SECTION 033000

CAST-IN-PLACE CONCRETE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. The drawings and general provisions of the Contract, including General and Supplementary Conditions, and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Features:

1. Cast-in-place structural concrete
2. Concrete mix design
3. Concrete placement procedures
4. Concrete finishing
5. Concrete curing
6. Repair of surface defects

B. Related Sections:

1. 013300 – Submittal Procedures
2. 014500 – Structural Testing, Inspection, and Quality Assurance
3. 031000 – Concrete Forming and Accessories
4. 032000 – Concrete Reinforcing
5. 033713 – Shotcrete
6. 033800 – Post-Tensioned Concrete

1.3 REFERENCE STANDARDS

A. The latest versions of the publications listed below form a part of this specification; comply with provisions of these publications except as otherwise shown or specified.

1.	ACI 117	Standard Specification for Tolerances for Concrete
2.	ACI 301	Standard Specifications for Structural Concrete, including other standards referred to in ACI 301, such as ASTM, etc.
3.	ACI 305.1	Standard Specification for Hot Weather Concreting
4.	ACI 306.1	Standard Specification for Cold Weather Concreting
5.	ACI 308.1	Standard Specification for Curing Concrete
6.	ASTM C1116	Standard Specification for Fiber-Reinforced Concrete

1.4 SUBMITTALS

A. General: Make submittals in accordance with Section 013300, "Submittal Procedures."

B. Concrete Mix Design Proportions: Submit concrete mixture proportions and characteristics. Submit the concrete mix design to the local building officials where required. Do not begin concrete production until concrete mix designs have been reviewed and approved. Mix designs shall include proportions of all ingredients, including admixtures added at time of batching or at job site. Include the following:

1. Specify the locations for each mix design.

2. Specify the method used to determine proposed concrete mix design. Include field test records or trial mix test data used to establish the average compressive strength of the concrete mixture.
3. For aggregates, submit types, pit or quarry locations, producers' names, gradings, specific gravities, certification, and evidence not more than 90 days old demonstrating compliance with this specification. Aggregate weights shall be based upon saturated surface dry conditions. Include concrete mix gradation of fine and coarse aggregates.
4. For admixtures, submit types, brand names, producers, manufacturer's technical data, and certification data.
5. Submit the cement type and certification, fly ash type and certification, water/cementitious materials ratio, and source of water supply.
6. Submit the slump.
7. Submit the air content of freshly mixed concrete.
8. Submit the concrete compressive strength at 7, 28, and 56 days. The 56-day strength is required only when specified in the Concrete Mix Specification Table in the General Notes.
9. Submit the chloride ion content of concrete.
10. For fibrous reinforcing, submit the type, fiber length, dosage rate, and dosage procedures.

C. Curing Methods: Submit written methods, procedures, and products for curing of all concrete.

D. Repair Methods: Submit the proposed methods of repair, along with repair material specification, manufacturer's data on the proposed patching material, and the proposed preparation and application procedure.

E. Construction Joints: Submit information for acceptance of proposed location and treatment of construction joints proposed but not indicated on the Construction Documents.

F. Qualification of Finishers: Submit qualifications of the finishing contractor and the finishers who will perform the Work.

G. Matching Sample Finish: When required by Contract Documents, submit sample finish.

H. Exposed-Aggregate Surface: When an exposed-aggregate surface is specified and a chemical retarder is proposed, submit specification and manufacturer's data for the retarder and the proposed method of use.

I. Records: Retain records of all concrete poured, including exact mix proportions, slumps, test strength, date, time, location of the placement, weather conditions at time of placement, and the source of concrete. Submit copy to Owner's Representative and Building Official.

1.5 QUALITY ASSURANCE

A. The Contractor is responsible for correcting Work that does not conform to the specified requirements, including strength, tolerances, and finishes. The Contractor shall submit the proposed solution for review and approval.

B. Unless otherwise noted, maintain the allowable tolerances in ACI 117.

C. Maintain records verifying materials used are of the specified and accepted types and sizes and are in conformance with the Contract Documents.

D. Special Inspection and Testing: Concrete work is subject to special inspection and testing as specified; notify the Testing Agency at least 48 hours before inspection is required.

E. Single Source Responsibility: Provide materials for concrete work made or produced from a single source of supply; no mixing of brands or types of cement will be allowed; no substitution of aggregate type or size from those approved will be permitted.

F. Concrete Contractor Qualifications: An experienced concrete contractor who has completed concrete Work similar in material, design, and extent to that indicated for this Project and whose work has resulted in construction with a record of successful in-service performance.

G. Concrete Producer Qualifications: A firm experienced in manufacturing ready-mixed concrete products complying with ASTM C94. Producer must be certified according to the National Ready Mixed Concrete Association's Certification of Ready Mixed Concrete Production Facilities.

H. Pre-Construction Conference: At least 30 days prior to start of concrete work, the Contractor shall hold a meeting to review the finish appearance requirements, reveal locations, joint spacings, concrete design mixes, requirements for submittals, construction procedures, schedules for testing, inspection, and certifications.

1. Notify attendees 10 days prior to the scheduled date of the meeting.
2. Required in attendance:
    a. Contractor and Subcontractors
    b. Testing Laboratory representative
    c. Concrete subcontractor
    d. Ready-mix producer
    e. Architect
    f. Engineer
    g. All subcontractors with work to be installed in or affected by concrete work
    h. Building official or appointed representative

1.6 DELIVERY, STORAGE, AND HANDLING

A. Cementitious Materials: Store cementitious materials in dry, weather-tight buildings, bins, or silos that will exclude contaminants.

B. Aggregates: Store and handle aggregate in a manner that will avoid segregation and prevent contamination with other materials or other sizes of aggregates. Store aggregates to drain freely. Do not use aggregates that contain frozen lumps.

C. Admixtures: Protect stored admixtures against contamination, evaporation, or damage. Protect liquid admixtures from freezing and from temperature changes that will adversely affect their characteristics. Store and handle products in a manner to retain original quality. Do not use products stored beyond the manufacturer's recommended shelf life.

D. Delivery of Materials: Deliver site applied materials, such as joint and curing materials, in original factory packaging and unopened containers and protect from damage and contamination.

E. Place concrete within the time limits specified. Concrete shall possess the specified characteristics in the freshly mixed state at the point of placing.

PART 2 - PRODUCTS

2.1 CONCRETE MATERIALS

A. Cementitious Materials

1. Portland Cement: Cements shall conform to either portland cement standard ASTM C150, Type I or Type II. ASTM C150 Type III cement may be used for cold weather construction. For architectural concrete, use one brand of cement throughout project, unless otherwise acceptable to the Architect.
2. Blended Hydraulic Cement: Cements shall conform to standards ASTM C595, Type IL, IS, IP, or IT.

3. Hydraulic Cement: Cements shall conform to standard ASTM C1157.
4. Alternative Cements: Alternative cements not conforming to the standards above will be subject to Structural Engineer's approval. Approval will be based on upon test data documenting the proposed concrete mixture made with the alternative cement meets the performance requirements for the application including structural, fire, and durability.
5. Fly Ash: Pozzolanic mineral admixture conforming to ASTM C618. Maximum loss on ignition to be 6 percent. Use fly ash from a single source for the whole project.
6. Slag: Ground-granulated blast-furnace slag conforming to ASTM C989.
7. Silica Fume: Silica fume conforming to ASTM C1240.
8. Use cementitious materials of same brand and type and from same manufacturing plant as cementitious materials used in the concrete represented by the submitted field test records or used in the trial mixtures.

B. Aggregate: Aggregates and aggregate grading requirements shall conform to ASTM C33 or C330. Aggregates shall be free from any substance that may be deleteriously reactive with the alkalis in the cement in an amount sufficient to cause excessive expansion of the concrete. Aggregates used in concrete shall be obtained from same sources and have the same size ranges as the aggregates used in the concrete represented by submitted historical data or used in trial mixtures.

C. Admixtures: The use of admixtures shall be the responsibility of the Contractor. When more than one admixture is used in the mix, furnish satisfactory evidence to the Architect that the admixtures to be used are compatible in combination with the cement and aggregates. Provide only one brand of each type of admixture. Admixtures shall be free of calcium chloride and thiocyanate (not more than 0.05% chloride ions). The following types of admixtures are approved:

1. Air-Entrainment Admixture: Master Builders "MB-AE, Micro-Air or MB-VR," W. R. Grace & Co. "Daravair or Darex Series," Sika "Sika Air" or approved equal conforming to ASTM C260.
2. Water-Reducing Admixture (Low Range): Master Builders "Pozzolith Series," W. R. Grace & Co. "WRDA, Mira, or ADVA Series," Sika "Plastocrete 161," or approved equal conforming to ASTM C494, Type A.
3. Water-Reducing Admixture (High Range): Master Builders "Rheobuild 1000 of Glenium Series," W. R. Grace & Co. "Daracem, Mira, or ADVA Series," Sika "Viscocrete 2100," or approved equal conforming to ASTM C494, Type F.
4. Retarding Admixture: Master Builders "Pozzolith Series or Delvo Series," W. R. Grace & Co. "Daratard Series or Recover," Sika "Plastiment ES" or approved equal conforming to ASTM C494, Type B.
5. Accelerating Admixture: Master Builders "Pozzolith NC 534 or Pozzutec 20+," W. R. Grace & Co. "Daraset Series, DCI, PolarSet, or Lubricon NCA", Sika "SikaSet NC", or approved equal conforming to ASTM C494, Type C.
6. Shrinkage Reducing Admixture: Master Builders "Tetraguard AS20," W.R. Grace & Co. "Eclipse Floor 200 (interior – non-air entrainable) or Eclipse 4500 (exterior – air entrainalble)", Sika "Sika Control 40", or approved equal conforming to ASTM C494, Type S.
7. Corrosion Inhibiting Admixture: Master Builders "Rheocrete CNI or Rheocrete 222+," W. R. Grace & Co. "DCI or DCI-S", Sika "Sika CNI", or approved equal conforming to ASTM C494, Type S. Calcium Nitrite based with solids content of 30 +/- 2%. Dosage rate varies between 2 and 4 gallons/cubic yards. Contact manufacturer's representative for corrosion-protection guidance based on chloride exposure level.

D. Water: Water shall be in conformance with ASTM C1602.

2.2 RELATED MATERIALS

A. Dissipating Resin Curing Materials: Liquid type membrane-forming curing compound complying with ASTM C309, Type I. Curing compound must be of a type that does not inhibit subsequent moist curing operations. The film shall chemically break down in a 6- to 8-week period and shall not affect adhesion of coverings or membranes. Acceptable products are Dayton Superior "Burke Aqua Resin Cure or Day-Chem Rez Cure (J-11-W)," Euclid Chemical Co. "Kurez DR," or approved equal.

B. Cure and Seal Combination Materials (Exposed Interior Concrete Slabs, including Garage Slabs): Use curing and sealing compounds that conform to ASTM C309 (Types 1 and 1D, Class B) or ASTM C1315. Acceptable products are Master Builders "Acryseal or Kure-N-Seal," Euclid Chemical Co. "Rez-Seal," or approved equal. Cure and seal material for use in parking garages must resist de-icing chemicals.

C. Moisture Retaining Cover: Use waterproof sheet materials that conform to ASTM C171.

D. High Density Insulation Fillers: Extruded polystyrene foam insulation complying with ASTM D6817 as noted in the Construction Documents. Where no type is indicated use ASTM D6817 EPS22.

E. Commercial Bonding Grout and Repair Materials: Use products in accordance with manufacturer's recommendations. Products include, but are not limited to, the following:

1. Portland-cement mortar modified with a latex acrylic, non-re-emulsifiable bonding agent conforming to ASTM C1059 Type II. Acceptable products include Euclid Chemical Co. "Flex-Con," Dayton Superior "Day-Chem Ad Bond (J-40)," or approved equal.
2. Epoxy mortars and epoxy compounds that are moisture-insensitive during application and after curing and that embody an epoxy binder conforming to ASTM C881. The type, grade, and class shall be appropriate for the application as specified in ASTM C881.
3. Shrinkage-compensating or nonshrink Portland cement grout conforming to ASTM C1107. Acceptable products include Master Builders "Masterflow 713 Grout," Dayton Superior "Sure-Grip High Performance Grout," Burke "Non-Ferrous Non-Shrink Grout," or approved equal.
4. Packaged, dry concrete repair materials conforming to ASTM C928. Acceptable products include Master Builders "Emaco T415," Dayton Superior "HD-50," Burke "Fast Patch 928," or approved equal.

2.3 PROPORTIONING AND DESIGN REQUIREMENTS OF CONCRETE MIXES

A. Prepare design mixes for each type and strength of concrete by Field Experience Method or, if not available, by Laboratory Trial Batch Methods as specified in ACI 301. Mix proportions shall produce consistent and workable concrete that can be worked readily into forms and around reinforcement without segregation or excessive bleeding.

1. Field Experience Method: If field test data is available, in accordance with ACI 301, submit for acceptance the mixture proportions along with the field test data.
2. Trial Batch Method: Use an independent, qualified Testing Facility for preparing and reporting proposed mix designs. All expenses connected with such testing and submittals shall be borne by the Contractor.

B. Concrete Mixes: Provide concrete mixes conforming to the requirements as indicated in the Structural Drawing General Notes.

1. Strength Requirements: Compressive strength requirements are indicated on drawings and are based on cylinder tests at indicated age. Concrete made with high-early strength

cement shall have a 7-day strength equal to the specified 28-day strength for concrete made with Type III Portland cement.

2. Cement Content for Slabs: Not less than those indicated in ACI 301.
3. Water/Cementitious Material Ratio: Not to exceed limits indicated on the Structural Drawings.
4. Air Entrainment: Use air-entraining admixture in exterior exposed concrete as indicated on the Structural Drawings.
5. Slump: The Contractor shall determine slump. Each concrete mix submitted shall have the slump specified. Slump tolerances shall meet the requirements of ACI 117.
6. Admixtures: Concrete may contain admixtures, such as water reducers, superplasticizers, or set retarding agents to provide special properties to the concrete. When admixtures are specified or required for workability for particular parts of the Work, use the types specified.
7. Chloride Ion: Maximum water soluble chloride ion concentrations in hardened concrete at ages 28 to 42 days contributed from the ingredients, including water, aggregates, cementitious materials and admixtures, shall not exceed a maximum, by weight of cement, of 0.06% for prestressed concrete and 0.30% for other concrete as tested in accordance with ASTM C1218.
8. Alternative Concrete Technologies: Alternative processes for mixing of concrete, such as carbon dioxide mineralization, are acceptable provided any such process is included in the laboratory trial batch and corresponding concrete mix submittal, subject to the engineer's approval.
9. Lightweight Concrete Density: Where lightweight concrete is specified, proportion lightweight concrete mixtures to meet equilibrium density specified in Contract Documents. Unless noted otherwise, calculate the approximate equilibrium density of mixture from measured or calculated oven-dry density in accordance with ASTM C567. Correlate equilibrium density with fresh density of concrete. Fresh density will be used as basis for acceptance during construction.

C. Adjustment to Concrete Mixes: Mix design adjustments may be requested by the Contractor when characteristics of materials, job conditions, weather, test results, or other circumstances warrant, at no additional cost to the Owner. New field data, data from new trial mixtures, or evidence that indicates that the change will not adversely affect the relevant properties of the concrete shall be submitted for acceptance before use.

PART 3 - EXECUTION

3.1 PREPARATION

A. Do not place concrete until the Architect approves all required submittals.

B. Remove snow, ice, frost, water, and other foreign materials from form surfaces, reinforcement, and embedded items against which concrete will be placed.

C. Place concrete on properly prepared and unfrozen sub-grade or forms and only in dewatered excavations and forms.

D. Do not allow mud or foreign materials into the concrete during placement operations.

E. When the ambient temperature necessitates the use of cold or hot weather concreting, make provisions in advance of concrete placement.

F. Do not begin placing concrete when the sun, heat, wind, or limitations of facilities furnished by the Contractor prevent proper consolidation, finishing and curing.

G. Do not begin placing concrete while rain, sleet, or snow is falling unless adequate protection is provided. Do not allow rainwater to increase mixing water or to damage the surface of the concrete.

3.2 JOINTS

A. Construction Joints: Locate construction joints as indicated on the structural drawings or as approved by the Architect. Remove laitance and thoroughly clean and dampen construction joints prior to placement of fresh concrete.

B. Bonded Construction Joints: Coat concrete joined with new concrete, including topping, with a concrete bonding compound. Mix and apply in strict accordance with manufacturer's recommendations for the conditions of the application. Concrete surfaces to which other concrete is to be bonded shall be roughened in an approved manner that will expose sound aggregate uniformly without damaging the concrete; remove all laitance and loose particles.

C. Control Joints in Slabs-on-Ground: Construct control joints in slabs-on-ground to form panels of patterns as approved. Use inserts 1/4 inch wide by depth indicated on the drawings. Where saw-cut joints are required or permitted, start cutting as soon as concrete has hardened sufficiently to prevent dislodgment of aggregates. Saw a continuous slot to the depth indicated on the drawings. Complete sawing within the timeframe indicated on the drawings. The aspect ratio of the slab panels should be a maximum of 1.5:1. "L" and "T" shaped panels should be avoided. If an alternative method, timing, or depth is proposed for saw cutting, submit detailed procedure plans for review and acceptance.

3.3 INSTALLATION OF EMBEDDED ITEMS

A. General: Set and build into work anchorage devices and other embedded items required for other work that is attached to, or supported by, cast-in-place concrete. Use setting drawings, diagrams, instructions, and directions provided by suppliers of items to be attached thereto.

1. Embedded items include, but are not limited to, expansion joints, joint fillers, waterstops, anchor bolts, embedded plates, dovetail anchor slots, etc.
2. Items shall be free of oil, loose scale, rust, etc.
3. Fill voids in sleeves, inserts, and anchor slots temporarily with readily removable material to prevent the entry of concrete into the voids.
4. Do not embed aluminum in concrete, except where the aluminum is protected from direct contact from the concrete.

3.4 INSTALLATION OF HIGH DENSITY INSULATION FILLER

A. Insulation Fillers: Lay high density insulation in areas as indicated on drawings. Use boards of maximum thickness to achieve full insulation depth as indicated. If required, apply adhesive to layers of insulation to prevent movement during concrete placement. After boards have been installed, protect until concrete topping is prepared and placed.

3.5 CONCRETE DELIVERY

A. Ready-Mix Concrete: Comply with requirements of ASTM C94 and as herein specified.

1. Elapsed time from start of batching at plant to completed discharge at job site shall not exceed 90 minutes or more than 300 revolutions, whichever comes first after introducing mixing water.
2. The concrete temperature shall be monitored in the truck. A rise in temperature of 5°F within 10 minutes or less indicates concrete setting has started before discharge and the load shall be rejected.
3. Ready-Mix Concrete: Provide certificate signed by authorized official of supplier with each load of concrete, stating the following:
   a. Time truck left plant
   b. Mix of concrete
   c. Amount of water and cement in mix

d. Amount and type of admixtures
e. Time truck is unloaded at site
f. Additional water amount allowed at the project site

4. A truck without batch tickets will be rejected.

B. Control of Mixing Water: Water may be added once to increase the slump of the concrete within the first 15 minutes after the truck arrives at the job-site, provided the following requirements are adhered to:

1. The specified slump and maximum allowable water/cement ratio is not exceeded.
2. The Independent Testing Agency is present to monitor the amount of water added to compare with the amount of water added at the plant. Testing Agency shall keep written record of the amount of water added at the job-site to each truckload delivered.
3. The drum shall be turned an additional 30 revolutions, or more if necessary, until the added water is uniformly mixed into the concrete.
4. Water shall not be added to the batch after the taking of test cylinders, unless new test cylinders are taken at the expense of the Contractor.
5. Do not add water to concrete after adding high-range water-reducing admixtures to mix unless approved by both the ready-mix producer and the admixture producer.

C. Admixtures: Add admixtures within an accuracy of 3%. Where two or more admixtures are used in the same batch, they shall be added separately and must be compatible. Approved admixtures must be added at the appropriate time in strict compliance with manufacturer's directions. Concrete that shows evidence of total collapse or segregation caused by the use of admixtures shall be removed from the site.

D. Lightweight Concrete Density: Acceptance of lightweight concrete will be based on fresh density measured in accordance with ASTM C138. Required fresh density is based on specified equilibrium density and correlated with fresh density. Unless approved otherwise, do not use concrete for which fresh density varies by more than 4 pounds per cubic foot from the required fresh density.

3.6 CONCRETE PLACEMENT

A. Pre-Placement Inspection: Before concrete placement operation begins, perform the following procedures:

1. Inspect and complete formwork installation and all reinforcing, and embed items. Notify other crafts to permit installation of their work.
2. Ensure that the reinforcing will be maintained in the proper position during concrete placement operations.
3. Moisten wood forms immediately before placing concrete where form coatings are not used.
4. At topping slabs, thoroughly saturate base slab just prior to placing topping, but do not leave pools of water.
5. Verify all dimensions and elevations.

B. Conveying: Methods of conveying concrete is the responsibility of the Contractor. Convey concrete from mixer to the place of final deposit rapidly by methods that prevent segregation or loss of ingredients and that will ensure the required quality of concrete. Do not use aluminum pipes or chutes. Use acceptable conveying equipment of a size and design that will prevent cold joints from occurring. Clean conveying equipment before each placement.

1. Provide runways or other means for wheeled equipment to convey concrete to deposit points. Do not run wheeled equipment used to deposit concrete over reinforcement; do not support runways on reinforcement.

2. Belt Conveyors: Use belt conveyors that are horizontal or at a slope that will not cause excessive segregation or loss of ingredients. Protect concrete to minimize drying and effects of temperature rise. Use an acceptable discharge baffle or hopper at the discharge end to prevent segregation. Do not allow mortar to adhere to the return length of the belt.
3. Chutes: Use metal or metal-lined chutes having rounded bottoms and a slope between 1:2 and 1:3 (vertical:horizontal). Chutes more than 20 feet long and those not meeting slope requirements may be used, provided they discharge into a hopper prior to distributing into the forms.
4. Pumping or Pneumatic Conveying: Use pumping conveying equipment that permits placement rates that avoid cold joints and prevent segregation in discharge of pumped concrete. In addition:
    a. Pipeline shall be steel pipe or heavy-duty flexible hose.
    b. Inside diameter of the pipe shall be at least five times the maximum size of the coarse aggregate.
    c. Distance to be pumped shall not exceed the limits recommended by the pump manufacturer.
    d. Provide continuous supply of concrete to the pump.
    e. When pumping is completed, the concrete remaining in the pipeline shall be ejected without contaminating the concrete in place.
5. Cleaning: Do not discharge rinse water into forms or areas to receive concrete.

C. Depositing: Deposit concrete continuously in one layer, or in multiple layers if the fresh concrete is deposited on in-place concrete that is still plastic. Do not deposit fresh concrete on concrete that has hardened sufficiently to cause the formation of seams or planes of weakness. If a section cannot be placed continuously, provide construction joint as specified. Deposit concrete as near to its final location as practicable to avoid segregation. In addition:

1. Do not subject concrete to procedures that will cause segregation.
2. Do not use concrete that has surface-dried or partially hardened or that contains foreign material.
3. Place concrete for beams, girders, brackets, column capitals, haunches, and drop panels at the same time as concrete for slabs.

D. Consolidating: Consolidate concrete by vibration. Thoroughly work concrete around reinforcement and embedded items and into corners of forms, eliminating air and stone pockets that may cause honeycombing, pitting, or planes of weakness.

1. Workers shall be experienced in use of the vibrators.
2. Vibrators shall have a frequency of not less than 8,000 vibrations per minute, and the head diameter and amplitude shall be appropriate for the concrete mix being placed. A spare vibrator shall be kept at the job site during all concrete placing operations.
3. Do not use vibrators to transport concrete inside forms. Insert and withdraw vibrators vertically at uniform spacing over the area of placement; distance between insertions shall be approximately 1-1/2 times the radius of action of the vibrator so that the area being vibrated will overlap the adjacent just vibrated area by a few inches. Do not place vibrators within 2-1/2 inches of form face.
4. Place vibrators to rapidly penetrate placed layer and at least 6 inches into preceding layer. Do not insert vibrators into lower layers of concrete that have begun to set; if there is a delay of more than 15 minutes, vibrate previous lift prior to placing the new concrete. At each insertion, limit duration of vibration to time necessary to consolidate concrete and complete embedment of reinforcement and other embedded items without causing segregation of mix. Withdraw vibrators slowly.
5. Consolidation of slabs shall be obtained with vibrating screeds, rolling pipe screeds, or internal vibrators.

E. Re-tamping of concrete that has taken its initial set is not allowed.

F. Cold Weather Placing: Protect concrete work from physical damage or reduced strength that could be caused by frost, freezing actions, or low temperatures, in compliance with ACI 306.1 and as specified herein.

1. When air temperature has fallen to or is expected to fall below 40°F, uniformly heat water and aggregates before mixing to obtain a concrete mixture temperature of not less than 50°F and not more than 80°F at point of placement.
2. Do not use frozen materials or materials containing ice or snow. Do not place concrete on frozen subgrade or on subgrade containing frozen materials.
3. Do not use calcium chloride, salt, or other materials containing antifreeze agents or chemical accelerators.

G. Hot Weather Placing: When hot weather conditions exist that would seriously impair quality and strength of concrete, place concrete in compliance with ACI 305.1 and as specified herein. Loss of slump, flash set, or cold joints due to temperature of concrete as placed are not acceptable.

1. Cool ingredients before mixing to maintain concrete temperature at time of placement below 95°F. Mixing water may be chilled, or chopped ice may be used to control temperature provided water equivalent of ice is calculated to total amount of mixing.
2. When temperature of steel reinforcement, embedments, or forms is greater than 120°F, fog steel reinforcement, embedments, and forms with water immediately before placing concrete. Remove standing water before placing concrete.
3. Keep subgrade moisture uniform without standing water, soft spots, or dry areas.
4. Use water-reducing retarding admixture when required by high temperatures, low humidity, or other adverse placing conditions, if approved by the Architect.

3.7 FINISHES FOR FORMED SURFACES

A. General: After removal of forms, give each formed surface one or more of the finishes described below. When Contract Documents do not specify a finish, finish surfaces as required by Unspecified Finishes.

B. When the finish is required by the Contract Documents to match a sample panel furnished by the Contractor, reproduce the sample finish on an area at least 100 square feet in a location designated by the Architect. Obtain acceptance before proceeding with that finish in the specified locations.

C. As-Cast Finishes: Coordinate finishes of all "as-cast" concrete finishes with construction of formwork. Produce as-cast form finishes in accordance with the following requirements:

1. Rough-Form Finish:
   a. Patch voids larger than 3/4 in. wide or 1/2 in. deep.
   b. Remove projections larger than 1/2 in.
   c. Tie holes need not be patched.
   d. Surface tolerance Class C as specified in ACI 117.
2. Smooth-Form Finish:
   a. Patch voids larger than 3/4 in. wide or 1/2 in. deep.
   b. Remove projections larger than 1/4 in.
   c. Patch tie holes.
   d. Surface tolerance Class B as specified in ACI 117.
3. Architectural Finish: Patch tie holes and defects, and remove fins. Produce architectural finishes as specified in the Contract Documents.

D. Rubbed Finishes: Remove forms as early as permitted, and produce one of the following finishes on concrete specified to have a smooth form finish:

1. Smooth-Rubbed Finish: Patch tie holes and defects, and remove fins. Produce finish on newly hardened concrete no later than the day following formwork removal. Wet the surface and rub it with carborundum brick or other abrasive until uniform color and texture are produced. Use no cement grout other than the cement paste drawn from the concrete itself by the rubbing process.
2. Grout-Cleaned Finish: Patch tie holes and defects, and remove fins. Begin cleaning operations after contiguous surfaces to be cleaned are completed and accessible. Do not clean surfaces as work progresses. Wet the surface and apply grout consisting of 1 part Portland cement and 1-1/2 parts fine sand with enough water to produce the consistency of thick paint. Add white cement as needed to match color of surrounding concrete. Scrub grout into voids, and remove excess grout. When grout whitens, rub the surface. Keep the surface damp for 36 hours afterward.
3. Cork-Floated Finish: Patch tie holes and defects, and remove fins. Wet the surface and apply stiff grout of 1 part Portland cement and 1 part fine sand, filling voids. Add white cement as needed to match color of surrounding concrete. Use enough water to produce a stiff consistency. Compress grout into voids by grinding the surface with a slow-speed grinder. Produce the final finish with cork float, using a swirling motion.

E. Sandblast Finish: After removal of forms and while concrete is still "green," apply a light abrasive blast finish to exposed-to-view surfaces to match approved sample. Perform abrasive blasting in a continuous operation, utilizing same work crew to maintain continuity of finish on each surface. Use wet sandblasting operations. Use same type and grading of abrasives as that used on approved sample. Continually wash off abraded mortar from sandblasted areas to prevent staining.

F. Unspecified Finishes: When a specific finish is not specified in Contract Documents for a concrete surface, apply the following finishes:

1. Rough-form finish on concrete surfaces not exposed to public view.
2. Smooth-form finish on concrete surfaces exposed to public view.

G. Related Unformed Surfaces: At tops of walls, horizontal offsets, and similar unformed surfaces adjacent to formed surfaces, strike off smooth and finish with a texture matching adjacent formed surfaces. Continue final surface treatment of formed surfaces uniformly across adjacent surfaces, unless otherwise indicated.

3.8 FINISHES FOR UNFORMED SURFACES

A. General: Finish slab surfaces in accordance with one of the finishes noted below, as designated in the Contract Documents. Finish all joints and edges with proper tools as approved.

B. Placement: Place concrete at a rate that allows spreading, straightedging, and darbying or bull floating before bleed water appears. Screed all slabs, topping fills to true levels and slopes. Work surfaces as required to produce specified finish. Do no finishing in areas where water has accumulated; drain and re-screed. In no case use a sprinkling of cement and sand to absorb moisture.

C. Tolerances: Measure floor slabs for suspended floors and slabs-on-grade to verify compliance with the tolerance requirements of ASTM E 1155 and ACI 117. Measure floor finish tolerances within 72 hours after slab finishing and before removal of supporting formwork or shoring.

D. Scratch Finish: Place, consolidate, strike off, and level concrete, eliminating high spots and low spots. Roughen the surface with stiff brushes or rakes before the final set. Produce a finish that will meet Moderately flat (Ff flatness = 25) requirements of ACI 117.

E. Float Finish: Place, consolidate, strike off, and level concrete, eliminating high spots and low spots. Do not work concrete further until it is ready for floating. Begin floating with a hand float,

a bladed power float equipped with float shoes, or a powered disk float when the bleed water sheen has disappeared and the surface has stiffened sufficiently to permit the operation. Produce a finish that will meet Moderately flat (Ff flatness = 25) requirements of ACI 117, then refloat the slab immediately to a uniform texture.

F. Light Steel Troweled Finish: Float concrete surface, then power trowel the surface. Hand trowel the surface smooth and free of trowel marks. Continue hand troweling until all "shine" has disappeared from surface; no final troweling is required. Tolerance for concrete floors shall be Moderately flat (Ff flatness = 25) in accordance with ACI 117.

G. Full Steel Trowel Finish: Float concrete surface, then power trowel the surface. Hand trowel the surface smooth and free of trowel marks. Continue hand troweling until a ringing sound is produced as the floor is troweled. Finished surface shall be free of trowel marks, uniform in texture and appearance. Tolerance for concrete floors shall be Moderately flat (Ff flatness = 25) in accordance with ACI 117.

H. Broom or Belt Finish: Immediately after concrete has received a floated finish, give the concrete surface a coarse transverse scored texture by drawing a broom or burlap belt across the surface. Degree of texture shall be as approved by the Architect. Tolerance for concrete floors shall be Moderately flat (Ff flatness = 25) in accordance with ACI 117.

I. Raked Finish: Immediately after concrete has received a floated finish, draw closely spaced rake across surface with ribs perpendicular to traffic flow. Notify Architect at time of finishing so that they may be present to approve the final degree of texture required. Tolerance for concrete floors shall be Moderately flat (Ff flatness = 25) tolerance in accordance with ACI 117.

J. Dry-Shake Finish: Blend metallic or mineral aggregate specified in Contract Documents with Portland cement in the proportions recommended by the aggregate manufacturer, or use bagged, premixed material specified in Contract Documents as recommended by the aggregate manufacturer.

1. Float-finish the concrete surface.
2. Apply approximately 2/3 of the blended material required for coverage to the surface by a method that ensures even coverage without segregation. Float-finish the surface after application of the first dry-shake.
3. Apply the remaining dry-shake material at right angles to the first application and in locations necessary to provide the specified minimum thickness. Begin final floating and finishing immediately after application of the dry-shake.
4. After selected material is embedded by the two floatings, complete operation with a broomed, floated, or troweled finish, as specified in the Contract Documents.

K. Exposed-Aggregate Finish: Immediately after surface of the concrete has been leveled to meet the Moderately flat (Ff flatness = 25) tolerance requirements of ACI 117 and the bleed water sheen has disappeared, spread aggregate of the color and size specified in Contract Documents uniformly over the surface to provide complete coverage to a depth of one stone.

1. Tamp the aggregate lightly to embed aggregate in the surface. Float the surface until the embedded stone is fully coated with mortar and the surface has been finished to meet the Moderately flat (Ff flatness = 25) tolerance requirements of ACI 117.
2. After the matrix has hardened sufficiently to prevent dislodgment of the aggregate, apply water carefully and brush the surface with a fine-bristled brush to expose the aggregate without dislodging it.
3. An acceptable chemical retarder sprayed on freshly floated concrete surface may be used to extend the working time for the exposure of aggregate.

L. Non-specified Finish: When the type of finish is not specified in Contract Documents, use one of the following appropriate finishes and accompanying tolerances.

1. Scratched Finish: For surfaces intended to receive bonded cementitious mixtures.
2. Floated Finish: For walks, drives, steps, ramps, and for surfaces intended to receive waterproofing, roofing, insulation, or sand-bed terrazzo.
3. Full Steel Troweled Finish: For floors intended as walking surfaces, floors in manufacturing, storage, and warehousing areas, or for reception of floor coverings.

3.9 CONCRETE CURING AND PROTECTION

A. General: Cure concrete in accordance with the Curing Methods noted below for a minimum of 7 days after placement. Cure high-early strength concrete for a minimum of 3 days after placement. Alternatively, moisture retention measures may be terminated when any of the following criteria are met:

1. Tests made on at least two cylinders kept adjacent to the structure and cured by the same methods as the structure indicate 70% of f'c, as determined in accordance with ASTM C39, has been attained.
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.
3. Strength of concrete reaches f'c as determined by accepted nondestructive test methods.

B. Additional Curing Periods: When the 7-day compression test cylinders, representative of parts of a structure already placed, indicate that the 28-day strengths may be less than 85 percent of the design strengths, give those parts of the structure additional curing.

C. Protection: Immediately after placement, protect concrete from premature drying, excessively hot or cold temperatures, and mechanical injury.

1. Protect concrete during the curing period such that the concrete temperature does not fall below requirements of ACI 306.1. The concrete shall be maintained with minimal moisture loss at a relatively constant temperature for the period necessary for hydration of the cement and to ensure the necessary strength development for structural safety.
2. Maintain protection in such a manner that the maximum decrease in temperature measured at the surface of the concrete in a 24-hour period shall not exceed the following:
   a. 50°F for sections less than 12 inches in the least dimension.
   b. 40°F for sections from 12 to 36 inches in the least dimension.
   c. 30°F for sections 36 to 72 inches in the least dimension.
   d. 20°F for sections greater than 72 inches in the least dimension.
3. Measure and record concrete temperature using a method acceptable to the Architect/Engineer. When the surface temperature of the concrete is within 20°F of the ambient temperature, protection measures may be removed.

D. Curing Unformed Concrete Surfaces: Apply one of the Curing Methods after completion of placement and finishing of concrete surfaces not in contact with forms.

E. Curing Formed Concrete Surfaces: Keep absorbent wood forms wet until they are removed. After formwork removal, cure concrete by one the Curing Methods.

F. Curing Methods: After placing and finishing, use one or more of the following methods to preserve moisture in concrete. Start initial curing as soon as free water has disappeared from concrete surface after placing and finishing, or as soon as marring of the concrete will not occur. When one of the curing procedures is used initially, the curing procedure may be replaced by one of the other procedures when concrete is 1 day old, provided the concrete is not permitted to become surface-dry at any time. Avoid rapid drying at end of final curing period.

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.
    a. Apply the compound in accordance with manufacturer's recommendation as soon as water sheen has disappeared from the concrete surface and after finishing operations.
    b. For rough surfaces, apply curing compound in two applications at right angles to each other.
    c. Do not use curing compound on any 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.
    d. Curing compound may be used on concrete that is to receive resilient flooring, carpet, sand cushion terrazzo, and wood flooring, unless otherwise required by finish treatment manufacturer. Provide written certification from the finish floor treatment manufacturer as previously specified.
    e. The Contractor shall be responsible for removing any traces of the dissipating curing compound that remains on the substrate prior to applying subsequent floor finish. This shall include, but is not limited to, removing the curing compound using power scrubbers and industrial strength detergents and using fresh water to remove the detergents. Comply with any additional instructions and recommendations of the manufacturer whose products are to be applied directly over concrete slab.
6. Application of other accepted moisture-retaining method.

3.10 CONCRETE SURFACE REPAIRS

A. General: All surface defects shall be reported to the Architect. Remove and replace concrete having defective surfaces if defects cannot be repaired to the satisfaction of the Architect.

B. Repair of Formed Surfaces: Surface defects include color and texture irregularities, cracks, spalls, air bubbles, honeycomb, rock pockets, fins, stains, and other discolorations that cannot be removed by cleaning.

1. Repair concealed formed surfaces that contain defects that affect the durability of concrete.
2. Repair tie holes and surface defects immediately after formwork removal. Where the concrete surface will be textured by sandblasting or bush-hammering, repair surface defects before texturing.

C. Repair of Unformed Surfaces: Surface defects include crazing, cracks in excess of 0.01 inch wide or which penetrate to reinforcement or completely through non-reinforced sections regardless of width, spalling, pop-outs, honeycomb, rock pockets, and other objectionable conditions.

1. Repair finished unformed surfaces that contain defects that affect durability of concrete.
2. Test unformed surfaces, such as monolithic slabs, for smoothness and verify surface plane to tolerances specified for each surface and finish. Correct low and high areas as specified. Test unformed surfaces sloped to drain for trueness of slope.
3. Correct high areas in unformed surfaces by grinding, after concrete has cured at least 14 days. Depth or removal shall not exceed 1/4 inch without scanning the affected area to verify required concrete cover will be maintained over reinforcing, post-tensioning tendons, or other embedment.
4. Correct low areas in unformed surfaces during or immediately after completion of surface finishing operations by cutting out low areas and replacing with fresh concrete. Finish repaired areas to blend into adjacent concrete. Proprietary patching compounds may be used when acceptable to the Architect.

D. Repair of Tie Holes: Plug tie holes except where stainless steel ties, non-corroding ties, or acceptably coated ties are used. When Portland cement patching mortar 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.

E. Repair of Surface Defects: Submit Method Statement of Repair that includes proposed repair product, surface preparation procedures, inspection schedule and application procedures prior to the commencement of work.

1. Surface Preparation: Unless otherwise directed by the repair product's manufacturer:
   a. Outline honeycombed or otherwise defective concrete with a 1/2- to 3/4-inch-deep saw cut and remove such concrete down to sound concrete.
   b. When chipping is necessary, leave chipped edges perpendicular to the surface or slightly undercut. Do not feather edges.
   c. Dampen the area to be patched, plus 6 inches around the patch area perimeter.
   d. Prepare bonding grout and thoroughly brush grout into the surface.
   e. When the bond coat begins to lose water sheen, apply patching mortar and thoroughly consolidate mortar into place. Strike off mortar, leaving the patch slightly higher than the surrounding surface to permit initial shrinkage.
   f. Leave the patch undisturbed for 1 hour before finishing. Keep the patch damp for 7 days.
2. Partially Exposed Reinforcement: The surface of partially exposed reinforcement where exposed less than and equal to 3/8-inch shall be cleaned of detritus material. Where reinforcement is exposed more than 3/8 inch, concrete shall be removed around the entire circumference of the reinforcement for a minimum of 1/4 inch plus the maximum aggregate size and cleaned of detritus material.

F. Removal of Stains: Remove stains, rust, efflorescence, and surface deposits considered objectionable by the Architect by acceptable methods.

G. Crack Repair: The Contractor shall carry an allowance for concrete crack repair. Submit crack map and repair procedures for review and approval prior to commencing work.

1. Flexible Repair: Prepare, treat rout and fill cracks according to ASTM C1127 and the manufacturer's recommendations. Prior to coating surfaces, remove debris and dust according to ASTM D4258. Comply with the recommendations in ASTM C1193 for joint sealant installations.
2. Structural Repair: Cracks shall be repaired by epoxy injection conforming to ASTM C881.
3. Repair full length of cracks if any part of the crack exceeds the widths specified in this Article.
4. Actual crack repair required shall be based on crack width as measured a minimum of 28 days after crack appears. Repair cracks as follows:
   a. Permanently Exposed Walls: Repair all cracks greater than 0.035 inch in width.
   b. Exterior Elevated Slabs: All cracks greater than 0.035 inch in width.
   c. Slab on Grade: Repair all cracks greater than 0.0625 inch in width.
   d. Interior Elevated Slabs: Repair all cracks greater than 0.0625 inch in width.

H. Site-Mixed Repair Materials:

1. Bonding Grout: Mix approximately 1 part cement and 1 part fine sand with water to the consistency of thick cream.
2. Repair Mortar: Mix repair mortar using the same materials as concrete to be patched with no coarse aggregate. Do not use more than 1 part cement to 2-1/2 parts sand by damp loose volume.
   a. For repairs in exposed concrete, make a trial batch and check color compatibility of repair material with surrounding concrete. Blend white Portland cement and standard Portland cement so that, when dry, patching mortar will match color surrounding.

b. Use repair mortar at a stiff consistency with no more mixing water than is necessary for handling and placing. Mix repair mortar and manipulate the mortar frequently with a trowel without adding water.

I. Commercial Repair Products: Acceptable commercial repair products other than site-mixed repair materials may be used for repair, as specified in Part 2. Use repair products in accordance with manufacturer's recommendations.

3.11 MISCELLANEOUS CONCRETE ITEMS

A. Curbs: Provide monolithic finish to interior curbs by stripping forms while concrete is still green and steel-troweling surfaces to a hard, dense finish with corners, intersections, and terminations lightly rounded.

B. Equipment Bases and Foundations: Form bases for the mounting of equipment shown on drawings. Coordinate sizes and requirements for bases with trade requiring same; make bases a minimum of 4 inches high, unless otherwise noted on drawings, and finish to match adjacent floor finish. Set anchor bolts for machines and equipment to correct elevations, complying with certified diagrams or templates of manufacturer furnishing machines and equipment.

C. Steel Pan Stairs: Provide concrete fill for steel pan stair treads and landings and associated items. Screed, tamp, and finish concrete surfaces with light broom finish.

END OF SECTION