float or equivalent, followed by a minimum of two power trowelings. Trowel marks left by the machine shall be removed by final, hard steel troweling by hand. The finished floor shall be moist cured in accordance with paragraph CURING AND PROTECTION, subparagraph MOIST CURING.]

3.4.2 Formed Surfaces

NOTE: Consult the appropriate DM for information on special architectural finishes. These finishes should also be shown in drawings. Contact the Division Office or CECW-EG for additional guidance if the use of architectural finishes is extensive. If any architectural finish is required other than the normal texture imparted by the forms, the optional sample panel in UFGS Section 03 11 13.00 10 FORMWORK FOR CONCRETE shall be required.

Unless another finish is specified, surfaces shall be left with the texture imparted by the forms except that defective surfaces shall be repaired as described in paragraph FORMED SURFACE REPAIR. [Other finishes shall be applied to the following structures or portions of structures:]

TYPES OF FINISH	STRUCTURE OR PORTION OF STRUCTURE
[Grout-cleaned	[_____]]
[Textured	[_____]]
[Exposed aggregate	[_____]]
[Sand-blast	[_____]]
[Tooled	[_____]]

Unless painting of surfaces is required, uniform color of the concrete shall be maintained by use of only one mixture without changes in materials or proportions for any structure or portion of structure that is exposed to view or on which a special finish is required. The form panels used to produce the finish shall be orderly in arrangement, with joints between panels planned in approved relation to openings, building corners, and other architectural features. [The finished surface of sand-blasted, textured, tooled, and exposed aggregate finishes shall duplicate the preapproved sample panel. The sample panel shall be prepared in accordance with Section 03 11 13.00 10 STRUCTURAL CONCRETE FORMWORK.] Forms shall not be reused if there is any evidence of surface wear or defects that would impair the quality of the surface.

3.4.2.1 [Grout-Cleaned Finish

NOTE: See the appropriate DM and EM 1110-2-2000 for surfaces to receive a grout-cleaned finish. Be sure this is shown in the drawings.

The surfaces of [_____] shall be given a grout-cleaned finish as described, as approved by the Contracting Officer and after all required curing, cleaning, and repairs have been completed. Surfaces to be grout-cleaned

shall be moist cured for the required period of time before application of the grout-cleaned finish. Grout-cleaning shall be delayed until near the end of construction on all surfaces not to be painted in order to achieve uniformity of appearance and reduce the chance of discoloring caused by subsequent construction operations. The temperature of the air adjacent to the surface shall be not less than 5 degrees C 40 degrees F for 24 hours prior to and 72 hours following the application of the finish. The finish for any area shall be completed in the same day, and the limits of a finished area shall be made at natural breaks in the finished surface. The surface to receive grout-cleaned finish shall be thoroughly wetted to prevent absorption of water from the grout but shall have no free water present. The surface shall then be coated with grout. The grout shall be applied as soon as the surface of the concrete approaches surface dryness and shall be vigorously and thoroughly rubbed over the area with clean burlap pads, cork floats or stones, so as to fill all voids. The grout shall be composed of one part portland cement as used on the project, to two parts by volume of well-graded sand passing a 600-µm (No. 30) sieve mixed with water to the consistency of thick paint. White portland cement shall be used for all or part of the cement as approved by the Contracting Officer to give the desired finish color. The applied coating shall be uniform, completely filling all pits, air bubbles, and surface voids. While the grout is still plastic, remove all excess grout by working the surface with a rubber float, burlap pad, or other means. Then, after the surface whitens from drying (about 30 minutes at normal temperature) rub vigorously with clean burlap pads. Immediately after rubbing is completed, the finished surface shall be continuously moist cured for 72 hours. Burlap pads used for this operation shall be burlap stretched tightly around a board to prevent dishing the mortar in the voids.]

3.4.2.2 [Textured Finish

This type of finish shall be applied where specified to conform to details shown in the drawings by use of approved textured form liners. Liner panels shall be secured in the forms by methods recommended by the manufacturer but not by methods that will permit impressions of nail heads, screw heads, washers, or the like to be imparted to the surface of the concrete. Edges of textured panels shall be sealed to each other to prevent grout leakage. The sealant used shall be nonstaining to the surface. The finish shall be similar to and shall closely match the finish on the sample panel.]

3.4.2.3 [Exposed Coarse-Aggregate Finish

Coarse aggregate shall be exposed by a method preapproved by the Contracting Officer. The finish shall be similar to and shall closely match the finish on the sample panel.]

3.4.2.4 [Sand-Blast Finish

The concrete surface shall be blasted to obtain a [brush] [light] [medium] [heavy] uniform finish prepared in accordance with the descriptive photographs in [ACI 303R](#). The finish shall be similar to and shall closely match the finish on the sample panel.]

3.4.2.5 [Tooled Finish

The thoroughly cured concrete shall be dressed with electric, air, or hand tools to a uniform texture and shall be given a [hand-tooled] [rough] [or] [fine-pointed] [crandalled] [or] [bush-hammered] surface texture. The

finish shall be similar to and shall closely match the finish on the sample panel.]

3.4.3 Formed Surface Repair

NOTE: Refer to EM 1110-2-2000 for direction on class of finish. Please note that definitions for class of finish have been changed recently. Class of finish shall also be shown in the drawings. The section on formwork presents materials for each class.

After removal of forms, all ridges, lips, and bulges on surfaces permanently exposed shall be removed. All repairs shall be completed within 48 hours after form removal.

3.4.3.1 Classes A, AHV, & B Finishes

Surfaces listed in Section 03 11 13.00 10 STRUCTURAL CONCRETE FORMWORK and as shown to have classes A, AHV, and B finishes shall have surface defects repaired as follows: defective areas, voids, and honeycombs smaller than 10 000 square mm 16 square inches in area and less than 13 mm 1/2 inch deep and bug holes exceeding 13 mm 1/2 inch in diameter shall be chipped and filled with dry-packed mortar. Holes left by removal of tie rods shall be reamed and filled with dry-packed mortar as specified in paragraph MATERIAL AND PROCEDURE FOR REPAIRS. Defective and unsound concrete areas larger than described shall be defined by 13 mm 1/2 inch deep dovetailed saw cuts in a rectangular pattern with lines parallel to the formwork, the defective concrete removed by chipping, and the void repaired with replacement concrete. The prepared area shall be brush-coated with an epoxy resin meeting the requirements of paragraph EPOXY RESIN, a latex bonding agent meeting the requirements of paragraph LATEX BONDING COMPOUND, or a neat cement grout after dampening the area with water. The void shall be filled with replacement concrete in accordance with paragraph MATERIAL AND PROCEDURE FOR REPAIRS.

3.4.3.2 Class C Finish

Surfaces listed in Section 03 11 13.00 10 STRUCTURAL CONCRETE FORMWORK and as shown shall have defects repaired as follows: defective areas, voids, and honeycombs smaller than 15 000 square mm 24 square inches and less than 50 mm 2 inches deep; bug holes exceeding 38 mm 1-1/2 inches in diameter shall be chipped and filled with dry-packed mortar; and holes left by removal of the tie rods shall be chipped and filled with dry-packed mortar. Defective and unsound concrete areas larger than 15 000 square mm 24 square inches and deeper than 38 mm 1-1/2 inches shall be defined by 13 mm 1/2 inch deep dovetailed saw cuts in a rectangular pattern, the defective concrete removed by chipping, and the void repaired with replacement concrete. The prepared area shall be brush-coated with an epoxy resin meeting the requirements of paragraph EPOXY RESIN, a latex bonding agent meeting the requirements of paragraph LATEX BONDING COMPOUND, or a neat cement grout after dampening the area with water. The void shall be filled with replacement concrete in accordance with paragraph MATERIAL AND PROCEDURE FOR REPAIRS.

3.4.3.3 Class D Finish

Surfaces listed in Section 03 11 13.00 10 STRUCTURAL CONCRETE FORMWORK and as shown to have class D finish shall have surface defects repaired as follows: defective areas, voids, and honeycombs greater than 30 000 square mm 48 square inches in area or more than 50 mm 2 inches deep shall be defined by 13 mm 1/2 inch deep dovetailed saw cuts in a rectangular pattern, the defective concrete removed by chipping and the void repaired with replacement concrete. The prepared area shall be brush-coated with an epoxy resin meeting the requirements of paragraph EPOXY RESIN, a latex bonding agent meeting the requirements of paragraph LATEX BONDING COMPOUND, or a neat cement grout after dampening the area with water. The void shall be filled with replacement concrete in accordance with paragraph MATERIAL AND PROCEDURE FOR REPAIRS.

3.4.3.4 Material and Procedure for Repairs

The cement used in the dry-packed mortar or replacement concrete shall be a blend of the cement used for production of project concrete and white portland cement properly proportioned so that the final color of the mortar or concrete will match adjacent concrete. Trial batches shall be used to determine the proportions required to match colors. Dry-packed mortar shall consist of one part cement to two and one-half parts fine aggregate. The fine aggregate shall be that used for production of project concrete. The mortar shall be remixed over a period of at least 30 minutes without addition of water until it obtains the stiffest consistency that will permit placing. Mortar shall be thoroughly compacted into the prepared void by tamping, rodding, ramming, etc. and struck off to match adjacent concrete. Replacement concrete shall be produced using project materials and shall be proportioned by the Contracting Officer. It shall be thoroughly compacted into the prepared void by internal vibration, tamping, rodding, ramming, etc. and shall be struck off and finished to match adjacent concrete. Forms shall be used to confine the concrete. If an expanding agent is used in the repair concrete, the repair shall be thoroughly confined on all sides including the top surface. Metal tools shall not be used to finish permanently exposed surfaces. The repaired areas shall be cured for 7 days. The temperature of the in situ concrete, adjacent air, and replacement mortar or concrete shall be above 5 degrees C 40 degrees F during placement, finishing, and curing. Other methods and materials for repair may be used only when approved in writing by the Contracting Officer. Repairs of the so called "plaster-type" will not be permitted.

3.5 CURING AND PROTECTION

3.5.1 Duration

The length of the curing period shall be determined by the type of cementitious material, as specified below. Concrete shall be cured by an approved method.

[Type III portland cement _____	3 days]
[Portland cement when accelerator is used to achieve high early strength, except when fly-ash or GGBF slag is used _____	3 days]
[Type I portland cement _____	7 days]
[[Type IS] [Type IP] cement _____	7 days]
[Portland cement blended with silica fume _____	7 days]

[Type II portland cement _____ 14 days]
[Portland cement blended with
25 percent of less fly-ash or GGBF slag _____ 14 days]

[Portland cement blended with more than
25 percent fly-ash or GGBF slag _____ 21 days]

Immediately after placement, concrete shall be protected from premature drying, extremes in temperatures, rapid temperature change, and mechanical damage. All materials and equipment needed for adequate curing and protection shall be available and at the placement site prior to the start of concrete placement. Concrete shall be protected from the damaging effects of rain for 12 hours and from flowing water for 14 days [7 days with Type III cement]. No fire or excessive heat including welding shall be permitted near or in direct contact with concrete or concrete embedments at any time.

3.5.2 Moist Curing

Moist-cured concrete shall be maintained continuously, not periodically, wet for the entire curing period. If water or curing materials stain or discolor concrete surfaces that are to be permanently exposed, they shall be cleaned as required in paragraph APPEARANCE. Where wooden form sheathing is left in place during curing, the sheathing shall be kept wet at all times. If steel forms are used in hot weather, nonsupporting vertical forms shall be carefully broken loose from the concrete, soon after the concrete hardens, and curing water continuously applied into the void so as to continuously saturate the entire concrete surface. Horizontal surfaces may be moist cured by ponding, by covering with a minimum uniform thickness of 50 mm 2 inches of continuously saturated sand, or by covering with saturated nonstaining burlap or cotton mats. Horizontal construction joints may be allowed to dry for 12 hours immediately prior to the placing of the following lift. Silica fume concrete, if used, shall be moist-cured. Curing of silica fume concrete shall start immediately after placement.

3.5.3 Membrane-Forming Curing Compound

Concrete may be cured with an approved membrane-forming curing compound in lieu of moist curing except that membrane curing will not be permitted on any surface to which a grout-cleaned finish is to be applied or other concrete is to be bonded, on any surface containing protruding steel reinforcement, on an abrasive aggregate finish, or any surface maintained at curing temperature by use of free steam. A styrene acrylate or chlorinated rubber compound may be used for surfaces that are to be painted or are to receive bituminous roofing or waterproofing, or for floors that are to receive adhesive applications of resilient flooring. The curing compound selected shall be compatible with any subsequent paint, roofing, waterproofing, or flooring specified.

3.5.3.1 Pigmented Curing Compound

A pigmented curing compound meeting the requirements of the above paragraph MEMBRANE-FORMING CURING COMPOUND may be used on surfaces that will not be exposed to view when the project is completed.

3.5.3.2 Nonpigmented Curing Compound

A nonpigmented curing compound containing a fugitive dye may be used on surfaces that will be exposed to view when the project is completed. Concrete cured with nonpigmented curing compound must be shaded from the sun for the first 3 days when the ambient temperature is 32 degrees C 90 degrees F or higher.

3.5.3.3 Application

The curing compound shall be applied to formed surfaces immediately after the forms are removed and prior to any patching or other surface treatment except the cleaning of loose sand, mortar, and debris from the surface. The surfaces shall be thoroughly moistened with water, and the curing compound applied as soon as free water disappears. The curing compound shall be applied to unformed surfaces as soon as free water has disappeared and bleeding has stopped. The curing compound shall be applied in a two-coat continuous operation by approved motorized power-spraying equipment operating at a minimum pressure of 500 kPa 75 psi, at a uniform coverage of not more than 10 square meters/L 400 square feet per gallon for each coat, and the second coat shall be applied perpendicular to the first coat. Concrete surfaces that have been subjected to rainfall within 3 hours after curing compound has been applied shall be resprayed by the method and at the coverage specified. All concrete surfaces on which the curing compound has been applied shall be adequately protected for the duration of the entire curing period from pedestrian and vehicular traffic and from any other cause that will disrupt the continuity of the curing membrane.

3.5.4 Evaporation Retardant

NOTE: The concrete that may be cured using
impervious sheet should be horizontal or near
horizontal finished surfaces such as roof slabs,
floors, or the first course of two-course floors, or
floors that are to be covered with tile or resilient
flooring.

The following concrete surfaces may be cured using sheet material:

[]
[]

Sheet curing shall not be used on vertical or near-vertical surfaces. All surfaces shall be thoroughly wetted and be completely covered with waterproof paper or polyethylene-coated burlap having the burlap thoroughly water-saturated before placing. Covering shall be laid with light-colored side up. Covering shall be lapped not less than 300 mm 12 inches and securely weighted down or shall be lapped not less than 100 mm 4 inches and taped to form a continuous cover with completely closed joints. The sheet shall be weighted to prevent displacement so that it remains in contact with the concrete during the specified length of curing. Coverings shall be folded down over exposed edges of slabs and secured by approved means. Sheets shall be immediately repaired or replaced if tears or holes appear during the curing period.

3.5.5 Cold-Weather Curing and Protection

When the daily outdoor low temperature is less than 0 degrees C 32 degrees F, the temperature of the concrete shall be maintained above 5 degrees C 40 degrees F for the first 7 days after placing. In addition, during the period of protection removal, the air temperature adjacent to the concrete surfaces shall be controlled so that concrete near the surface will not be subjected to a temperature differential of more than 15 degrees C 25 degrees F as determined by observation of ambient and concrete temperatures indicated by suitable temperatures measuring devices furnished by the Government as required and installed adjacent to the concrete surface and 50 mm 2 inches inside the surface of the concrete. The installation of the thermometers shall be made by the Contractor at such locations as may be directed.

3.6 SETTING OF BASE PLATES AND BEARING PLATES

3.6.1 Setting of Plates

After being plumbed and properly positioned, column base plates, bearing plates for beams and similar structural members, and machinery and equipment base plates shall be provided with full bearing with nonshrink grout. The space between the top of concrete or masonry-bearing surface and the bottom of the plate shall be approximately 1/24 of the width of the plate, but not less than 13 mm 1/2 inch for plates less than 300 mm 12 inches wide. Concrete surfaces shall be rough, clean, and free of oil, grease, and laitance, and they shall be damp. Metal surfaces shall be clean and free of oil, grease, and rust.

3.6.2 Nonshrink Grout Application

Nonshrink grout shall conform to the requirements of paragraph NONSHRINK GROUT. Water content shall be the minimum that will provide a flowable mixture and fill the space to be grouted without segregation, bleeding, or reduction of strength.

3.6.2.1 Mixing and Placing of Nonshrink Grout

Mixing and placing shall be in conformance with the material manufacturer's instructions and as specified. Ingredients shall be thoroughly dry-mixed before adding water. After adding water, the batch shall be mixed for 3 minutes. Batches shall be of size to allow continuous placement of freshly mixed grout. Grout not used within 30 minutes after mixing shall be discarded. The space between the top of the concrete or masonry-bearing surface and the plate shall be filled solid with the grout. Forms shall be of wood or other equally suitable material for retaining the grout and shall be removed after the grout has set. If grade "A" grout as specified in ASTM C 1107/C 1107M is used, all surfaces shall be formed to provide restraint. The placed grout shall be worked to eliminate voids; however, overworking and breakdown of the initial set shall be avoided. Grout shall not be retempered or subjected to vibration from any source. Where clearances are unusually small, placement shall be under pressure with a grout pump. Temperature of the grout, and of surfaces receiving the grout, shall be maintained at 20 to 30 degrees C 65 to 85 degrees F until after setting.

3.6.2.2 Treatment of Exposed Surfaces

After the grout has set, those types containing metallic aggregate shall

have the exposed surfaces cut back 25 mm 1 inch and immediately covered with a parge coat of mortar proportioned by mass of one part portland cement, two parts sand, and sufficient water to make the mixture placeable. The parge coat shall have a smooth, dense finish. The exposed surface of other types of nonshrink grout shall have a smooth, dense finish.

3.6.2.3 Curing

Grout and parge coats shall be cured in conformance with paragraph CURING AND PROTECTION.

3.7 TESTS AND INSPECTIONS

Tests and inspections shall conform to the following requirements.

3.7.1 General

NOTE: The title of the certification provided by
ACI that concrete inspectors/technicians have to
have to perform concrete testing was changed from
"Concrete Transportation Construction Inspector" to
"Concrete Construction Inspector" in 2004. Since
the certification is good for 5 years, both titles
will be kept in the specifications through 2006;
pick the correct bracketed statement for projects
prior to 2004.

The Contractor shall perform the inspections and tests described below, and, based upon the results of these inspections and tests, he shall take the action required and submit reports as required. When, in the opinion of the Contracting Officer, the concreting operation is out of control, concrete placement shall cease. The laboratory performing the tests shall be on site and shall conform with ASTM C 1077. The individuals who sample and test concrete or the constituents of concrete as required in this specification shall have demonstrated a knowledge and ability to perform the necessary test procedures equivalent to the ACI minimum guidelines for certification of Concrete Field Testing Technicians, Grade I. The individuals who perform the inspection of concrete construction shall have demonstrated a knowledge and ability equivalent to the ACI minimum guidelines for certification of [Concrete Transportation Construction Inspector (CTCI)] [Concrete Construction Inspector (CCI)]. The Government will inspect the laboratory, equipment, and test procedures prior to start of concreting operations and at least once per year thereafter for conformance with ASTM C 1077.

3.7.2 Testing and Inspection Requirements

3.7.2.1 Fine Aggregate

a. Grading - 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 C 136 and COE CRD-C 104 for the fine aggregate or for each size range of 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.

b. Corrective Action for Fine Aggregate Grading - 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 immediately be reported to the Contracting Officer.

c. Moisture Content Testing - When in the opinion of the Contracting Officer the electric moisture meter is not operating satisfactorily, there shall be at least four tests for moisture content in accordance with [ASTM C 566](#) during each 8-hour period of mixing plant operation. The times for the tests shall be selected randomly within the 8-hour period. An additional test shall be made whenever the slump is shown to be out of control or excessive variation in workability is reported by the placing foreman. When the electric moisture meter is operating satisfactorily, at least two direct measurements of moisture content shall be made per week to check the calibration of the meter. The results of tests for moisture content shall be used to adjust the added water in the control of the batch plant.

d. Moisture Content Corrective Action - Whenever the moisture content of the fine aggregate changes by 0.5 percent or more, the scale settings for the fine-aggregate batcher and water batcher shall be adjusted (directly or by means of a moisture compensation device) if necessary to maintain the specified slump.

3.7.2.2 Coarse Aggregate

a. Grading - At least once during each shift in which the concrete plant is operating, there shall be a sieve analysis in accordance with [ASTM C 136](#) 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 which are coarser than the specification limits for samples taken at locations other than as delivered to the mixer to allow for degradation during handling.

b. Corrective Action for Grading - 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 five tests are outside specification limits, the operation shall be considered out of control and shall be reported to the Contracting Officer. Concreting shall be stopped and immediate steps shall be taken to correct the grading.

c. Coarse Aggregate Moisture Content - A test for moisture content of each size group of coarse aggregate shall be made at least twice per week. When two consecutive readings for smallest size coarse aggregate differ by more than 1.0 percent, frequency of testing shall be increased to that specified above for fine aggregate, until the difference falls below 1.0 percent.

d. Coarse Aggregate Moisture Corrective Action - Whenever the moisture

content of any size of coarse aggregate changes by 0.5 percent or more, the scale setting for the coarse aggregate batcher and the water batcher shall be adjusted if necessary to maintain the specified slump.

3.7.2.3 Quality of Aggregates

NOTES: Tests should be those listed in paragraph QUALITY.

The petrographic examination shall be used to identify deleterious substances in aggregates. Deleterious substances shall be listed individually with respective limits.

Depending upon the quality pf aggregates available, some tests may not be required. Refer to EM 1110-2-2000 for the purpose of each test.

a. Frequency of Quality Tests - Thirty days prior to the start of concrete placement the Contractor shall perform all tests for aggregate quality listed below. In addition, after the start of concrete placement, the Contractor shall perform tests for aggregate quality in accordance with the frequency schedule shown below. Samples tested after the start of concrete placement shall be taken immediately prior to entering the concrete mixer.

PROPERTY	FINE AGGREGATE	FREQUENCY COARSE AGGREGATE	TEST
Specific Gravity	Every 3 months	Every 3 months	ASTM C 127 ASTM C 128
Absorption	Every 3 months	Every 3 months	ASTM C 127 ASTM C 128
[Durability Factor Using, (Procedure A)	Every 12 months	Every 12 months	COE CRD-C 114 ASTM C 666/C 666M]
[Clay Lumps and Friable Particles	Every 3 months	Every 3 months	ASTM C 142]
[Material Finer than the 75-µm (No. 200) Sieve	Not applicable	Every 3 months	ASTM C 117]
Impurities	Every 3 months	Not applicable	ASTM C 40 ASTM C 87
[A.L. Abrasion	Not applicable	Every 6 months	ASTM C 131 ASTM C 535]
[Soft and Friable (Scratch Hardness)	Not applicable	Every 6 months	COE CRD-C 130]

PROPERTY	FINE AGGREGATE	FREQUENCY COARSE AGGREGATE	TEST
[Petrographic Examination	Every 6 months	Every 6 months	ASTM C 295]
[Chert, less than 2.40 specific gravity	Every 6 months	Every 6 months	ASTM C 123]
[Coal and Lignite, less than 2.00 gravity	Every 6 months	Every 6 months	ASTM C 123]

b. Corrective Action for Aggregate Quality - If the result of a quality test fails to meet the requirements for quality immediately prior to start of concrete placement, production procedures or materials shall be changed and additional tests shall be performed until the material meets the quality requirements prior to proceeding with either mixture proportioning studies or starting concrete placement. After concrete placement commences, whenever the result of a test for quality fails the requirements, the test shall be rerun immediately. If the second test fails the quality requirement, the fact shall be reported to the Contracting Officer and immediate steps taken to rectify the situation.

3.7.2.4 Scales

a. Weighing Accuracy - The accuracy of the scales shall be checked by test weights prior to start of concrete operations and at least once every 3 months for conformance with the applicable requirements of paragraph BATCHING EQUIPMENT. Such tests shall also be made as directed whenever there are variations in properties of the fresh concrete that could result from batching errors.

b. Batching and Recording Accuracy - Once a week the accuracy of each batching and recording device shall be checked during a weighing operation by noting and recording the required weight, recorded weight, and the actual weight batched. The Contractor shall confirm that the calibration devices described in paragraph BATCH PLANT for checking the accuracy of dispensed admixtures are operating properly.

c. Scales Corrective Action - When either the weighing accuracy or batching accuracy does not comply with specification requirements, the plant shall not be operated until necessary adjustments or repairs have been made. Discrepancies in recording accuracies shall be corrected immediately.

3.7.2.5 Batch-Plant Control

The measurement of all constituent materials including cementitious materials, each size of aggregate, water, and admixtures shall be continuously controlled. The aggregate weights and amount of added water shall be adjusted as necessary to compensate for free moisture in the aggregates. The amount of air-entraining agent shall be adjusted to

control air content within specified limits. A report shall be prepared indicating type and source of cement used, type and source of pozzolan or slag used, amount and source of admixtures used, aggregate source, the required aggregate and water weights per cubic meter yard, amount of water as free moisture in each size of aggregate, and the batch aggregate and water weights per cubic meter yard for each class of concrete batched during plant operation.

3.7.2.6 Concrete Mixture

a. Air Content Testing - Air content tests shall be made when test specimens are fabricated. In addition, at least two tests for air content shall be made on randomly selected batches of each separate concrete mixture produced during each 8-hour period of concrete production. Additional tests shall be made when excessive variation in workability is reported by the placing foreman or Government quality assurance representative. Tests shall be made in accordance with ASTM C 231. Test results shall be plotted on control charts which shall at all times be readily available to the Government. Copies of the current control charts shall be kept in the field by the Contractor's quality control representatives and results plotted as tests are made. When a single test result reaches either the upper or lower action limit a second test shall immediately be made. The results of the two tests shall be averaged and this average used as the air content of the batch to plot on both the control chart for air content and the control chart for range, and for determining the need for any remedial action. The result of each test, or average as noted in the previous sentence, shall be plotted on a separate chart for each mixture on which an "average line" is set at the midpoint of the specified air content range from paragraph AIR CONTENT. An upper warning limit and a lower warning limit line shall be set 1.0 percentage point above and below the average line. An upper action limit and a lower action limit line shall be set 1.5 percentage points above and below the average line, respectively. The range between each two consecutive tests shall be plotted on a control chart for range where an upper warning limit is set at 2.0 percentage points and upper action limit is set at 3.0 percentage points. Samples for air content may be taken at the mixer, however, the Contractor is responsible for delivering the concrete to the placement site at the stipulated air content. If the Contractor's materials or transportation methods cause air content loss between the mixer and the placement, correlation samples shall be taken at the placement site as required by the Contracting Officer and the air content at the mixer controlled as directed.

b. Air Content Corrective Action - Whenever points on the control chart for percent air reach either warning limit, an adjustment shall immediately be made in the amount of air-entraining admixture batched. As soon as is practical after each adjustment, another test shall be made to verify the result of the adjustment. Whenever a point on the control chart range reaches the warning limit, the admixture dispenser shall be recalibrated to ensure that it is operating accurately and with good reproducibility. Whenever a point on either control chart reaches an action limit line, the air content shall be considered out of control and the concreting operation shall immediately be halted until the air content is under control. Additional air content tests shall be made when concreting is restarted. All this shall be at no extra cost to the Government.

c. Slump Testing - In addition to slump tests which shall be made when test specimens are fabricated, at least four slump tests shall be made on randomly selected batches in accordance with [ASTM C 143/C 143M](#) for each separate concrete mixture produced during each 8-hour or less period of concrete production each day. Also, additional tests shall be made when excessive variation in workability is reported by the placing foreman or Government's quality assurance representative. Test results shall be plotted on control charts which shall at all times be readily available to the Government. Copies of the current control charts shall be kept in the field by the Contractor's quality control representatives and results plotted as tests are made. When a single slump test reaches or goes beyond either the upper or lower action limit, a second test shall immediately be made on the same batch of concrete. The results of the two tests shall be averaged and this average used as the slump of the batch to plot on both the control chart for percent air and the chart for range, and for determining the need for any remedial action. An upper warning limit shall be set at [13 mm 1/2 inch](#) below the maximum allowable slump on separate control charts for percent air used for each type of mixture as specified in paragraph SLUMP, and an upper action limit line and lower action limit line shall be set at the maximum and minimum allowable slumps, respectively, as specified in the same paragraph. The range between each consecutive slump test for each type of mixture shall be plotted on a single control chart for range on which an upper action limit is set at [50 mm 2 inches](#). Samples for slump shall be taken at the mixer, however, the Contractor is responsible for delivering the concrete to the placement site at the stipulated slump. If the Contractor's materials or transportation methods cause slump loss between mixer and the placement, correlation samples shall be taken at the placement site as required by the Contracting Officer and the slump at the mixer controlled as directed.

d. Slump Corrective Action - Whenever points on the control chart for slump reach the upper warning limit, an adjustment shall be immediately made in the batch weights of water and fine aggregate. The adjustments are to be made so that the total water content does not exceed that amount allowed by the maximum W/C specified, based upon aggregates which are in a saturated surface-dry condition. When a single slump reaches the upper or lower action limit, no further concrete shall be delivered to the placing site until proper adjustments have been made. Immediately after each adjustment, another test shall be made to verify the correctness of the adjustment. Whenever two consecutive slump tests, made during a period when there was no adjustment of batch weights, produce a point on the control chart for range at or above the upper action limit, the concreting operation shall immediately be halted and the Contractor shall take appropriate steps to bring the slump under control. Also, additional slump tests shall be made as directed. All this shall be at no additional cost to the Government.

e. Temperature - The temperature of the concrete shall be measured when compressive strength specimens are fabricated. Measurement shall be in accordance with [ASTM C 1064/C 1064M](#). The temperature shall be reported along with the compressive strength data.

f. Compressive-Strength Specimens - At least one set of test specimens shall be made each day on each different concrete mixture placed during the day. Additional sets of test cylinders shall be made, as directed by the Contracting Officer, when the mixture proportions are changed or when low strengths have been detected. A random sampling plan shall be

developed by the Contractor and approved by the Contracting Officer prior to the start of construction. The plan shall assure that sampling is done in a completely random and unbiased manner. A set of test specimens for concrete with a 28-day specified strength per paragraph DESIGN REQUIREMENTS shall consist of four cylinders, two to be tested at 7 days and two at 28 days. A set of test specimens for concrete with a 90-day strength per specified paragraph DESIGN REQUIREMENTS shall consist of six cylinders, two tested at 7 days, two at 28 days, and two at 90 days. Test specimens shall be molded and cured in accordance with [ASTM C 31/C 31M](#) and tested in accordance with [ASTM C 39/C 39M](#). All compressive-strength tests shall be reported immediately to the Contracting Officer. Quality control charts shall be kept for individual strength tests, moving average for strength, and moving average for range for each mixture. The charts shall be similar to those found in [ACI 214R](#).

3.7.2.7 Inspection Before Placing

Foundation or construction joints, forms, and embedded items shall be inspected for quality by the Contractor in sufficient time prior to each concrete placement to certify to the Contracting Officer that they are ready to receive concrete. The results of each inspection shall be reported in writing.

3.7.2.8 Placing

- a. Placing Inspection - The placing foreman shall supervise all placing operations, shall determine that the correct quality of concrete or grout is placed in each location as directed and shall be responsible for measuring and recording concrete temperatures and ambient temperature hourly during placing operations, weather conditions, time of placement, yardage placed, and method of placement.
- b. Placing Corrective Action - The placing foreman shall not permit batching and placing to begin until he has verified that an adequate number of vibrators in working order and with competent operators are available. Placing shall not be continued if any pile of concrete is inadequately consolidated. If any batch of concrete fails to meet the temperature requirements, immediate steps shall be taken to improve temperature controls.

3.7.2.9 Vibrators

- a. Vibrator Testing and Use - The frequency and amplitude of each vibrator shall be determined in accordance with [COE CRD-C 521](#) prior to initial use and at least once a month when concrete is being placed. Additional tests shall be made as directed when a vibrator does not appear to be adequately consolidating the concrete. The frequency shall be determined at the same time the vibrator is operating in concrete with the tachometer held against the upper end of the vibrator head while almost submerged and just before the vibrator is withdrawn from the concrete. The amplitude shall be determined with the head vibrating in air. Two measurements shall be taken, one near the tip and another near the upper end of the vibrator head and these results averaged. The make, model, type, and size of the vibrator and frequency and amplitude results shall be reported in writing.
- b. Vibrator Corrective Action - Any vibrator not meeting the requirements of paragraph VIBRATORS shall be immediately removed from

service and repaired or replaced.

3.7.2.10 Curing

a. Moist-Curing Inspections - At least once each shift, and once per day on nonwork days an inspection shall be made of all areas subject to moist curing. The surface moisture condition shall be noted and recorded.

b. Moist-Curing Corrective Action - When a daily inspection report lists an area of inadequate curing, immediate corrective action shall be taken, and the required curing period for such areas shall be extended by one (1) day.

c. Membrane-Curing Inspection - No curing compound shall be applied until the Contractor's authorized representative has verified that the compound is properly mixed and ready for spraying. At the end of each operation, he shall estimate the quantity of compound used by measurement of the container and the area of concrete surface covered and compute the rate of coverage in **square meters/L square feet per gallon**. He shall note whether or not coverage is uniform.

d. Membrane-Curing Corrective Action - When the coverage rate of the curing compound is less than that specified or when the coverage is not uniform, the entire surface shall be sprayed again.

e. Sheet-Curing Inspection - At least once each shift and once per day on nonwork days, an inspection shall be made of all areas being cured using material sheets. The condition of the covering and the tightness of the laps and tapes shall be noted and recorded.

f. Sheet-Curing Corrective Action - When a daily inspection report lists any tears, holes, or laps or joints that are not completely closed, the tears and holes shall promptly be repaired or the sheets replaced, the joints closed, and the required curing period for those areas shall be extended by one (1) day.

3.7.2.11 Cold-Weather Protection and Sealed Insulation Curing

At least once each shift and once per day on nonwork days, an inspection shall be made of all areas subject to cold-weather protection. The protection system shall be inspected for holes, tears, unsealed joints, or other deficiencies that could result in damage to the concrete. Special attention shall be taken at edges, corners, and thin sections. Any deficiencies shall be noted, corrected, and reported.

3.7.2.12 Cold-Weather Protection Corrective Action

When a daily inspection report lists any holes, tears, unsealed joints, or other deficiencies, the deficiency shall be corrected immediately and the period of protection extended 1 day.

3.7.2.13 Mixer Uniformity

a. Stationary Mixers - Prior to the start of concrete placing and once every 6 months when concrete is being placed, or once for every **57,000 cubic meters 75,000 cubic yards** of concrete placed, whichever results in the longest time interval, uniformity of concrete mixing shall be determined in accordance with **ASTM C 94/C 94M**.

b. Truck Mixers - Prior to the start of concrete placing and at least once every 6 months when concrete is being placed, uniformity of concrete shall be determined in accordance with ASTM C 94/C 94M. The truck mixers shall be selected randomly for testing. When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of the blades may be regarded as satisfactory.

3.7.2.14 Mixer Uniformity Corrective Action

When a mixer fails to meet mixer uniformity requirements, either the mixer shall be removed from service on the work, the mixing time shall be increased, batching sequence changed, batch size reduced, or adjustments shall be made to the mixer until compliance is achieved.

3.7.3 Reports

All results of tests or inspections conducted shall be reported informally as they are completed and in writing daily. A weekly report shall be prepared for the updating of control charts covering the entire period from the start of the construction season through the current week. During periods of cold-weather protection, reports of pertinent temperatures shall be made daily. These requirements do not relieve the Contractor of the obligation to report certain failures immediately as required in preceding paragraphs. Such reports of failures and the action taken shall be confirmed in writing in the routine reports. The Contracting Officer has the right to examine all test and inspection records.

_____, 20__

LIST OF FINE AND COARSE AGGREGATE SOURCES

LAT/LONG	PIT LOCATION, ADDRESS AND TELEPHONE NUMBER	MAIN OFFICE, ADDRESS AND TELEPHONE NUMBER
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FINE AGGREGATE

___/___	_____	_____
	_____	_____
	_____	_____
___/___	_____	_____
	_____	_____
	_____	_____
___/___	_____	_____
	_____	_____
	_____	_____
___/___	_____	_____
	_____	_____
	_____	_____
___/___	_____	_____
	_____	_____
	_____	_____

COARSE AGGREGATE

___/___	_____	_____
	_____	_____
	_____	_____
___/___	_____	_____
	_____	_____
	_____	_____
___/___	_____	_____
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