SECTION 03 3021

REINFORCED CONCRETE – HIGH CONFIDENCE

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LANL MASTER SPECIFICATION

Word file at <http://engstandards.lanl.gov>

In general, this section applies to nuclear facilities and their safety class (SC) structures, systems and components (SSCs). It specifically applies to structural concrete for buildings that are designed in accordance with ACI 349, facilities classified as Seismic Design Category (SDC) 3 or Natural Phenomena Hazards (NPH) Performance Category (PC)‑3, and ML-1/Safety Class SSCs. Use of this section requires an Independent Review.

Certain ML-2/Safety Significant projects may also be required to use this section beginning with the Spring 2015 revision of ESM Chapter 5 Structural (depending on DOE O 420.1C Chg 1).

For lesser NPH facilities projects, use Section 03 3001, Reinforced Concrete – Normal Confidence.

Procurement of ML-1/2 requires use of either an IESL (LANL-qualified) supplier meeting ASME NQA-1 or (more likely) use of a commercial grade dedication approach; For CGD see [IDED-STD-03\_3001 Reinforced Concrete Commercial Grade Dedication (CGD) Package/Traveler](http://engstandards.lanl.gov/specs/IDED-STD-03_3001R0.doc) posted under this section in the [Div 03](http://engstandards.lanl.gov/specs.shtml#03) Master Spec index and upgrade as appropriate.

When editing to suit project, author shall add job-specific requirements and delete only those portions that in no way apply to the activity (e.g., an aspect that does not apply). Note: Items in brackets are to be added or omitted according to job specific requirements. To seek a variance from applicable requirements, contact the Engineering Standards Manual (ESM) Structural Specs [POC](http://engstandards.lanl.gov/POCs.shtml#struc). Please contact POC with suggestions for improvement as well.

When assembling a specification package, include applicable specifications from all Divisions, especially Division 1, General Requirements.

Delete information within and including “stars” during editing.

Mass Concrete Note: Given the incorporation of ACI 301 into this section (indicated in Paras. 1.4 and 1.6 below), and the fact that ACI 301 contains provisions for mass concrete that require the attention of, and action(s) by, the Engineer of Record, if project includes mass concrete, EDIT THIS SECTION SUCH THAT MASS CONCRETE IS CONSTRUCTED IN ACCORDANCE WITH THE ACI 301 PROVISIONS.

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1. GENERAL
	1. SCOPE
2. This section provides the requirements for furnishing and delivering high confidence Portland-cement concrete including:
	* + 1. Portland cement,
			2. supplementary cementitious materials,
			3. water,
			4. admixtures,
			5. aggregates,
			6. mixture designs,
			7. batching and mixing facilities,
			8. transport units,
			9. concrete work-preplacement and placement,
			10. erecting and designing forms,
			11. concrete reinforcing and accessories,
			12. control, expansion, and contraction joint devices,
			13. bracing,
			14. shoring,
			15. anchorage, and
			16. non-structural/cosmetic repair of concrete.
		1. The nuclear safety elements of this project that require high-confidence, reinforced concrete include the [concrete mat foundation and turndowns, walls, roof slab, and parapets. These elements are credited for strength and durability during normal operation as well as during and after a design basis earthquake event.]
		2. Related Sections
			1. Division 1 - General Specifications

[2. 03 3001 Reinforced Concrete (normal confidence)]

[3. 03 3053 Miscellaneous Cast-in-Place Concrete (non-safety concrete work associated with civil site work)]

[4. 03 6000 Grout]

[5. 05 0521 Post-Installed Concrete Anchors – High Confidence]

[6. 05 0520 Post-Installed Concrete and Grouted-Masonry Anchors – Normal Confidence]

* 1. Definitions
		1. Engineer-of-record and Architect/Engineer are synonymous and indicate the responsible engineer for the overall design of the facility or project. [For this project the EOR and the Contractor are the same entity.]
		2. Hold Point: A mandatory verification point in the progression of a process activity that cannot be passed without being released by the responsible party that established the Hold Point. It is mandatory that the Subcontractor formally notify Contractor five (5) business days prior to a scheduled Hold Point, or within a time period agreed to by the Contractor. A Hold Point cannot be bypassed without the specific release by the approved official of the designating organization.
		3. Witness Point: A verification point in the sequence of Work which is designated for Contractor to do monitoring and which Work may PROCEED ONLY after notifying the LANL Subcontractor Technical Representative (STR). It’s mandatory that the Subcontractor formally notifies the STR two (2) business days in advance of all Witness points, or within a time period agreed to by the Contractor.
		4. Alkali-Silica Reactivity (ASR): The alkali–silica reaction is a reaction which occurs over time in [concrete](http://en.wikipedia.org/wiki/Concrete) between the highly alkaline [cement](http://en.wikipedia.org/wiki/Portland_cement) paste and reactive non-crystalline ([amorphous](http://en.wikipedia.org/wiki/Amorphous)) [silica](http://en.wikipedia.org/wiki/Silica), which is found in many common [aggregates](http://en.wikipedia.org/wiki/Construction_aggregate).
		5. Certificate of Conformance (C of C): A document signed or otherwise authenticated by an authorized individual certifying the degree to which items or services meet specified requirements.
		6. Certified Material Test Report (CMTR): A written and signed document that is approved by a qualified party and contains data and information that attests to the actual properties of an item and the actual results of all required tests.
		7. National Institute of Standards and Testing (NIST).
		8. Admixture: Material other than water, aggregate, or hydraulic cement, used as an ingredient of concrete and added to concrete before or during its mixing to modify its properties.
		9. Aggregate: Granular material, such as sand, gravel, crushed stone, and iron blast-furnace slag, used with a cementing medium to form a hydraulic-cement concrete or mortar.
		10. Cementitious materials: Materials as specified in ACI 349 Chapter 3, which have cementing value when used in concrete either by themselves, such as Portland cement, blended hydraulic cements, and expansive cement, or such materials in combination with fly ash, other raw or calcined natural pozzolans, silica fume, and/or ground-granulated blast-furnace slag.
		11. Concrete: Mixture of Portland cement or any other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixtures.
		12. Concrete, specified compressive strength of, (f’c): Compressive strength of concrete used in design and evaluated in accordance with provisions of Chapter 5 of ACI 349, expressed in pounds per square inch (psi). Whenever the quantity f’c is under a radical sign, square root of numerical value only is intended, and result has units of pounds per square inch (psi).
		13. Contraction joint: Formed, sawed, or tooled groove in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure.
		14. Creep: Time-dependent deformation due to sustained load.
		15. Deformed reinforcement: Deformed reinforcing bars, bar mats, deformed wire, and welded wire reinforcement conforming to ACI 349, section 3.5.3.
		16. Development length: Length of embedded reinforcement, including pretensioned strand, required to develop the design strength of reinforcement at a critical section. See ACI 349, Section 9.3.3.
		17. Effective depth of section (d): Distance measured from extreme compression fiber to centroid of longitudinal tension reinforcement.
		18. Embedment: A steel component embedded in the concrete to transmit applied loads to the concrete structure. The embedment can be fabricated of plates, shapes, fasteners, reinforcing bars, shear connectors, inserts, or any combination thereof.
		19. Embedment length: Length of embedded reinforcement provided beyond a critical section.
		20. Engineer: The licensed professional engineer, employed by the owner-contracted design authority or other agency, responsible for issuing design drawings, specifications, or other documents.
		21. Contractor: The managing contractor of the Los Alamos National Lab; e.g., Los Alamos National Security, LLC (LANS), which acts as Owner. Contractor also means Subcontract Administrator, the individual authorized to act on the behalf of LANS.
		22. Evaluation: An engineering review of an existing safety related concrete structure with the purpose of determining physical condition and functionality. This review may include analysis, condition surveys, maintenance, testing, and repair.
		23. Isolation joint: A separation between adjoining parts of a concrete structure, usually a vertical plane, at a designed location such as to interfere least with performance of the structure, yet such as to allow relative movement in three directions and avoid formation of cracks elsewhere in the concrete and through which all or part of the bonded reinforcement is interrupted.
		24. Reinforced concrete: Structural concrete reinforced with no less than the minimum amounts of prestressing steel or nonprestressed reinforcement specified in ACI 349 Chapters 1 through 21 and Appendixes A through C.
		25. Reinforcement: Material that conforms to ACI 349, section 3.5, excluding prestressing steel unless specifically included.
		26. Reshores: Shores placed snugly under a concrete slab or other structural member after the original forms and shores have been removed from a larger area, thus requiring the new slab or structural member to deflect and support its own weight and existing construction loads applied before the installation of the reshores.
		27. Shores: Vertical or inclined support members designed to carry the weight of the formwork, concrete, and construction loads above.
		28. Shrinkage: Time-temperature-humidity-dependent volume reduction of concrete as a result of hydration, moisture migration, and drying process.
		29. Stirrup: Reinforcement used to resist shear and torsion stresses in a structural member; typically bars, wires, or welded wire reinforcement either single leg or bent into L, U, or rectangular shapes and located perpendicular to or at an angle to longitudinal reinforcement. The term “stirrups” is usually applied to lateral reinforcement in flexural members and the term “ties” to those in compression members. See also tie.
		30. Structural walls: Walls proportioned to resist combinations of shears, moments, and axial forces induced by earthquake motions. A shearwall is a structural wall. Structural walls shall be categorized as follows:
		31. Ordinary reinforced concrete structural wall: A wall complying with the requirements of ACI 349 Chapters 1 through 18.
		32. Special reinforced concrete structural wall: A cast-in-place wall complying with the requirements of ACI 349, sections 21.2 and 21.7 in addition to the requirements for ordinary reinforced concrete structural walls.
		33. Technical safety requirements: The limits, controls, and related actions that establish the specific parameters and requisite actions for the safe operation of a nuclear facility.
		34. Tie: Loop of reinforcing bar or wire enclosing longitudinal reinforcement. A continuously wound bar or wire in the form of a circle, rectangle, or other polygon shape without re-entrant corners is acceptable. See also stirrup.
		35. Wall: Member, usually vertical, used to enclose or separate spaces.
		36. Welded wire reinforcement: Reinforcing elements consisting of plain or deformed wires, conforming to ASTM A 82 or A 496, respectively, fabricated into sheets in accordance with ASTM A 185 or A 497, respectively.
		37. Yield strength: Specified minimum yield strength or yield point of reinforcement. Yield strength or yield point shall be determined in tension according to applicable ASTM standards as modified by ACI 349, section 3.5.
		38. f’c: Specified compressive strength of concrete, psi.
		39. f’cr: Required average compressive strength of concrete used as the basis for selection of concrete proportions, psi.
		40. db: Nominal diameter of bar, wire, or prestressing strand, in.

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Revise the paragraph below in accordance with Project specifics. The bracketed text in the subparagraphs merely serves as examples of the level of specificity required.

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* 1. SAFETY FUNCTION PERFORMANCE REQUIREMENTS

[A. The reinforced concrete structure will support equipment and distribution systems during normal operation, as well as during and after the design basis earthquake (DBE).]

[B. The interior reinforced concrete wall protects [ ] systems from fire under any design event including the DBE.]

* 1. References
		1. References noted in these specifications form a part of these specifications to the extent applicable. The publications are referred to in the text by the basic designation only. The related publishing organizations are stipulated in Section 01 4200, References and in 1.4.C below.
		2. Work, products, and materials shall conform to ACI 301, ACI 349, and other specific referenced publications and standards except where otherwise specified herein.
		3. Codes and standards: The following tables provide the codes standards that shall be used and referenced for this project. Notes: (1) The applicable edition/version of a given code or standard shall be either the latest one or the one referenced by the version of ACI 349 that applies to the project. (2) Codes and standards that are referenced within the tabulated codes and standards shall be considered applicable to this project.
			1. American Concrete Institute (ACI)

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| --- | --- |
| 117 | Standard Specifications for Tolerances of Concrete Construction and Materials |
| 201.2R | Guide to Durable Concrete |
| 301 | Specifications for Structural Concrete |
| 304R | Guide for Measuring, Mixing, Transporting, and Placing Concrete  |
| 304.2R | Placing Concrete by Pumping Methods  |
| 304.4R | Placing Concrete with Belt Conveyors  |
| 305R | Hot Weather Concreting |
| 306R | Cold Weather Concreting |
| 309R | Guide for Consolidation of Concrete |
| 318 | Building Code Requirements for Reinforced Concrete |
| 347 | Guide to Formwork for Concrete |
| 349 | Code Requirements for Nuclear Safety Related Concrete Structures |

* + - 1. American Society of Mechanical Engineers: Quality Assurance Requirements for Nuclear Facility Applications, ASME NQA-1
			2. ASTM International

|  |  |
| --- | --- |
| A 82 | Standard Specification for Steel Wire, Plain, for Concrete Reinforcement |
| A 184/A 184M | Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement |
| A 185 | Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete |
| A 370 | Standard Test Methods and Definitions for Mechanical Testing of Steel Products |
| A 496 | Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement |
| A 497/A 497M | Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete |
| A 706/A 706M | Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement |
| C 31/C 31M | Standard Practice for Making and Curing Concrete Test in the Field |
| C 33 | Standard specification for Concrete Aggregates |
| C 39/C 39M | Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens |
| C 88 | Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate |
| C 94 | Standard specification for Ready-Mixed Concrete |
| C 131 | Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine |
| C 138/C138M | Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete |
| C 143/C143M | Standard Test Method for Slump ofHydraulic-Cement Concrete |
| C 150 | Standard specification for Portland Cement |
| C 171 | Standard Specification for Sheet Materials for Curing Concrete |
| C 172 | Standard Practice for Sampling Freshly Mixed Concrete |
| C 192/C192M | Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory |
| C 231 | Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method |
| C 260 | Standard specification for Air-Entraining Admixtures for Concrete |
| C 289 | Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method) |
| C 295 | Standard Guide for Petrographic Examination of Aggregates for Concrete |
| C 309 | Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete |
| C 494 | Standard Specification for Chemical Admixtures for Concrete |
| C 595 | Standard Specification for Blended Hydraulic Cements |
| C 618 | Standard Specification for Fly Ash and Raw or Calcinated Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete |
| C 685/C685M | Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing |
| C 845 | Standard Specification for Expansive Hydraulic Cement |
| C 881/C 881M | Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete |
| C 928 | Standard Specification for Packaged, Dry, Rapid Hardening Cementitious Materials for Concrete Repairs |
| C 989 | Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars |
| C 1017/C1017M | Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete |
| C 1059 | Standard Specification for Latex Agents for Bonding Fresh to Hardened Concrete |
| C 1064/C1064M | Standard Test Methods for Temperature of Freshly Mixed Hydraulic-Cement Concrete |
| C 1077 | Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation |
| C 1107 | Standard Specification for Packaged Dry, Hydraulic Cement Grout (Nonshrink) |
| C 1157 | Standard Performance Specification for Hydraulic Cement |
| C 1218/C1218M | Standard Test Method for Water-Soluble Chloride in Mortar and Concrete |
| C 1240 | Standard Specification for Silica Fume Used in Cementitious Mixtures |
| C 1567 | Standard Test Method for Determining toe Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method) |
| C 1602 | Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete |
| D 1751 | Standard Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types) |
| E 204 | Standard Practices for Identification of Material by Infrared Absorption Spectroscopy, Using the ASTM Coded Band and Chemical Classification Index |
| E 329 | Standard Specification for AgenciesEngaged in Construction Inspection and/or Testing |
| E 1155 | Standard Test Method for Determining FF Floor Flatness and FL Floor Levelness Numbers |

* + - 1. American Welding Society: D1.4 Structural Welding Code – Reinforcing Steel
			2. Concrete Reinforcing Steel Institute: CRSI MSP-2 Manual of Standard Practice
			3. International Code Council: International Building Code (IBC)
	1. SUBMITTALS AND RECORD MANAGEMENT
		1. Submit the following in accordance with project submittal procedures for specified items. Note: All submittals require Contractor approval.
			1. General Requirements:
				1. Subcontractor Quality Assurance (QA) program including all subtier Subcontractors.
				2. Commercial Grade Dedication Plans compliant with ASME NQA‑1, Part II, Subpart 2.14 for concrete, concrete constituents, and reinforcing steel, as required, and as included within this specification in accordance with Subcontractor’s QA Plan as approved by the Contractor.
				3. An inspection or Verification of Inspection and Test (VIT) Plan that complies with Subcontractor’s QA program for approval by the Contractor. A template for use by Subcontractor is included as [Attachment A to Specification Section 01 4000, Quality Requirements] [ESM Chapter 16 Section IBC-IP Att I] [other]. Subcontractor shall prepare comprehensive VIT Plan consistent with [Attachment A (Spec Section 01 4000)] format that includes all inspections and tests required by applicable codes, specification, and CGD Plans applicable to the work.
				4. Documentation required by VIT plan such as logs and results of tests and inspections performed.
				5. Documentation that testing agencies have been accepted by the Contractor before performing any testing work. Acceptance by Contractor includes LANL LBO and EOR acceptance
				6. Documentation that testing agencies have been approved by the LANL Building Official (LBO) and are NQA-1 compliant prior to performing any work. Important note: This also applies to subtier concrete fabricators and batch plants. This places a premium on planning to assure that the testing agencies are properly approved before all of the required concrete constituent / material testing is begun to support any alternate mix design(s) which have to be submitted for LANL engineering approval
				7. Submit the Quality Assurance/Quality Control program of the concrete supplier
				8. The Subcontractor's testing agency shall submit test and inspection results that pertain to the Work to the Contractor and concrete supplier within 3 days of performing such inspections and tests. Any deficiencies discovered shall be reported to the Contractor in writing during the shift of discovery and managed in accordance with Subcontractor QA Program.
			2. Formwork and Formwork Accessories:
				1. Drawings and procedures for installation and removal of reshoring and backshoring. Refer to ACI 347 and ACI 347.2R for guidance on items to consider.
				2. Data on formwork release agent or formwork liners.
				3. Design calculations, and drawings for formwork, shoring and reshoring.
				4. Data sheet on form ties.
				5. Data and sample of expansion joint materials (sealer and filler).
				6. Form-facing materials.
			3. Reinforcement, Reinforcement Supports, Embeds and Accessories:
				1. Rebar manufacturer’s Certified Material Test Report (CMTRs) traceable to the heat# or test identification # on the shipping tags.
				2. Shop drawings indicating bar sizes, spacing, locations, piece numbers, and quantities of reinforcing steel, bending and cutting schedules, supporting and spacing devices. Identify all lap splice lengths.
				3. CMTRs for other construction materials such as, pre-stress strands, Form Savers, cadwelds, etc. Mechanical splice submittals shall also be provided with ICC evaluation reports showing full compliance to the IBC.
				4. CMTRs for steel embedments in concrete.
			4. Concrete Mixture:
				1. Concrete Mixture Design. This shall include the following:

CMTR’s and/or test reports and/or manufacturer data showing conformance with specification requirements for aggregates, cement, other cementitious materials, water source, all admixtures, materials for curing and any other manufactured products used including materials for repairs.

Methodology and test data used to establish mixture proportions,

Mix proportions and characteristics.

Information on types, classes, producers’ names, and plant locations for cementitious materials; types, pit or quarry locations, producers’ names, gradings, and properties required by ASTM C 33 for aggregates; types, brand names, and producers’ names for admixtures; and source of supply for water and ice. Except for admixtures and water, test results confirming conformance to applicable specifications shall not be older than 90 days. Test results for aggregate soundness, abrasion, and reactivity may be older than 90 days, but not older than 1 year, provided test results for the other properties specified in ASTM C 33 indicate that aggregate quality has not changed.

Documentation indicating compliance of the mix design with the specified requirements for sulfate resistance.

Documentation verifying compliance of the mix design with the specified requirements for alkali-silica reactivity (ASR).

Documentation verifying compliance with specified requirements for freezing and thawing exposure.

Test reports for mix design, all materials, and testing as required by this specification and/or referenced codes and standards.

* + - 1. Handling, Placing, and Constructing:
				1. Concrete placement records.
				2. Concrete cylinder test reports and charts
				3. Reports for construction and removal of forms and reshoring
				4. Any significant construction loadings on completed floors, members, or walls.
				5. Subcontractor Cold-Weather Plan and cold-weather protection activities.
				6. Subcontractor Hot-Weather Plan.
				7. Description of conveying equipment.
				8. Subcontractor hazardous/inclement weather placement protection plan.
				9. Method of measuring concrete surface temperature changes.
				10. Method for removal of stains, rust, efflorescence, and surface deposits.
				11. Qualifications of finishing Subcontractor and flatwork finishers (ACI flatwork certification). The supervisor for the subcontractor responsible for the concrete finishing (or at least one finisher) must have a current ACI-flatwork certification.
				12. Pre-placement activities to ensure the pre-placement activities are properly inspected, if necessary.
				13. Wet-weather protection activities.
				14. One legible copy of the batch ticket for each load of concrete. Information on the batch ticket shall include (but not necessarily limited to) the following:

Name of ready-mix batch plant

Serial number of ticket

Date

Truck number

Name of purchaser

Specific designation of job (name and location)

Specific class or designation (design mix number) of the concrete in conformance with that employed in job specifications

Amount of concrete in cubic yards

Time loaded or of first mixing of cement and aggregates

Reading of revolution counter at the first addition of water

Type and brand, and amount of cement

Type and brand, and amount of admixtures

Class, brand, and amount of coal fly ash, raw or calcined natural pozzolans, grade, brand and amount of ground granulated blast-furnace slag

Information necessary to calculate the total mixing water. Total mixing water includes free water on the aggregates, water, and ice batched at the plant, and water added by the truck operator from the mixer tank (must be witnessed by LANL representative).

Maximum size of aggregate

Weights of fine and coarse aggregate

Ingredients certified as being previously approved

Water/cementitious material ratio

Daily fine and coarse aggregate moisture content

Amount of water that can be added at the jobsite without exceeding the water/cementitious material ratio

Water added by receiver of concrete and his initials. Note: any water added to the truck must also be witnessed by the LANL field engineer or inspector.

* + 1. Records: The subcontractor QA program shall address record documentation and shall include the following minimum requirements:
			1. Subcontractors shall identify, collect, compile, maintain, and protect complete files and all quality related records for supplied equipment in accordance with their approved QA Program.
			2. Records shall be protected by the Subcontractor in a manner compliant with ASME NQA-1 requirements, and shall be made accessible to the Contractor, throughout the design, procurement, manufacture, test, and shipping processes.
			3. Unless specified in the associated Specification Sections, within 5 working days after completion of the work, or as requested by Contractor for any portion or portions of the work, all quality related records generated throughout the order completion process shall be submitted to Contractor for inclusion into the permanent project record. A copy of the records shall be kept by the Subcontractor in accordance with subcontract requirements.
			4. Records shall be completed, as required, for the Work accomplished.
			5. Records shall be legible.
			6. Records shall be readable.
			7. Records shall be original, unless unobtainable.
			8. Records shall be traceable to associated items and activities.
			9. Records shall be accurate.
			10. Records shall reflect the Work accomplished or the information required.
			11. Records shall be appropriate for the Work accomplished.
			12. Records shall be authenticated by stamping, initialing, signing and dating, as applicable or by providing a signed and dated statement of authenticity.
			13. Corrections to any record shall be accomplished by the following method:
				1. Draw a single line through incorrect information.
				2. Enter the correct information next to the incorrect information.
				3. Initial and date each correction.
1. White out or correction tape is not permitted on permanent records.
2. Destruction of incorrect records is not permitted.
	* 1. The Subcontractor must schedule and manage any sub-tiers to ensure that the proper approach and scheduling is used to obtain all necessary approvals and tests and inspections.
		2. For LANL's records, submit copies, licenses, certifications, records, inspection reports, releases, jurisdictional settlements, notices, receipts for fee payments, judgments, correspondence, and similar documents, used to establish compliance with standards and regulations that pertain to performance of the Work.
	1. QUALITY ASSURANCE
		1. Refer to Section 01 4000 for quality requirements.
		2. All safety related material shall be procured as “High Confidence” from a LANL-qualified (IESL) supplier (meeting ASME NQA) or procured as Commercial Grade Items (CGI) in accordance with ASME NQA-1 Part II Subpart 2.14 and Subcontractor’s QA program with a nuclear safety designation.
		3. The placement of all concrete and reinforcing shall be compliant with ASME NQA-1 2008, 2009 addenda or later and Subcontractor’s QA Program.
		4. Critical characteristics required for the concrete to perform its credited safety function are:
			1. Reinforcing material properties must conform to ASTM A 706 (Grade 60) specifications for tensile strength, elongation, bar diameter, and deformation size and spacing.
			2. Concrete strength: Lack of achieving specified strength could result in the inability of a structure to perform its design function.
			3. Durability:  Premature cracking, pitting, crumbling leading to structural failure during design basis event.
		5. Witness or hold points for the work shall be as follows:
			1. Hold and witness points per the Contractor-approved commercial grade dedication (CGD) plan.
			2. Hold point before placing concrete for approval of mix designs.
			3. Hold point before formwork and reinforcing steel is placed to verify subgrade is prepared in accordance with specifications.
			4. Hold point to verify reinforcing material properties prior to placement.
			5. Hold point to verify reinforcement placed in accordance with Subcontract requirements prior to placement.
			6. Witness point to verify concrete material properties prior to placement.
			7. Hold point for Contractor to perform “owner” inspections required by ACI 349 and this specification.
		6. Unless stated otherwise herein, the work shall comply with the most stringent of the following documents: ACI 301 and ACI 349; CRSI Manual of Standard Practice and Placing Reinforcing Bars; and ACI Manual of Concrete Practice and ANSI/ASTM A184. The required versions of these documents are provided in 1.4.C.
		7. The work shall be available for inspection at all times by the Contractor and Contractor’s Independent Testing Agency for the purpose of determining that the work is properly executed in accordance with this specification. Failure to detect defective workmanship or material during any interim inspection shall not constitute acceptance of workmanship and materials.
		8. Acquire cement, aggregate, and fly ash from same source as used to produce the specific mix design for all work. Formally notify the Contractor of any material source changes prior to concrete delivery including the test agency test documentation. The subcontractor must provide the Contractor a certificate of conformance (C of C) prior to the initial delivery that confirms the source of the constituents, that tests confirm compliance, and that these sources are the same for the mix design testing and the delivered mix.
		9. The Subcontractor shall use ACI 305R when concreting during hot weather, or 306R during cold weather, to develop the required cold / hot weather plan. See 3.7 and 3.8 for details of plan and plan development.
		10. Testing Agency Qualifications: Testing agencies that perform High Confidence concrete related inspection and testing shall be nationally accredited in accordance with ASTM C1077 and ASTM E329. Testing agency shall perform work under an NQA-1 compliant program. Field and laboratory testing agencies shall be approved by the Contractor, or designee, in accordance with the contract documents, provisions of the IBC.
		11. Reinforcing steel shall comply with the provisions of ASTM A 706. In addition, the rebar fabricator shall maintain Heat Number Traceability for all rebar to assure heat numbers for the rebar are traceable to the rebar delivered. These heat numbers (or lot numbers if they correlate to the heat numbers on the CMTR documentation) must be identified on the tags attached to the rebar bundles and traceable to the associated CMTR(s). Once the tags on the rebar bundles are confirmed to match the associated CMTRs by the appropriate receiving inspection; the bundles may be broken and the rebar located as required. Note: Unless specifically authorized by Contractor, foreign reinforcing steel is not allowed.
		12. The batch plant providing concrete to the Subcontractor must be certified (and maintain current certification) under the National Ready Mix Concrete Association (NRMCA) process and work under the Contractor-approved QA program.
		13. Devices used for acceptance or testing, including all levels of sub-tiers, must be calibrated within recognized tolerances specified by this specification and reference codes and standards (see 1.4.C for versions) and calibrated to NIST or other recognized national standards. The devices must be suitably marked for traceability to the calibration documentation with recalibration due dates marked on each device. The users must maintain a usage log and identify any “as-found/as-received” out of tolerance devices to the Contractor in accordance with the Contractor-approved Subcontractor Quality Assurance Plan within 3 working days along with where the device(s) were used.
	2. DELIVERY, STORAGE AND HANDLING
		1. Handling, storage, shipping and receiving of “High Confidence” items shall be in accordance with Section 01 4000 Quality Requirements, ASME NQA-1, and Subcontractor’s QA Program.
		2. Do not deliver concrete until forms (including confirmation of approved calculations for formwork when required), reinforcement, embedded items, chamfer strips, and any other prerequisites specified in the job specific “Test and Inspection Plan” are in place and ready for concrete placement. Job site storage of materials shall be in accordance with ACI 301 and NQA-1. Protect materials from contaminants such as grease, oil, and dirt. Ensure materials can be accurately identified after bundles are broken and tags removed.
		3. Inspection/Documentation Verification Hold Point: Product and raw material inspection shall be performed at time of delivery to site receiving area and prior to off-loading and incorporation into the work. Verify conformance with specified requirements and project environmental, safety and health (ES&H) and radiological requirements through inspection of material, shipping documentation, material safety data sheets (MSDS) documentation, data sheets, test documentation and other shipping manifest information. Material not passing inspection shall be dispositioned per the Contractor-approved Subcontractor Quality Assurance Plan.
		4. Measures shall be established to provide for storage materials so as to prevent damage or deterioration. When necessary for particular products, special protective environments such as inert gas atmosphere, specific moisture content levels, and controlled temperatures shall be provided. All stored materials shall be properly tagged or labeled to permit identification.
		5. Cementitous materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign matter. Any material that has deteriorated or has been contaminated shall not be used for concrete.
		6. Reinforcing material shall be stored in such a manner as to permit inventory control and to preclude damage or degradation of properties to less than ASTM specification requirements. Protect from contaminants such as grease, oil, and dirt. Reinforcing steel, by groups of bars or shipments, shall be identifiable by documentation, tags, or other means of control, to a specific heat number or heat code until review of the certified material test report has been performed. Ensure bar sizes can be accurately identified after bundles are broken and tags removed. Painting on reinforcement must be approved in writing by the Contractor.
3. Products and Materials
	1. General
		1. All concrete work, projects and materials shall conform to applicable provisions of the codes and standards listed in 1.4.C above except as otherwise specified herein.
		2. The Contractor shall have the right to order testing of any materials used in concrete construction to determine if materials are of quality specified.
		3. A complete record of tests of materials and of concrete shall be available for inspection, by the Contractor.
		4. ACI 201.2R shall be considered when selecting materials for concrete mix design. The more stringent requirements between this specification and ACI 201.2R shall be used.
	2. FORM MATERIALS AND ACCESSORIES
		1. Design of Formwork:
			1. Shop drawings and calculations shall be prepared and submitted to the Contractor for approval prior to construction. All documents shall be sealed by a professional engineer licensed in the state of New Mexico. ACI 347 shall be used as the guide for design, inspection, and construction of formwork.
			2. Forms shall result in a final structure that conforms to shapes, lines, and dimensions of the members as required by the design drawings and specifications.
			3. Forms shall be substantial and sufficiently tight to prevent leakage of mortar.
			4. Forms shall be properly braced or tied together to maintain position and shape.
			5. Forms and their supports shall be designed so as not to damage previously placed structure.
			6. Design of formwork shall include consideration of the following factors:
				1. Rate and method of placing concrete;
				2. Construction loads, including vertical, horizontal, and impact loads;
				3. Special form requirements for construction of shells, folded plates, domes, architectural concrete, or similar types of elements.
				4. When using steel liners as formwork, special attention shall be given to 2.2.A.6.D.i and 2.2.A.6.D.ii.

To liner supports to provide the required tolerances for penetrations.

To the depth of placement to limit the deformation of the liner.

* + - * 1. Where coating systems are to be applied to the concrete, formwork shall be compatible with the coating system
		1. Smooth-Formed Finished Concrete: Form-facing panels that will provide continuous, true, and smooth concrete surfaces. Furnish in largest practicable sizes to minimize number of joints
			1. Plywood, metal, or other approved panel materials.
				1. Metal form surfaces shall not contain irregularities, dents, or sags.
				2. Exterior-grade plywood panels, suitable for concrete forms, complying with APA PS 1, and as follows:

High-density overlay, Class 1 or better.

Medium density overlay, Class 1 or better; mill-release agent treated and edge sealed.

Structural 1, B-B or better; mill oiled and edge sealed.

B-B (Concrete Form), Class 1 or better; mill oiled and edge sealed.

* + - * 1. AHA A135.4, hardboard for smooth form lining.
			1. Prefabricated forms.
				1. Preformed Steel Forms: Minimum 16 gage matched, tight fitting, stiffened to support weight of concrete without deflection detrimental to tolerances and appearance of finished surfaces.
				2. Glass Fiber Fabric Reinforced Plastic Forms: Matched, tight fitting, stiffened to support weight of concrete without deflection detrimental to tolerances and appearance of finished concrete surfaces.
				3. Pan Type: Glass fiber of size and profile required.
				4. Tubular Column Type: Round, spirally wound laminated fiber material, surface treated with release agent, non-reusable, of sizes required.
				5. Void Forms: Moisture resistant treated paper faces, biodegradable, structurally sufficient to support weight of wet concrete mix until initial set; 2 inch thick.
		1. Rough-Formed Finished Concrete: Plywood, lumber, metal or another approved material. Provide lumber dressed on at least two edges and one side for tight fit.
		2. Form Ties: Snap-off type, plastic cone type free of defects that could leave holes larger than 1 in. in concrete surface.
		3. Form-Release Agent: Colorless mineral oil which will not stain concrete, absorb moisture, or impair natural bonding or color characteristics of coating intended for use on concrete.
		4. Corners: Chamfered, wood strip type; ¾ x ¾ in. size.
		5. Dovetail Anchor Slot: Galvanized steel, 22 gage thick, foam filled, release tape sealed slots, anchors for securing to concrete formwork.
		6. Flashing Reglets: Galvanized steel, 22 gage thick, longest possible lengths, with alignment splines for joints, foam filled, release tape sealed slots, anchors for securing to concrete formwork.
		7. Nails, Spikes, Lag Bolts, Through Bolts, Anchorages: Size as required, of sufficient strength and character to maintain formwork in place while placing concrete.

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Include the following item if waterstops are necessary (e.g., a below-grade joint in-between exterior wall and the foundation, etc.). If item is deleted then delete associated installation provision (i.e., 3.10.A.15).

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[J. Waterstops: Polyvinyl chloride, minimum 1750 psi tensile strength, minimum 50 degrees F to plus 175 degrees F working temperature range, maximum possible lengths, ribbed profile, preformed corner sections. A C of C from the manufacturer is required as confirmation that the waterstop(s) used meets the requirements in this paragraph.]

* 1. REINFORCING AND ACCESSORIES
		1. Reinforcing Steel
			1. All deformed bars and stirrups, and ties, shall conform to ASTM A 706 grade 60 unless noted otherwise on the drawings.
			2. A minimum of one tensile test shall be required for each 50 tons of each bar size produced from each heat of steel (ASTM A370) or as specified in the Contractor approved Commercial Grade Dedication Plan, whichever is more stringent.
			3. Manufacturer’s CMTRs are required for each delivery and they must be traceable to the reinforcing steel tag bundles via the lot or heat number. Once the documentation is confirmed to be adequate and traceable by the responsible receiving inspection personnel, the bundles may be broken and no further traceability is required.
			4. Other construction materials such as Form Savers, cadwelds, mechanical splices, etc. must be supported by ICC evaluation reports showing full compliance to the applicable IBC code of record for the project.
		2. Fabricate concrete reinforcing in accordance with CRSI Manual of Standard Practice.
		3. Locate and install reinforcing splices as indicated on Drawings.
		4. Welding of reinforcing bars will be permitted only with approval of the Contractor. Welding, if approved, shall conform to ACI 301 Sect. 3 and AWS D.1.4 and shall meet the requirements of Section 01 4455, Onsite Welding and Joining Requirements including approval of the welding procedures. Filler material CMTRs are required. Reinforcing steel cannot be used for filler metal, gap filler, lightning grounding, or other uses that involve welding.
		5. Chairs, Bolsters, Bar Supports, Spacers
			1. Size and shape for strength and support of reinforcement during concrete placement conditions including load bearing pad on bottom to prevent vapor barrier puncture.
			2. Special chairs, bolsters, bar supports, spacers adjacent to weather exposed concrete surfaces to be plastic coated steel type; size and shape as required.
			3. Note: concrete “dobie” blocks used to hold up and position rebar must have documentation to show that they are at least the PSI compression strength of the concrete used for the placement.
		6. Tie Wire: Minimum 16 gage annealed type.
		7. Couplers: Couplers shall be Dayton Superior Bar Lock couplers or Contractor approved alternates and shall meet the following requirements:
			1. Mechanical splices shall develop 125% of the yield strength of the bar in compression.
			2. Mechanical splices shall develop the specified tensile strength of the bar.
			3. Mechanical splices shall have an International Code Council (ICC) Evaluation Service Report (ESR) that is compliant with the code of record for the project.
	2. CONCRETE MATERIALS
		1. Cements
			1. Cement shall conform to ASTM C 150.
			2. Cement used in the work shall correspond to that on which selection of concrete proportions was based.
			3. Every shipment of cement shall be accompanied by a CMTR stating the results of tests representing the cement in shipment and the ASTM specification limits for each item of required chemical, physical, and optional characteristics. No cement shall be used in any structural concrete prior to receipt of 7-day mill test strengths.
		2. Aggregates
			1. Concrete aggregates shall conform to ASTM C33.
			2. Testing requirements
				1. All tests required by the Subcontractor’s Contractor approved CGD plan.
				2. Tests for full conformance with each of the requirements of ASTM C33, including tests for potential reactivity (ASTM C 289), and any additional requirements identified in this section and/or in the Contractor-approved CGD plan, shall be performed before usage in construction.
				3. A daily inspection control program shall be carried out during concrete production to determine and control consistency in potentially variable characteristics such as aggregate water content, gradation, fineness modulus, and material finer than No. 200 sieve.
				4. Tests for conformance with ASTM C 131, ASTM C 289, and ASTM C 88 shall be repeated as directed by the Contractor, and at a minimum of every 3 months, and whenever there is reason to suspect a change in the basic geology or mineralogy of the aggregates.
				5. Obtain a petrographic examination of coarse aggregate in accordance with ASTM C 295. Specifically include an assessment by the petrographer of the proposed aggregates for use in Portland cement concrete. Perform all tests recommended by the petrographer required for confirming suitability of the proposed aggregate. Submit the petrographic examination report and associated test reports for Contractor approval prior to production.
				6. Test for aggregate moisture content shall be performed daily or more often if there is a reason to suspect a change in moisture content.
		3. Water
			1. Water used in mixing concrete shall conform to ASTM C1602.
	3. ADMIXTURES
		1. Admixtures to be used in concrete shall be submitted with the mixture design and approved by the Contractor prior to use.
		2. An admixture shall be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions in accordance with 2.7.B.
		3. Air-entraining admixtures shall conform to “Standard Specification for Air-Entraining Admixtures for Concrete” (ASTM C 260).
		4. Water-reducing admixtures, retarding admixtures, accelerating admixtures, water-reducing and retarding admixtures, and water-reducing and accelerating admixtures: Conform to ASTM C494.
		5. Fly ash or other pozzolans used as admixtures shall conform to “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete” (ASTM C 618).
		6. Ground-granulated blast-furnace slag used as an admixture shall conform to “Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars” (ASTM C 989)
		7. Admixtures used in concrete containing ASTM C 845 expansive cements shall be compatible with the cement and produce no deleterious effects.
		8. Silica fume used as an admixture shall conform to “Standard Specification for Silica Fume Used in Cementitious Mixtures” (ASTM C 1240).
		9. Testing
			1. Shall be performed as required by the Subcontractor’s Contractor approved CGD plan and VIT plan.
			2. Tests for compliance with the specification for each admixture shall be required prior to initial shipment and acceptance on site for usage in construction and as directed by the Contractor and at a minimum of every 3 months.
			3. An infrared spectrum trace of the conformance test sample of air-entraining and water-reducing admixture shall be furnished with the conformance test results (ASTM E 204).
	4. ACCESSORIES
		1. Bonding Agent: Polymer resin emulsion.
		2. Non-Shrink Grout: Refer to Section 03 6000, Grout.
		3. Joint Filler: ASTM D 1751; asphalt impregnated fiberboard or felt
	5. CONCRETE QUALITY, MIXING, AND PLACING
		1. General Requirements
			1. Concrete shall be proportioned to provide an average compressive strength f’cr, as prescribed in 2.7.C.2, and shall satisfy the durability criteria of 2.7.F. Concrete shall be produced to minimize the frequency of strength tests below f’c, as prescribed in 3.9.C.3.
			2. The concrete strength, f’c, shall be based on 28-day tests in accordance with ASTM C39.
			3. Splitting tensile strength tests shall not be used as a basis for field acceptance of concrete.
		2. Selection of Concrete Proportions
			1. Proportions of materials for concrete shall be established to provide:
				1. Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed, without segregation or excessive bleeding;
				2. Resistance to special exposures as required by 2.7.F;
				3. Conformance with strength requirements as shown on the drawings and 3.9.
			2. Where different materials are to be used for different portions of the proposed work, each combination shall be evaluated.
			3. Concrete proportions shall be established in accordance with one of the two following methods and shall meet the applicable requirements in 2.7.F:
				1. Proportioning on the Basis of field experience or trial mixtures, or both, or
				2. Proportioning without field experience of trial mixtures
		3. Proportioning on the Basis of field experience or trial mixtures, or both
			1. Sample standard deviation
				1. Where a concrete production facility has test records, a sample standard deviation ssshall be established. Test records from which ss is calculated:

Shall represent materials, quality control procedures, and conditions similar to those expected and changes in materials and proportions within the test records shall not have been more restrictive than those for proposed work;

Shall represent concrete produced to meet a specified concrete strength or strengths within 1000 psi of f’c;

Shall consist of at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests as defined in 3.9.B.3, except as provided in 2.7.C.1.b.

* + - * 1. Where a concrete production facility does not have test records meeting the requirements of 2.7.C.1.a, but does have a record based on 15 to 29 consecutive tests, a sample standard deviation ss shall be established as the product if the calculated sample standard deviation and modification of Table 2-1 below. To be acceptable, test records shall meet the requirements of 2.7.C.1.a.i and 2.7.C.1.a.ii, and represent only a single record of consecutive tests that span a period of not less than 45 calendar days.

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| **Table 2-1 Modification factor for sample standard deviation when less than 30 tests are available** |
| No. of tests\* | Modification factor for sample standard deviation |
| Less than 15 | Use Table 2-3 |
| 15 | 1.16 |
| 20 | 1.08 |
| 25 | 1.03 |
| 30 or more | 1.00 |
| \*Interpolate for intermediate number of tests |

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Using the Project-specific concrete properties indicated in para. 3.1.I, the EOR shall edit the following tables accordingly: 2-2 – 2-8.

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* + - 1. Required average strength:
				1. The required average compressive strength f’cr used as the basis for selection of concrete proportions shall be determined from Table 2-2 using the sample standard deviation ss, calculated in accordance with 2.7.C.1.a or 2.7.C.1.b

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| **Table 2-2 Required average compressive strength when data are available to establish a sample standard deviation** |
| Compressive strength, psi | Required average compressive strength, psi |
| f’c ≤ 5000 | Use the larger value computed from the following equations: |
| f’c > 5000 | Use the larger value computed from the following equations: |

* + - * 1. When a concrete production facility does not have a field strength test records for calculation of ss meeting the requirements of 2.7.C.1.a or 2.7.C.1.b, f’cr shall be determined from Table 2-3, and documentation of average strength shall be in accordance with 2.7.C.3.

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| **Table 2-3 Required average compressive strength when data are not available to establish a sample standard deviation** |
| Compressive strength, psi | Required average compressive strength, psi |
| f’c < 3000 |  |
| 3000 ≤ f’c ≤ 5000 |  |
| f’c > 5000 |  |

* + - 1. Documentation of average compressive strength: Documentation that the proposed concrete proportions will produce an average compressive strength f’cr shall consist of a field strength test record, several strength test records, or trial mixtures.
				1. When test records are used to demonstrate that proposed concrete proportions will produce f’cr(see 2.7.C.2) such records shall represent materials and conditions similar to those expected. Changes in materials, conditions, and proportions within the test records shall not have been more restrictive than those for proposed work. For the purpose of documenting average strength potential, test records consisting of less than 30 but not less than 10 consecutive tests are acceptable, provided test records encompass a period of time not less than 45 days. Required concrete proportions shall be permitted to be established by interpolation between the strengths and proportions of two or more test records, each of which meets other requirements of this paragraph.
				2. When an acceptable record of field test results is not available, concrete proportions established from trial mixtures meeting the following restrictions shall be permitted:

Combinations of materials shall be those for the proposed work;

Trial mixtures having proportions and consistencies required for proposed work shall be made using at least three different water-cementitious material ratios or cementitious material contents that will produce a range of strengths encompassing f’cr;

Trial mixtures shall be designed to produce a slump within ±0.75 in. of maximum permitted, and for air-entrained concrete, within ±0.5% of maximum allowable air content;

For each water-cementitious material ratio or cementitious material content, at least three test cylinders for each test age shall be made and cured in accordance with “Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory” (ASTM C 192). Cylinders shall be tested at 28 days or at test age designated for determination of f’cr;

From results of cylinder tests, a curve shall be plotted showing the relationship between water-cementitious material ratio or cementitious material content and compressive strength at designated test age;

Maximum water-cementitious material ratio or minimum cementitious material content for concrete to be used in proposed work shall be that shown by the curve to produce f’cr required by 2.7.C.2, unless a lower water-cementitous material ratio or higher strength is required by 2.7.F.

* + 1. Proportioning without field experience or trial mixtures
			1. If data required by 2.7.C are not available, concrete proportions shall be based on other experience or information, if approved by the Contractor. The required average compressive strength f’cr of concrete produced with materials similar to those proposed for use shall be at least 1200 psi greater than f’c.  This method shall not be used if f’c is greater than 5000psi.
			2. Concrete proportioned by 2.7.D shall conform to the durability requirements in 2.7.F and to compressive strength test criteria of 3.9.
		2. Average compressive strength reduction
			1. As data become available during construction, it shall be permitted to reduce the amount by which the required average concrete strength f’cr must exceed f’c, provided:
				1. Thirty or more test results are available and average of test results exceeds that required by 2.7.C.2.a, using a sample standard deviation calculated in accordance with 2.7.C.1.a; or
				2. Fifteen to 29 test results are available and average of test results exceeds that required by 2.7.C.2.a using a sample standard deviation calculated in accordance with 2.7.C.1.b.
				3. Special exposure requirements of 2.7.F are met.
		3. Durability requirements
			1. Water-cementitious material ratio
				1. The water-cementitious material ratios specified in Tables 2-4 and 2-5 shall be calculated using the weight of cement meeting ASTM C 150, C 595, C 845, or C 1157 plus the weight of fly ash and other pozzolans meeting ASTM C 618, except as noted in 2.7.B, slag meeting ASTM C 989, and silica fume meeting ASTM C 1240, if any, except as limited by 2.7.F.2.c.

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| **Table 2-4 Requirements for Special Exposure Conditions** |
| Exposure condition | Maximum water-cementitious material ratio\*, by weight, normal weight concrete | Minimum f’c, normal weight concrete, psi\*  |
| Concrete intended to have low permeability when exposed to water | 0.50 | 4000 |
| Concrete exposed to freezing and thawing in a moist condition or to deicing chemicals | 0.45 | 4500 |
| For corrosion protection of reinforcement in concrete exposed to chlorides from deicing chemicals, salt, brackish water, or spray from these sources | 0.40 | 5000 |
| When both tables 2-4 and 2-5 are considered, the lowest maximum water-cementitious material ratio and highest applicable minimum f’c shall be used. |

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| **Table 2-5 Requirements for concrete exposed to sulfate-containing solutions** |
| Sulfate exposure | Water-soluble sulfate (SO4) in soil, % by weight | Sulfate (SO4) in water, ppm | Cement type | Maximum w/cm, by weight, normal weight concrete | Minimum f’c, normal weight concrete, psi1 |
| Negligible | 0.00 ≤ SO4 < 0.10 | 0 ≤ SO4 < 150 | --- | --- | --- |
| Moderate2 | 0.10 ≤ SO4 < 0.20 | 150 ≤ SO4 < 1500 | II, IP(MS), IS(MS), P(MS), I(PM)(MS), I(SM)(MS) | 0.50 | 4000 |
| Severe | 0.20 ≤ SO4 < 2.00 | 1500 ≤ SO4 < 10,000 | V | 0.45 | 4500 |
| Very Severe | SO4 > 2.00 | SO4 > 10,000 | V plus pozzolan3 | 0.45 | 4500 |
| 1. When both Tables 2-5 and 2-4 are considered, the lowest applicable maximum water-cementitious material ratio and highest applicable minimum f’c shall be used.
2. Seawater.
3. Pozzolan that has been determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement.
 |

* + - 1. Freezing and thawing exposures
				1. Normal weight concrete exposed to freezing and thawing or deicing chemicals shall be air-entrained with air content indicated in Table 2-6. Tolerance on air content as delivered shall be ±1.5%. For f’c greater than 5000 psi, air content indicated in Table 2-6 shall be permitted to be reduced by 1.0 percentage points as measured as point of placement.

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| **Table 2-6 Total air content for frost-resistant concrete** |
| Nominal maximum aggregate size, in1 | Air content, % |
| Severe exposure | Moderate exposure |
| 3/8 | 7.5 | 6 |
| 1/2 | 7 | 5.5 |
| 3/4 | 6 | 5 |
| 1 | 6 | 4.5 |
| 1-1/2 | 5.5 | 4.5 |
| 22 | 5 | 4 |
| 32 | 4.5 | 3.5 |
| 1) \*Refer to ASTM C 33 for tolerance on oversize for various nominal maximum size designations. 2) These air contents apply to total mixture, as for the preceding aggregate sizes. When testing these concretes, however, aggregate larger than 1-1/2 in. is removed by handpicking or sieving, and air content is determined on the 1-1/2 in. fraction of mixture (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value determined on the 1-1/2 in. fraction. |

* + - * 1. Concrete that will be subject to the exposures given in Table 2-4 shall conform to the corresponding maximum water-cementitious material ratios and minimum f’c requirements of that table. In addition, concrete that will be exposed to deicing chemicals shall conform to the limitations of 2.7.F.2.c.
				2. For concrete exposed to deicing chemicals, the maximum weight of fly ash, other pozzolans, silica fume, or slag that is included in the concrete shall not exceed the percentages of the total weight of cementitious materials given in Table 2-7.

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| **Table 2-7 Requirements for concrete exposed to deicing chemicals** |
| Cementitious materials | Maximum percent of total cementitious materials by weight1 |
| Fly ash or other pozzolans conforming to ASTM C 618 | 25 |
| Slag conforming to ASTM C 989 | 50 |
| Silica fume conforming to ASTM C 1240 | 10 |
| Total of fly ash or other pozzolans, slag, and silica fume | 502 |
| Total of fly ash or other pozzolans and silica fume | 352 |
| 1) The total cementitious material also includes ASTM C 150, C 595, C 845, and C 1157 cement. The maximum percentages shall include: a) fly ash and other pozzolans present in Type IP or I(PM) blended cement (ASTM C 595 or C 1157); b) slag used in the manufacture of an IS or I(SM) blended cement (ASTM C 595 or C 1157); and c) silica fume (ASTM C 1240) present in a blended cement.2) Fly ash or other pozzolans and silica fume shall constitute no more than 25 or 10%, respectively, of the total weight of the cementitious materials. |

* + - 1. Sulfate Exposures
				1. Concrete to be exposed to sulfate-containing solutions or soils shall conform to requirements of Table 2-5 or shall be concrete made with cement that provides sulfate resistance and that has a maximum water-cementitious material ratio and minimum fc′ from Table 2-5.
				2. Calcium chloride as an admixture shall not be used in concrete to be exposed to severe or very severe sulfate containing solutions, as defined in Table 2-5.
			2. Corrosion protection of reinforcement
				1. For corrosion protection of reinforcement in concrete, maximum water-soluble chloride ion concentrations in hardened concrete at ages from 28 to 42 days contributed from the ingredients including water, aggregates, cementitious materials, and admixtures shall not exceed the limits of Table 2-8. When testing is performed to determine water-soluble chloride ion content, test procedures shall conform to ASTM C 1218.

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| **Table 2-8 Maximum chloride ion content for corrosion protection of reinforcement** |
| Type of Member | Maximum water-soluble chloride ion (CL-) in concrete, percent by weight of cement |
| Prestressed concrete  | 0.06 |
| Reinforced concrete | 0.15 |

* + - * 1. When reinforced concrete will be exposed to deicing chemicals, salt, brackish water, seawater, or spray from these sources, requirements of Table 2-4 for maximum water-cementitious material ratio and minimum f’c, and the minimum concrete cover requirements of 3.11.F shall be satisfied.
			1. Identification of Potential Alkali-Silica Reactivity
				1. Subcontractor shall test the mixture design using ASTM C1567.
				2. Mixture design shall be considered acceptable if the 16 day expansion is less than 0.10%.
1. EXECUTION
	1. GENERAL
		1. Work shall conform to applicable provision of ACI 301 and ACI 349 unless otherwise specified herein.
		2. Construction tolerances shall be as shown on the construction drawings and ACI 117, or this specification whichever is more stringent.
		3. Prior to placement of concrete, ensure that all inspections of formwork and reinforcing have been completed in accordance with approved VIT Plan.
		4. Place concrete in accordance with ACI 301. Consolidate concrete by internal vibration per ACI 309R; whichever is more stringent, unless otherwise directed by the Contractor.
		5. Notify the Contractor a minimum of 48 hours prior to commencement of concrete operations.
		6. Install joint filler, primer and sealant in accordance with manufacturer’s instructions.
		7. Install joint devices in accordance with manufacturer’s instructions.
		8. Place concrete continuously between predetermined expansion, control, and construction joints.

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Edit the following para to indicate the required concrete properties.

To increase the likelihood of good quality control, limit the number of mix designs used on a project to as few as necessary.

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* + 1. Project Requirements: Concrete supplied for this project shall conform to this specification including the following:

[Exterior and interior walls, foundation, slab and roof slab]

* + - * 1. Cement shall be Type [I, II, I/II Low-Alkali] cement in accordance with ASTM C150. CMTRs for cement shall include equivalent alkalies (%). Equivalent alkalies shall be less than [0.6%].
				2. Minimum concrete compressive strength, f’c = [5000psi @ 28 days].
				3. Air-entrained in accordance with Table 2-6 for [Moderate] Exposure.

[d. Sulfate Exposure shall be considered negligible for Table 2-5 unless the geotechnical report indicates sulfates are present in the soil. If the geotechnical report indicates sulfates are present in the soil, the requirements of Table 2-5 shall be met].

1. Water-cementitious material ratio shall meet the maximum ratio for [“Concrete exposed to freezing and thawing in a moist condition”] per Table [2-4].
2. Slump shall meet the requirements of paragraph 3.3.c.
3. Maximum nominal large aggregate size shall be [3/4] in unless approved by Contractor.
	1. PREPARATION OF EQUIPMENT and PLACE OF DEPOSIT
		1. Preparation before concrete placement shall include the following:
			1. All equipment for mixing and transporting concrete shall be clean;
			2. All debris and ice shall be removed from spaces to be occupied by concrete;
			3. Forms shall be properly coated;
			4. Masonry filler units that will be in contact with concrete shall be well drenched;
			5. Reinforcement shall be thoroughly clean of ice, concrete or other deleterious coatings;
			6. Water shall be removed from place of deposit before concrete is placed unless a tremie is to be used or it shall be displaced by methods that shall exclude incorporation of additional water in the concrete during placement and consolidation;
			7. All laitance and other unsound material shall be removed before additional concrete is placed against hardened concrete.
			8. All concrete shop drawings shall be reviewed and coordinated by all interfacing subtier Subcontractors having work that impacts the design and/or installation of the concrete.  A pre-pour inspection checklist will be signed off by all interfacing subcontractors before placing concrete. A pre-pour meeting shall be held a minimum of 24 hours prior to planned placement and attended by all interfacing subtier Subcontractors and Contractor representatives.
	2. MIXING
		1. All concrete shall be batched using automated equipment with digital recordation and shall be mixed until there is a uniform distribution of materials and shall be discharged completely before mixer is recharged.
		2. Ready mixed concrete shall be mixed and delivered in accordance with requirements of “Standard Specification for Ready-Mixed Concrete” (ASTM C 94) or “Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing” (ASTM C 685).
		3. Slump
			1. Unless otherwise specified or permitted, concrete shall have, at the point of delivery, a slump of 4 in. Determine the slump by ASTM C143/C143M. Slump tolerances shall meet the requirements of ACI 117. When a Type I or II plasticizing admixture conforming to ASTM C1017/C1017M or a Type F or G high-range water-reducing admixture conforming to ASTM C494/C494M is permitted per the Contractor approved mixture design to increase the slump of concrete, concrete shall have been a proportioned to a slump of 2 to 4 in. before the admixture is added and a maximum slump of 8 in. at the point of delivery after the admixture is added, unless otherwise specified.
		4. Adding mixing water in the field is only permitted if the ready-mix producer held back water at the batch plant and the slump after transport is less than that specified in the design documents. Care must be taken not to exceed the water-cement ratio. To adjust for measuring technique accuracy, the amount of water that can be added shall be reduced by 10% from the maximum calculated water holdback volume. In addition, mixing water added in the field to adjust slump is permitted only when the water measuring device used is as follows:
			1. A Contractor-approved mechanical calibrated device; or
			2. The ready mix truck sight glass may be used if the following condition is met:
4. The water-measuring device shall be manually verified prior to the addition of water. This requirement need not exceed one verification per set of water additions by a given truck in a given project-site visit. The intent of the verification to ensure that the measuring device is accurate within a tolerance of + 5%. This can be accomplished by dispensing water in a graduated cylinder/container and the measuring device reading compared to the graduation marks in the cylinder/ container. The amount of water added to the concrete mix is adjusted in accordance with the results of the verification.
	1. CONVEYING
		1. Concrete shall be conveyed from mixer to place of final deposit by methods that will prevent separation or loss of materials.
		2. Conveying equipment shall be capable of providing a supply of concrete at site of placement without separation of ingredients and without interruptions sufficient to permit loss of plasticity between successive increments.
		3. Aluminum pipe shall not be used to convey concrete.
	2. DEPOSITING
		1. Concrete shall be deposited as nearly as practical in its final position to avoid segregation due to re-handling or flowing.
		2. Concreting shall be carried on at such a rate that concrete is at all times plastic and flows readily into spaces between reinforcement.
		3. Concrete that has exceeded 90 minutes from batching time, partially hardened or been contaminated by foreign materials shall not be deposited in the structure.
		4. Re-tempered concrete shall not be used.
		5. After concreting is started, it shall be carried on as a continuous operation until placing of a panel or section, as defined by its boundaries or predetermined joints, is completed except as permitted or prohibited by 3.10.D.
		6. Top surfaces of vertically formed lifts shall be generally level.
		7. When construction joints are required, joints shall be made in accordance with 3.10.D.
		8. All concrete shall be thoroughly consolidated by suitable means during placement and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms.
		9. When the ambient temperature falls below 40 °F or rises above 95 °F the cold or hot weather plan, respectively, shall be implemented and a record shall be kept of concrete temperatures and of protection given to concrete during placement and curing.
	3. CURING
		1. Curing and protection
			1. Curing -- Unless otherwise specified or permitted, cure concrete in accordance with 3.6.A.2 or 3.6.A.3 for at least 7 days after placement. Unless otherwise specified, cure high early-strength concrete for at least 3 days after placement. When permitted, and when the duration of curing is to achieve a specified level of in-place strength, moisture retention measures may be terminated when any one of the following conditions has been met, unless otherwise specified:
				1. Tests of at least two 6 x 12 in. or at least three 4 x 8 in. cylinders, that have been field cured in accordance with ASTM C31/C31M, indicate compressive strength of at least 70% of f’c when tested in accordance with ASTM C39/C39M;
				2. The compressive strength of laboratory-cured cylinders, representative of the in-place concrete, exceeds 85% f’c, provided the temperature of the in-place concrete has been maintained at 50°F or higher during curing; and
				3. Concrete strength reaches f’c as determined by accepted in-place test methods meeting the requirements of ACI 301 2.3.4.2.

When one of the curing procedures in 3.6.A.4 is used initially, the curing procedure may be replaced by one of the other procedures after concrete is 1 day old, provided the concrete is not permitted to become surface-dry at any time. Use a curing procedure of 3.6.A.4 that supplies additional water during the entire curing period for concrete containing silica fume and when specified in Contract Documents.

* + - 1. Unformed concrete surfaces -- Apply one of the procedures in 3.6.A.4 after placement and finishing of concrete surfaces that are not in contact with forms.
			2. Formed concrete surfaces—Keep absorbent wood forms wet until they are removed. After formwork removal, cure concrete by one of the methods in 3.6.A.4.

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The following paragraph does not indicate “accelerated curing” as being a permissible curing method despite the fact that it is included in ACI 349 (ref. para. 5.11.3, which refers to ACI 318, 5.11.3). The reason being the Commentary (found in ACI 318, R5.11.3) indicates “…Accelerated curing procedures require careful attention to obtain uniform and satisfactory results…”

If, for some reason (i.e., special/ extenuating/ unique circumstances), accelerating curing is desired then Contractor permission must be formally requested and received prior to including it in the following para. (e.g., in/under 4.f, etc.). The formal request for permission shall include measures that will be taken to ensure that “uniform and satisfactory results” will be obtained (e.g., inclusion in Subcontractor’s QA Plan, pre-pour inspection checklist and meeting, etc.). If such permission is granted then the number of days indicated in paras. 6 and 7 can be reduced in accordance with ACI 349.

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* + - 1. Curing methods -- After placing and finishing, provide or preserve moisture in concrete. Unless otherwise specified, use one or more of the following methods:
				1. Ponding, continuous fogging, or continuous sprinkling;
				2. Application of mats or fabric kept continuously wet;
				3. Continuous application of steam (under 150°F);
				4. Application of sheet materials conforming to ASTM C171;
				5. Application of a curing compound conforming to ASTM C309 or C1315. Apply the compound in accordance with manufacturer’s recommendation as soon as water sheen has disappeared from the concrete surface and after finishing operations. The application rate shall not be less than 1 gal/200 ft2 for each coat. For rough surfaces, such as those specified in ACI 301, sections 5.3.4.2.a and 5.3.4.2.d, apply curing compound in two applications at right angles to each other. Do not use curing compound on surface where concrete or other material will be bonded, unless the curing compound will not prevent bond or unless measures are to be taken to completely remove the curing compound from areas to receive bonded applications; and
				6. Application of other Contractor-accepted curing methods.
			2. Protection -- Within 30 minutes after finishing operations are complete, protect concrete from premature drying or excessively hot or cold temperatures, and mechanical injury. Maintain concrete protection to prevent freezing of the concrete and to ensure necessary strength development for structural safety. Remove protection so that the maximum decrease in temperature measured at the concrete surface in a 24-hour period shall not exceed the following:
				1. 50°F for sections less than 12 in. in the least dimension;
				2. 40°F for sections from 12 to 36 in. in the least dimension;
				3. 30°F for sections 36 to 72 in. in the least dimension; and
				4. 20°F for sections greater than 72 in. in the least dimension.

Measure concrete temperature using a method acceptable to the Contractor, and record the concrete temperature. When the concrete surface temperature is within 20°F of the ambient or surrounding temperature, protection measures may be removed.

* + - 1. Concrete [other than high-early-strength] shall be maintained above 50 °F and, in a moist condition, for at least the first 7 days after placement.

[7. High-early-strength concrete shall be maintained above 50 °F and, in a moist condition, for at least the first 3 days after placement.]

* + 1. When required by the Contractor, supplementary strength tests in accordance with 3.9.D shall be performed to assure that curing is satisfactory.
		2. Where a liquid membrane curing compound is used, particular attention shall be given to its compatibility with any protective coatings that are to be applied following curing.
	1. COLD WEATHER REQUIREMENTS
		1. When concrete must be placed in cold weather as defined by ACI 306R, the Subcontractor must develop a detailed “Cold-Weather Implementation Plan” and submit for approval by the Contractor. This approval shall account for those recommendations addressed in ACI 306R and ACI 349 (curing) as appropriate and any elements required for worker safety. This cold-weather plan shall cover:
			1. the production,
			2. transportation,
			3. placement,
			4. protection,
			5. curing (ACI 349) and
			6. temperature-monitoring of concrete during cold weather; in the submittal, include procedures to be implemented upon abrupt changes in weather conditions or equipment failures.

Do not begin cold weather concreting until these procedures have been submitted to and approved by the Contractor.

Note: ACI 301 applies for any conditions not specifically addressed by one of the standards / guides noted.

* + 1. Protection may be removed when the concrete surface temperature is within 20ºF of the ambient temperature measured with a calibrated measuring device.
		2. Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather.
		3. All concrete materials and all reinforcement, forms, fillers, and ground with which concrete is to come in contact shall be free from frost.
		4. Frozen materials or materials containing ice shall not be used.
		5. Concrete shall comply with the requirements of ACI 306R and this specification. Where a contradiction exists, this specification shall govern.
	1. HOT WEATHER REQUIREMENTS
		1. When concrete must be placed in hot weather as defined below, Subcontractor must develop a detailed “Hot-Weather Implementation Plan” and submit for approval by the Contractor. This approval shall account for those recommendations addressed in ACI 305R and ACI 349 (curing) as appropriate and any elements required for worker safety. This hot-weather plan shall cover:
			1. the production,
			2. transportation,
			3. placement,
			4. protection,
			5. curing (ACI 349) and
			6. temperature-monitoring of concrete during cold weather; in the submittal, include procedures to be implemented upon abrupt changes in weather conditions or equipment failures.

Do not begin hot weather concreting until these procedures have been submitted to and approved by the Contractor.

* + 1. Note: ACI 301 applies for any conditions not specifically addressed by one of the standards / guides noted.

Protection may be removed when the concrete surface temperature is within 20ºF of the ambient temperature measured with a calibrated measuring device.

* + 1. These practices (ACI 305R) shall be used when the ambient daytime temperature at any time at the job-site is 80ºF or more.
		2. During hot weather, proper attention shall be given to ingredients, production methods, handling, placing, protection, and curing to prevent excessive concrete temperatures or water evaporation that could impair required strength or serviceability of the member or structure.
		3. Concrete shall comply with the requirements of ACI 305R and this specification. Where a contradiction exists, this specification shall govern.
	1. EVALUATION AND ACCEPTANCE OF CONCRETE
		1. Concrete shall be tested in accordance with the requirements of 3.9.B through 3.9.E. Qualified field testing technicians shall perform tests on fresh concrete at the job site, prepare specimens required for curing under field conditions, prepare specimens required for testing in the laboratory, and record the temperature of the fresh concrete when preparing specimens for strength tests. Qualified laboratory technicians shall perform all required laboratory tests at the point of placement.
		2. Frequency of testing
			1. Samples for strength tests of concrete should be taken at least once per day for each class of concrete placed, or at least once for each 50 yd3 of concrete placed, or as specified in the approved CGD plan, whichever is more stringent.
			2. If total volume of concrete is such that frequency of testing required by 3.9.B.1 would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.
			3. A strength test shall be the average of the strengths of a minimum of two cylinders made from the same sample of concrete and tested at 28 days or at test age designated for determination of f’c.
		3. Laboratory-cured specimens
			1. Samples for strength tests shall be taken in accordance with ASTM C 172.
			2. Cylinders for strength tests shall be molded and laboratory-cured in accordance with ASTM C 31 and tested in accordance with ASTM C 39.
			3. Strength level of an individual class of concrete shall be considered satisfactory if both of the following requirements are met:
				1. Every arithmetic average of any three consecutive strength tests equals or exceeds f’c ;
				2. No individual strength test (average of two cylinders) falls below f’c by more than 500 psi when f’c is 5000 psi or less; or by more than 0.10 f’c when f’c is more than 5000 psi.
		4. Field-cured specimens
			1. The Contractor may require strength tests of cylinders cured under field conditions to check the adequacy of curing and protection of concrete in the structure.
			2. Field-cured cylinders shall be cured under field conditions in accordance with ASTM C 31.
			3. Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.
			4. Procedures for protecting and curing concrete shall be improved when strength of field-cured cylinders at test age designated for determination of f’c is less than 85% of that of companion laboratory-cured cylinders. The 85% limitation shall not apply if field-cured strength exceeds f’c by more than 500 psi.
		5. Appearance
			1. The concrete surface shall be free from honeycombs, embedded debris, and dimensional variance beyond ACI 301 and its references.
	2. FORMWORK, EMBEDDED PIPES AND CONSTRUCTION JOINTS
		1. General
			1. Prior to placement of formwork, ensure that all inspections are complete and documentation has been accepted by the contractor in accordance with approved VIT Plan.
			2. Hand trim sides and bottom of earth forms. Remove loose soil prior to placing concrete.
			3. Erect formwork, shoring and bracing to achieve design requirements and maintain tolerances in accordance with requirements of ACI 301 and ACI 347 (or more stringent design requirements as specified in this specification or construction drawings). Contact surfaces of the formwork should be carefully installed to produce neat and symmetrical joint patterns, unless otherwise specified. Joints should be vertical or horizontal and, where possible, should be staggered to maintain structural continuity.
			4. Provide bracing to ensure stability of formwork. Shore or strengthen formwork subject to overstressing by construction loads.
			5. Arrange and assemble formwork to permit dismantling, stripping and removal of remaining principal shores. Do not damage concrete during stripping.
			6. Align joints and make watertight. Keep form joints to a minimum.
			7. Provide chamfer strips on external corners of beams, joists, columns, and walls.
			8. Apply form release agent prior to placement of reinforcing steel, anchoring devices, and embedded items.
			9. Do not apply form release agent where concrete surfaces receive special finishes or applied coverings which are affected by agent. Soak inside surfaces of untreated forms with clean water. Keep surfaces coated prior to placement of concrete.
			10. Install void forms in accordance with manufacturer’s recommendations. Protect forms from moisture or crushing.
			11. Provide formed openings where required for items to be embedded in or passing through concrete work.
			12. Locate and set in place items which cast directly into concrete.
			13. Clean formed cavities of debris prior to placing concrete. Clean and remove foreign matter as erection proceeds.
			14. Install accessories in accordance with manufacturer’s instructions, straight, level, and plumb. Ensure items are not disturbed during concrete placement.
			15. Install waterstops in construction joints and at other joints indicated to form a continuous diaphragm. Install in the longest lengths practicable. Support and protect exposed waterstops during progress of the Work. Field-fabricate joints in waterstops according to manufacturer’s written instructions.
			16. Provide temporary ports or openings in formwork where required to facilitate placement, cleaning and inspection. Locate openings at bottom of forms to allow flushing water to drain.
			17. Close temporary openings with tight fitting panels, flush with inside face of forms, and neatly fitted so joints will not be apparent in exposed concrete surfaces.
			18. During cold weather, remove ice and snow from within forms. Do not use deicing salts or water to clean out forms. Use compressed air or other means to remove foreign matter. Ensure that water and debris drain to exterior through clean-out ports.
			19. Do not remove forms or bracing until concrete has gained sufficient strength to carry its own weight and other imposed loads without excessive deflection or creep or until the concrete strength identified in 3.10.B.5 has been achieved. Perform form removal in accordance with the recommendations of ACI 347.
			20. Store removed forms in manner to avoid any damage to form surfaces that will later be in contact with fresh concrete. Discard damaged forms.
			21. After formwork removal, place construction or equipment loads on reinforced concrete only after cylinder break results indicate strengths meet specified requirements. Exceptions to this requirement must be approved in writing by the Contractor.
			22. Verify lines, levels, and centers before proceeding with formwork. Ensure that dimensions agree with the Drawings. Verify “square” for slabs, floors, and walls. “Square” specifically means a 90 degree corner or connection, whether horizontal or vertical, such as a floor, wall or ceiling. Note: all required preliminary activities, such as inspections, geotechnical and soil compaction/moisture testing, must be approved by the Contractor to proceed with the placement.
			23. Inspect erected formwork, shoring, and bracing to ensure that work is in accordance with formwork design, and that supports, fastenings, wedges, ties, and items are secure.
			24. Verify that concrete cover for reinforcement conforms to the drawings and to Para 3.11.F below.
		2. Removal of forms, shores, and reshoring
			1. Removal of forms—Forms shall be removed in such a manner as not to impair safety and serviceability of the structure. Concrete exposed by form removal shall have sufficient strength not to be damaged by removal operation.
			2. Removal of shores and reshoring—the provisions of 3.10.B.2.a.i through 3.10.B.2.a.iii shall apply to slabs and beams except where cast on the ground.
				1. Before starting construction, the subcontractor shall develop a procedure and schedule for removal of shores and installation of reshores and for calculating the loads transferred to the structure during the process.

The structural analysis and concrete strength data used in planning and implementing form removal and shoring shall be furnished by the subcontractor to the Contractor when so requested;

No construction loads shall be supported on, nor any shoring removed from, any part of the structure under construction except when that portion of the structure in combination with remaining forming and shoring system has sufficient strength to support safely its weight and loads placed thereon;

Sufficient strength shall be demonstrated by structural analysis considering proposed loads, strength of forming and shoring system, and concrete strength data. Concrete strength data shall be based on tests of field-cured cylinders or, when approved by the Contractor, on other procedures to evaluate concrete strength.

* + - * 1. No construction loads exceeding the combination of superimposed dead load plus specified live load shall be supported on any unshored portion of the structure under construction, unless analysis indicates adequate strength to support such additional loads.
			1. Where coating systems are to be applied to the concrete, only those hardeners, additives, and form release agents that are compatible with the coating system shall be used.
			2. Loosen forms carefully. Do not wedge pry bars, hammers, or tools against finish concrete surfaces scheduled for exposure to view.
			3. Concrete forms shall not be permitted to be removed until the following strengths have been achieved:

| **Table 3-1 – Required Concrete Strength for Formwork Removal**  |
| --- |
| Structural Element | Required Strength |
| Foundation and ground supported flatwork | 50% f’c |
| Walls and parapets | 75% f’c  |
| Roof slab | 75% f’c |

If this specification or referenced codes require higher strength prior to stripping the forms, then the more stringent requirements shall be used.

* + - 1. Concrete curing shall be maintained in accordance with 3.6 and the applicable ACI codes after forms have been removed.
		1. Conduits and pipes embedded in concrete
			1. Conduits, pipes, and sleeves of any material not harmful to concrete and within limitations of 3.10.C shall be permitted to be embedded in concrete with approval of the Contractor, provided they are not considered to replace structurally the displaced concrete, except as provided in 3.10.C.5.
			2. Conduits and pipes of aluminum shall not be embedded in structural concrete unless effectively coated or covered to prevent aluminum-concrete reaction or electrolytic action between aluminum and steel.
			3. Conduits, pipes, and sleeves passing through a slab, wall, or beam shall not significantly impair the strength of the construction.
			4. Except when conduits and pipes are shown on the project drawings, conduits and pipes embedded within a slab, wall, or beam (other than those merely passing through) shall satisfy 3.10.C.4.a through 3.10.C.4.c.
				1. They shall not be larger in outside dimension than 1/3 the overall thickness of slab, wall, or beam in which they are embedded.
				2. They shall not be spaced closer than three diameters or widths on center.
				3. They shall not significantly impair the strength of the construction.
			5. Conduits, pipes, and sleeves shall be permitted to be considered as replacing structurally in compression the displaced concrete provided in 3.10.C.5.a through 3.10.C.5.c.
				1. They are not exposed to rusting or other deterioration.
				2. They are of uncoated or galvanized iron or steel not thinner than standard Schedule 40 steel pipe.
				3. They have a nominal inside diameter not over 2 in. and are spaced not less than three diameters on centers.
			6. All piping and fittings, where required by the respective project specifications, shall be tested as a unit for leaks before concrete placement. Pressure tests shall be in accordance with the applicable piping Specification, Code or standard.
			7. No liquid, gas, or vapor, except water not exceeding 90 °F nor 50 psi pressure, shall be placed in the pipes until the concrete has attained its design strength, unless otherwise approved by the Contractor.
			8. In solid slabs, piping, unless it is for radiant heating or snow melting, shall be placed between top and bottom reinforcement.
			9. Concrete cover for pipes, conduits, and fittings shall not be less than 1-1/2 in. for concrete exposed to earth or weather, nor less than 3/4 in. for concrete not exposed to weather or in contact with ground.
			10. Reinforcement with an area not less than 0.002 times area of concrete section shall be provided normal to piping.
			11. Piping and fittings shall be assembled according to the construction specifications. Screw connections shall be prohibited.
			12. Piping and conduit shall be so fabricated and installed that cutting, bending, or displacement of reinforcement from its proper location will not be required.
			13. All piping containing liquid, gas, or vapor pressure in excess of 200 psi above atmospheric pressure or temperature in excess of 150 °F shall be sleeved, insulated, or otherwise separated from the concrete and/or cooled to limit concrete stresses to allowable design strength and to limit concrete temperatures to the following:
				1. For normal operation or any other long-term period, the temperatures shall not exceed 150 °F, except for local areas that are allowed to have increased temperatures not to exceed 200 °F;
				2. During an accident or for any other short-term interruption, the temperatures shall not exceed 350 °F for the interior surface. However, local areas are allowed to reach 650 °F from fluid jets in the event of a pipe failure;
				3. Higher temperatures than given in Items (a) and (b) may be allowed in the concrete if tests are provided to evaluate the reduction in strength and this reduction is applied to the design strength. Evidence shall also be provided that verifies that the increased temperatures do not cause deterioration of the concrete with or in the absence of applied loads.
		2. Construction Joints
			1. Surface of concrete construction joints shall be clean of all materials that inhibit bond. Materials such as curing compounds, laitance, saw dust, wood, dirt, polyethylene, pipe tape coating, and paper shall be removed. If a bonding agent is used, preparation / cleaning (above and beyond that described) shall be in accordance with manufacturer’s written instructions. Where key joints are not provided, the finished surface amplitude shall be 1/4 in.
			2. A maximum of 10 minutes before new concrete is placed, all construction joints shall be wetted and standing water removed.
			3. Construction joints shall be located as shown on the drawings or shall be approved by the Contractor.
			4. Construction joints in floors shall be located within the middle third of spans of slabs, beams, and girders.
			5. Construction joints in girders shall be offset a minimum distance of two times the width of intersecting beams.
			6. Beams, girders, or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support members is no longer plastic.
			7. Beams, girders, haunches, drop panels, and capitals shall be placed monolithically as part of a slab system, unless otherwise shown in design drawings or specifications.
		3. Contraction Joints
			1. While the concrete is still plastic (i.e., within several hours after placement), provide joints in slabs at no more than 10 feet on center in each direction or as shown on the drawings. The depth of each joint will be at least one-quarter of the slab thickness, but not less than one inch.
	1. DETAILS OF REINFORCEMENT
		1. Standard hooks
			1. The term “standard hook,” as used in this document, shall mean one of the following:
				1. A 180-degree bend plus 4db extension, but not less than 2-1/2 in. at free end of bar.
				2. A 90-degree bend plus 12db extension at free end of bar.
				3. For stirrup and tie hooks

No. 5 bar and smaller, 90-degree bend plus 6db extension at free end of bar; or

No. 6, No. 7, and No. 8 bar, 90-degree bend plus 12db extension at free end of bar; or

No. 8 bar and smaller, 135-degree bend plus 6db extension at free end of bar.

* + - * 1. Seismic hooks defined as follows: a hook on a stirrup, hoop, or crosstie having a bend not less than 135 degrees, except that circular hoops shall have a bend not less than 90 degrees. Hooks shall have a six-diameter (but not less than 3 in.) extension that engages the longitudinal reinforcement and projects into the interior of the stirrup or hoop.
		1. Minimum bend diameters
			1. Diameter of bend measured on the inside of the bar, other than for stirrups and ties in sizes No. 3 through No. 5, shall not be less than the values in Table 3-2.

|  |
| --- |
| **Table 3-2 Minimum Diameters of Bend** |
| Bar Size | Minimum Diameter |
| No. 3 through No. 8 | 6db |
| No. 9, No. 10, and No. 11 | 8db |
| No. 14 and No. 18 | 10db |

* + - 1. Inside diameter of bend for stirrups and ties shall not be less than 4db for No. 5 bar and smaller. For bars larger than No. 5, diameter of bend shall be in accordance with Table 3-2.
		1. Bending
			1. All reinforcement shall be bent cold, unless otherwise permitted by the Contractor.
			2. Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the Contractor.
		2. Surface conditions of reinforcement
			1. At the time concrete is placed, reinforcement shall be free from mud, oil, or other nonmetallic coatings that decrease bond.
			2. Steel reinforcement with rust, mill scale, or a combination of both shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire-brushed test specimen comply with applicable ASTM specifications referenced in 1.4 and 2.3.
		3. Placing reinforcement
			1. Reinforcement shall be accurately placed and adequately supported before concrete is placed, and shall be secured against displacement within tolerances permitted in 3.11.E.2.
			2. Unless otherwise specified by the Contractor, reinforcement shall be placed within the tolerances in 3.11.E.2.a and 3.11.E.2.b.
				1. Tolerance for *d* and minimum concrete cover in flexural members, walls, and compression members shall be as follows except that tolerance for the clear distance to formed soffits shall be -1/4 in. and tolerance for cover shall not exceed -1/3 the minimum concrete cover required in the design drawings or in the specifications.

|  |
| --- |
| **Table 3-3 Tolerance for *d* and minimum concrete cover in flexural members** |
|  | Tolerance on d | Tolerance on minimum concrete cover |
| d ≤ 8 in | ± 3/8 in | -3/8 in |
| 8 in < d ≤ 24 in | ± 1/2 in | -1/2 in |
| d > 24 in | ± 1 in | -1/2 in |

* + - * 1. Tolerance for longitudinal location of bends and ends of reinforcement shall be ±2 in., except the tolerance shall be ±1/2 in. at the discontinuous ends of brackets and corbels, and ±1 in. at the discontinuous ends of other members. The tolerance for minimum concrete cover of 3.11.E.2.a shall also apply at discontinuous ends of members.
			1. Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the Contractor.
			2. Bars shall be permitted to be moved as necessary to avoid interference with other reinforcing steel, conduits, or embedded items subject to the approval of the Contractor. If bars are moved more than one bar diameter, or enough to exceed the above tolerances, the resulting arrangement of bars shall be subject to approval by the Contractor.

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The following minimum cover requirements come from ACI 318 Ch. 7 (since that’s what ACI 349 defers to for ‘cover’), and apply ONLY when BOTH of the following conditions are met:

1. Larger cover is not required by corrosion and /or fire-protection requirements of Ch. 7.

2. The concrete is cast-in-place (CIP), nonprestressed.

If both of these conditions are not met then the following para. must be edited in accordance with Chapter. 7.

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

* + 1. Concrete protection for reinforcement

Cast-in-place concrete (nonprestressed) -- The following minimum concrete cover shall be provided for reinforcement:

| **Table 3-4 Minimum Concrete Cover**  |
| --- |
| Condition  | cover, in. |
| Concrete cast against and permanently exposed to earth | 3 |
| Concrete exposed to earth or weather: |  |
| No. 6 through No. 18 bars | 2 |
| No. 5 bar, and smaller | 1-1/2 |
| Concrete not exposed to weather or in contact with ground: |  |
| Slabs, walls, joists |  |
| No. 14 and No. 18 bars | 1-1/2 |
| No. 11 bar and smaller | 3/4 |
| Beams, columns |  |
| Primary reinforcement, ties, stirrups, spirals | 1-1/2 |

Where the above table and the drawings are in conflict the following shall be used:

* + - * 1. Requirements of Table 3-4 are less than the cover requirements on the drawings: The drawings shall be used for cover requirements.
				2. Requirements of Table 3-4 are greater than the cover requirements on the drawings: Contractor shall be notified to provide direction. The concrete shall not be permitted to be cast until cover is resolved.
	1. Defective Concrete
		1. Defective concrete is concrete not conforming to acceptance criteria in this specification and referenced codes and standards.
			1. NOTE: In accordance with the contract, concrete that has not been placed in accordance with the applicable portions of this specification can be considered defective due to the potential for such concrete to not be durable (e.g., concrete that is not placed properly in ‘cold/hot weather’ is subject to poor long-term performance, etc.).
		2. Do not accept or place defective concrete that is not in conformance with acceptance criteria. Return the fresh concrete to the supplier.
		3. Defective concrete shall be address through the Non-Conformance Report (NCR) process and the Contractor-approved Subcontractor QA plan. The subcontractor repair method shall not be permitted to be implemented until approved by the Contractor.

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*The following finishing requirements apply to an “industrial-use, concrete-box” building (i.e., the building consists of concrete shear walls, and roof & floor slabs, for which only the most basic finishing requirements are necessary). If Project structure consists of something other than such a building then the following para. must be edited in accordingly.

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

* 1. CONCRETE FINISHING
		1. Finish Requirements - Unless noted otherwise on the drawings, the concrete finish shall meet the following requirements:
			1. Wall finishes:
				1. Exterior Permanently Exposed Areas – Smooth-formed finish in accordance with ACI 310, section 5.3.3.4.a.
				2. Interior Permanently Exposed Areas - Smooth-formed finish in accordance with ACI 310, section 5.3.3.4.a.
				3. Exterior Covered Areas - Smooth-formed finish. In accordance with ACI 301, section 5.3.3.3.b.
			2. Floor Finish and Flatness/Levelness Requirements:
				1. Finish – Trowel finish in accordance with ACI 301, section 5.3.4.2.c.
				2. Flatness and levelness requirements – The floor flatness (FF) and levelness (FL) numbers shall be 20/15, respectively in accordance with ACI 117 as measured in accordance with ASTM E1155.
			3. Roof Slab Finish and Flatness/Levelness Requirements:
				1. Finish – Float finish in accordance with ACI 301, section 5.3.4.2.b.
				2. Tolerance shall meet the requirements of conventional bullfloated slab in accordance with ACI 117, section 4.5.7
	2. Nonstructural/Cosmetic Concrete Repair
		1. Non-Structural Repair/Cosmetic Concrete Repair: NOTE: This paragraph is only applicable for non-structural deficiencies that do not affect the critical characteristics identified in 1.6.D as determined by Contractor. Concrete with structural deficiencies shall be addressed through the Non-Conformance Report (NCR) process and the Contractor approved subcontractor QA plan.
		2. Nonstructural cosmetic defects that are required to be repaired shall be defined as follows:
			1. Voids larger 3/4 in. wide or 1/2 in. deep. Note: This does not apply if the void has exposed rebar; repairs of this type shall be submitted for approval by the Contractor through the NCR process and in accordance with the Contractor approved subcontractor QA Program.
			2. Projections larger than 1/8 in.
			3. Unless otherwise required by this specification or other contract documents, minor surface imperfections left by air bubbles or sand streaks need not be repaired.
		3. Repair materials used shall be submitted to the Contractor for approval prior to use.
		4. Repair tie-holes and other surface defects immediately after formwork removal, unless otherwise permitted.
		5. Repair of tie-holes: Plug tie-holes. When Portland-cement patching mortar conforming to 3.12.C.4 is used for plugging, clean and dampen tie-holes before applying the mortar. When other materials are used, apply them in accordance with manufacturer’s recommendations. If other materials are used, material manufacturer data shall be submitted to the Contractor for approval prior to use.
		6. Repair of surface defects other than tie-holes: Outline honeycombed or otherwise defective concrete with a 1/2 to 3/4 in. deep saw cut and remove such concrete down to sound concrete. When chipping is necessary, leave chipped edges perpendicular to the surface or slightly undercut. Do not feather edges. Dampen the area to be patched plus another 6 in. around the patch area perimeter. Prepare bonding grout according to 3.14.G. Thoroughly brush grout into the surface. When the bond coat begins to lose water sheen, apply patching mortar prepared in accordance with 3.13.H, and thoroughly consolidate mortar into place. Strike-off mortar, leaving the patch slightly higher than the surrounding surface to compensate for shrinkage. Leave the patch undisturbed for 1 hour before finishing. Keep the patch damp for seven days.
		7. Preparation of bonding grout: For bonding grout, mix approximately one part cement and one part fine sand with water to the consistency of thick cream.
		8. Site-mixed Portland-cement repair mortar: Mix repair mortar using the same materials as concrete to be patched with no coarse aggregate. Do not use more than one part cement to two and one-half parts sand by damp loose volume. For repairs in exposed concrete, make a trial batch and check color compatibility of repair material with surrounding concrete. When the repair is too dark, substitute white Portland cement for a part of the gray cement to produce a color closely matching surrounding concrete. Use a repair mortar at a stiff consistency with no more mixing water than is necessary for handling and placing. Mix the repair mortar and manipulate the mortar frequently with a trowel without adding water.
		9. Repair materials other than site-mixed Portland cement mortar: Acceptable repair materials other than site mixed Portland-cement mortar may be used for repair. Use repair materials in accordance with manufacturer’s recommendations. Manufacturer data sheets shall be submitted to the Contractor for approval prior to use. Materials include, but are not limited to, 3.14.I.1 and 3.14.I.2:
			1. Shotcrete;
			2. Commercial patching products, including:
				1. Portland-cement mortar modified with a latex bonding agent conforming to ASTM C 1059 Type II;
				2. Epoxy mortars and epoxy compounds that are moisture- insensitive during application and after curing, that embody an epoxy binder conforming to ASTM C 881/C 881M, Type III. The type, grade, and class shall be appropriate for the application as specified in ASTM C 881/C 881M;
				3. Shrinkage-compensating or nonshrink Portland-cement grout conforming to ASTM C 1107; and
				4. Packaged, dry concrete repair materials conforming to ASTM C 928.
	3. FIELD QUALITY CONTROL
		1. Provide a certified testing agency to perform field testing in accordance with ACI 301 and NQA-1-2008/2009a. Testing laboratory certification may be obtained through AASHTO or another nationally recognized accreditation service as allowed by ASTM C 1077. National accreditations must be specific to the specific facility and/or mobile unit. The Contractor, or designee, must approve the test agency prior to performance of any work.
			1. Testing agencies for performing testing services on concrete materials shall meet the requirements of ASTM C 1077.
			2. Field testing of concrete shall be performed by an ACI Certified Concrete Field Testing Technician – Grade I.
			3. Laboratory testing of concrete shall be done by ACI-Certified concrete laboratory technician-Grade I or equivalent per ASTM C 1077
		2. Inform the Contractor 48 hours in advance of field testing to allow for witnessing of testing.
		3. The Testing Agency shall perform the following tests in accordance with this specification. Samples for Acceptance Testing are to be taken at the discharge from the transit mixer (and into a wheel barrow per ASTM C 172), except when using concrete pumps or conveyors to transport concrete to its final placement location. When pumps or conveyors are used, the samples for acceptance tests shall be taken at the end of the pipe or last conveyor belt. Pumping of concrete should follow ACI 304.2R and belt conveying ACI-304.4R. Note: The tests below shall always be performed whenever concrete test specimens are taken.
		4. Sample concrete in accordance with ASTM C 172.
		5. Record temperature of concrete in accordance with ASTM C 1064.
		6. Perform slump test in accordance with ASTM C 143.
		7. Perform air content test in accordance with ASTM C 231, pressure method.
		8. Perform density testing in accordance with ASTM C 138 when required by ASTM C94.
		9. Take 4 concrete strength test cylinders in accordance with ASTM C 31.
		10. The Testing Agency shall test the strength test cylinders in accordance with ASTM C 39 at 7 days and 28 days. Strength test cylinders must be picked-up at the job site between 8 and 48 hours after molding. See ASTM C94 and ASTM C31 for specific curing times.
		11. Coordinate the sequencing of concrete construction to schedule Contractor special inspection per the requirements of IBC Chapter 17. Provide 48-hour notification to schedule special inspectors.

END OF SECTION

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Do not delete the following reference information:
\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

THE FOLLOWING REFERENCE IS FOR LANL USE ONLY

This project specification is based on LANL Master Specification 03 3021 Rev. 0, dated January 9, 2015