

TECHNICAL SPECIFICATIONS
DIVISION 3
CONCRETE

**CONCRETE
FORMWORK**

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Design, construction, erection and removal of structural concrete formwork.

1.02 UNIT PRICES

- A. No separate payment will be made for concrete formwork under this Section. Include payment in unit price for structural concrete.

1.03 SUBMITTALS

- A. Conform to all provisions and sections of these specifications.
- B. Shop Drawings: Show location, member size and loading of shoring. When reshoring is permitted, submit plans showing locations and member size of reshoring.
- C. Product Data and Samples:
1. Corrugated Fiberboard Carton Forms: Submit certification of compliance with design criteria, description of forms, and one-foot-long sample.
 2. Form-coating Materials: Submit trade or brand names of manufacturers and complete description of products.
 3. Form ties and related accessories, including taper tie plugs, if taper ties are used.
 4. Form gaskets.
- D. Detailed Layout for Slip-forming: Submit detailed layout of proposed slipforming, including description of equipment, rate of progress, and other data to show suitability of method. Show provisions for ensuring attainment of required concrete surface finish.

PART 2 PRODUCTS

2.01 MATERIAL

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- A. Smooth Forms: New plywood, metal, plastic, tempered concrete-form hardboard, dressed lumber faced with plywood or fiberboard lining, or metal-framed plywood-faced panel material, to provide continuous, straight, smooth surfaces. Form material shall be free of raised grain, torn surfaces, worn edges, patches, dents or other defects. Furnish material in largest practical sizes to minimize number of joints and, when indicated on Drawings, conform to joint system indicated. Form material shall have sufficient strength and thickness to withstand pressure of newly placed concrete without bow or deflection.
- B. Rough Forms: Plywood, metal, dressed or undressed lumber free of knots, splits or other defects or other material acceptable to the Owner's Representative of sufficient strength and thickness to withstand pressure of newly placed concrete without bow or deflection.
- C. Plywood: Conform to PS 1, Class 1.
- D. Lumber: Conform to PS 20.
- E. Edge Forms and Intermediate Screed Strips: Type and strength compatible with the screed equipment and methods used.
- F. Plastic Forms: One-piece forms for domes, beams and pan joists. Single lengths for columns not exceeding height of 7'-6". For columns over 7'-6", use 7'-6" sections and filler sections as needed. To facilitate removal of pan joist forms, taper sides 1 inch per foot.
- G. Metal Pan Joist Forms: Removable type; fabricated of minimum 14-gage steel; one piece between end closures. Adjustable forms not allowed. Taper sides 1 inch per foot to facilitate removal.
- H. Earth Cuts for Forms:
1. Use earth cuts for forming unexposed sides of grade beams cast monolithically with slabs on grade.
 2. Where sides of excavations are stable enough to prevent caving or sloughing, following surfaces may be cast against neat-cut excavations:
 - a. Sides of footings.
 - b. Inside face of perimeter grade beams not monolithic with slab on grade. When inside face is cast against earth, increase beam width indicated on Drawings by 1 inch.

- c. Both faces of interior grade beams not monolithic with slab on grade. When grade beam is cast against earth, increase beam width indicated on Drawings by 2 inches.
- I. Corrugated Fiberboard Carton Forms:
- 1. Corrugated fiberboard carton forms, when called for, are intended to form a void space beneath pile-supported and pier-supported slabs and other structural elements as shown.
 - 2. Provide products of a reputable manufacturer regularly engaged in commercial production of double-faced corrugated fiberboard carton forms, constructed of waterproof paper and laminated with waterproof adhesive.
 - 3. Fiberboard forms: Capable of supporting required dead load plus construction loads, and designed to lose their strength upon prolonged contact with moisture and soil bacteria.
 - 4. Seal cuts and ends of each form section by dipping in waterproof wax, unless liners and flutes are completely impregnated with waterproofing.
 - 5. Size forms as indicated on Drawings. Assemble as recommended by manufacturer, either with steel banding at 4'-0" maximum on centers, or, where liners and flutes are impregnated with waterproofing, with adequate stapling.
- J. Circular Forms:
- 1. Form round-section members with paper or fiber tubes, constructed of laminated plies using water-resistant adhesive with wax-impregnated exterior for weather and moisture protection. Provide units with sufficient wall thickness to resist loads imposed by wet concrete without deformation. Provide manufacturer's seamless units to minimize spiral gaps and seams.
 - 2. Fiberglass or steel forms may be used for round-section members.
- K. Shores: Wood or adjustable metal, with bearing plates; with double wedges at lower end.
- L. Form Ties:
- 1. Use commercially-manufactured ties, hangers and other accessories for embedding in concrete. Do not use wire not commercially fabricated for use as a form accessory.

2. Fabricate ties so ends or end fasteners can be removed without causing spalling of concrete faces. Depth from formed concrete face to the embedded portion: At least 1 inch, or twice the minimum dimension of tie, whichever is greater.
 3. Provide waterstop feature for form ties used on liquid-containing structures and on concrete walls which will have earth backfill on one side.
 4. Removable ties: Taper ties may be used when approved by the Owner's Representative. In the hole left by the removal of the taper tie, insert a preformed neoprene or polyurethane plug sized to seat at the center of the wall.
- M. Form Coating: Commercial formulation of form oil or form-release agent having proven satisfactory performance. Coating shall not bond with, stain or otherwise adversely affect concrete surfaces, or impair their subsequent treatment, including application of bonding agents, curing compounds, paint, protective liners and membrane waterproofing.
- N. Coating for Plastic Forms: Alkali-resistant gel-coat.
- O. Chamfer Strips: Unless otherwise indicated on Drawings, provide 3/4 inch chamfer strips in corners of forms to produce beveled edges where required by Part 3, Execution.
- P. Form Gaskets: Polyethylene rod, closed cell, 1-inch diameter.

2.02 DESIGN OF FORMWORK

- A. Conform to ACI 117, ACI 347 and building codes, unless more restrictive requirements are specified or shown on Drawings. Contractor shall design and engineer concrete formwork, including shoring and bracing. Design formwork for applicable gravity loads, lateral pressure, wind loads and allowable stresses. Camber formwork to compensate for anticipated deflection during placement of concrete when required to maintain specified tolerances. Design formwork to be readily removed without impact, shock or damage to concrete surfaces and adjacent materials.
- B. Slip Forming: Permitted on written approval of the Owner's Representative. Contractor shall demonstrate suitability of method proposed.

PART 3 EXECUTION

3.01 INSTALLATION

A. Formwork Construction

1. Construct and maintain formwork so that it will maintain correct sizes of members, shape, alignment, elevation and position during concrete placement and until concrete has gained sufficient strength. Provide for required openings, offsets, sinkages, keyways, recesses, moldings, anchorages and inserts.
2. Construct forms for easy removal without damage to concrete surfaces.
3. Make formwork sufficiently tight to prevent leakage of cement paste during concrete placement. Solidly butt joints and provide backup material at joints as required to prevent leakage and fins. Provide gaskets for wall forms to prevent concrete paste leakage at their base.
4. Place chamfer strips in forms to bevel edges and corners permanently exposed to view, except top edges of walls, and slabs which are indicated on Drawings to be tooled. Do not bevel edges of formed joints and interior corners unless indicated on Drawings. Form beveled edges for vertical and horizontal corners of equipment bases. Unless otherwise indicated on Drawings, make bevels 3/4 inch wide.
5. Provide temporary openings at bases of column and wall forms and other points as required for observation and cleaning immediately before concrete is placed.
6. Where runways are required for moving equipment, support runways directly on the formwork or structural members. Do not allow runways or supports to rest on reinforcing steel.
7. Use smooth forms on formed concrete surfaces required to have smooth form finish or rubbed finish as specified in Section 03345 - Concrete Finishing.
8. Rough forms may be used on formed concrete surfaces indicated to have rough form finish as specified in Section 03345 - Concrete Finishing.

B. Forms for Surfaces Requiring Smooth Form Finish:

1. Drill forms to suit ties used and to prevent leakage of concrete mortar around tie holes. Uniformly space form ties and align in horizontal and vertical rows. Install taper ties, if used, with the large end on the wet face of the wall.
2. Provide sharp, clean corners at intersecting planes, without visible edges or offsets. Back up joints with extra studs or girts to maintain true, square intersections.

3. Form molding shapes, recesses and projections with smooth-finish materials and install in forms with sealed joints to prevent displacement.
 4. Form exposed corners of beams and columns to produce square, smooth, solid, unbroken lines.
 5. Provide exterior exposed edges with 3/4-inch chamfer or 3/4-inch radius.
 6. Arrange facing material in orderly and symmetrical fashion. Keep number of joints to practical minimum. Support facing material adequately to prevent deflection in excess of allowable tolerances.
 7. For flush surfaces exposed to view in completed structure, overlap previously-placed hardened concrete with form sheathing by approximately 1 inch. Hold forms against hardened concrete to maintain true surfaces, preventing offsets or loss of mortar.
- C. Forms for Surfaces Requiring Rubbed Finish: Provide forms as specified in paragraph 3.01B, Smooth Form Finish. Use smooth plywood or fiberboard linings or forms, in as large sheets as practicable, and with smooth, even edges and close joints.
- D. Edge Forms and Screed Strips for Slabs: Set edge forms or bulkheads and intermediate screed strips for slabs to obtain required elevations and contours in finished slab surface. Provide and secure supports for types of screeds required.
- E. Circular Forms: Set forms in one piece for full height of member.
- F. Surfaces to Receive Membrane Waterproofing: Coordinate surface finish, anchors, reglets and similar requirements with membrane waterproofing applicator.
- G. Fireproofing Steel Member: Construct forms to provide not less than the concrete thickness necessary, measured from face of steel member, to provide the required fire rating. Forms for concealed surfaces may be unlined.
- H. Tolerances:
1. Unless noted otherwise on Drawings, construct formwork so concrete surfaces will conform to tolerance limits listed in Tables 03100A and 03100B at end of this Section.
 2. Establish sufficient control points and benchmarks as references for tolerance checks. Maintain these references in undisturbed condition until final completion and acceptance of the work.
- I. Adjustment of Formwork:

1. Use wedges or jacks to provide positive adjustment of shores and struts. After final inspection and before concrete placement, fasten in position wedges used for final adjustment of forms.
2. Brace forms securely against lateral deflections. Prepare to compensate for settling during concrete placement.
3. For wall openings, construct wood forms that facilitate necessary loosening to counteract swelling of forms.

J. Corrugated Fiberboard Carton Forms:

1. Place on smooth firm bed of suitable material to prevent vertical displacement; set tight to prevent horizontal displacement. Exercise care to avoid buckling of forms. Install in accordance with manufacturer's directions and recommendations.
2. Fit carton forms tightly around piles and piers; completely fill the space between subgrade and concrete placement with carton forms to form a void space.
3. Protect carton forms from moisture and maintain in a dry condition until concrete is placed on them. If they become wet before placement of concrete, allow them to dry and carefully inspect for strength before concrete is placed.
4. Before concrete placement, replace damaged or deteriorated forms which are incapable of supporting concrete dead load plus construction live loads.

3.02 PREPARATION OF FORM SURFACES

- A. Clean surfaces of forms and embedded materials before placing concrete. Remove accumulated mortar, grout, rust and other foreign matter.
- B. Coat forms for exposed or painted concrete surfaces with form oil or form-release agent before placing reinforcement. Cover form surfaces with coating material in accordance with manufacturer's printed instructions. Do not allow excess coating material to accumulate in forms or to contact hardened concrete against which fresh concrete will be placed. Remove coating material from reinforcement before placing concrete.
- C. Forms for unexposed surfaces, other than retained-in-place metal forms, may be wet with water immediately before concrete placement in lieu of coating. When possibility of freezing temperatures exists, however, the use of coating is mandatory.

3.03 REMOVAL OF FORMS

- A. Time Limits:
1. When repair of surface defects or finishing is required before concrete is aged, forms on vertical surfaces may be removed as soon as concrete has hardened sufficiently to resist damage from removal operations.
 2. Remove top forms on sloping surfaces of concrete as soon as concrete has attained sufficient stiffness to prevent sagging. Loosen wood forms for wall openings as soon as this can be accomplished without damage to concrete. Leave formwork for water-retaining structures in place for at least 4 days. Formwork for non-water-retaining columns, walls, sides of beams and other formwork components not supporting weight of concrete may be removed after 12 hours, provided concrete has hardened sufficiently to resist damage from removal operations, and provided removal of forms will not disturb members supporting weight of concrete.
 3. Forms and shoring supporting weight of concrete or construction loads: Leave in place until concrete has reached minimum strength specified for removal of forms and shoring. Do not remove such forms in less than 4 days.
- B. Circular Paper or Spiral Tube Forms: Follow manufacturer's directions for form removal. Take necessary precautions to prevent damage to concrete surface. When removal is done before completion of curing time, replace form, tie in place and seal to retard escape of moisture.
- C. Removal Strength:
1. Control Tests: Suitable strength-control tests will be required as evidence that concrete has attained specified strength for removal of formwork or shoring supporting weight of concrete in beams, slabs and other structural members. Furnish test cylinders and data to verify strength for early form removal.
 - a. Field-cured Test Cylinders: When field-cured test cylinders reach specified removal strength, formwork or shoring may be removed from respective concrete placements.
 - b. Laboratory-cured Test Cylinders: When concrete has been cured as specified for structural concrete for same time period required by laboratory-cured cylinders to reach specified strength, formwork or shoring may be removed from respective concrete placements. Determine length of time that concrete has been cured by totaling the days or fractions of days, not necessarily consecutive, during which air temperature surrounding concrete is above 50 degrees F and concrete

has been damp or thoroughly sealed against evaporation and loss of moisture.

2. Compressive Strengths: The minimum concrete compressive strength for removal of formwork supporting weight of concrete is 75 percent of specified minimum 28-day strength for class of concrete involved.

3.04 RESHORING

- A. When reshoring is permitted, plan operations in advance and obtain the Owner's Representative's approval of such operations. While reshoring is under way, keep live load off new construction. Do not permit concrete in any beam, slab, column or other structural member to be subjected to combined dead and construction loads in excess of loads permitted for developed concrete strength at time of reshoring.
- B. Place reshores as soon as practicable after form-stripping operations are complete but in no case later than end of day on which stripping occurs. Tighten reshores to carry required loads without over stressing construction. Leave reshores in place until tests representative of concrete being supported have reached specified strength at time of removal of formwork supporting weight of concrete.
- C. Floors supporting shores under newly-placed concrete: Leave original supporting shores in place, or re-shore. Locate reshores directly under shore position above. Extend reshoring over a sufficient number of stories to distribute weight of newly-placed concrete, forms and construction live loads in such manner that design superimposed loads of floors supporting shores are not exceeded.

3.05 FORM REUSE

- A. Do not reuse forms that are worn or damaged beyond repair. Thoroughly clean and recoat forms before reuse. For wood and plywood forms to be used for exposed smooth finish, sand or otherwise dress concrete contact surface to original condition or provide form liner facing material. For metal forms, straighten, remove dents and clean to return forms to original condition.

TABLE 03100A

TOLERANCES FOR FORMED SURFACES CONCRETE IN BUILDINGS**

VARIATION FROM	VARIATION IN	FOR ANY 10-FOOT LENGTH	FOR ANY 20-FOOT LENGTH OR ANY BAY	MAXIMUM FOR ENTIRE DIMENSION
PLUMB OR SPECIFIED BATTER	Lines And Surfaces of Columns, Piers, Walls And Arrises	1/4"	---	1"
	Exposed Corner Columns, Control Joint Grooves, And Other Conspicuous Lines	---	1/4"	1/2"
LEVEL OR SPECIFIED GRADE	Slab Soffits, Ceilings, Beam Soffits, And Arrises (Measured Before Removal of Shores)	1/4"	3/8"	3/4"
	Exposed Lintels, Sills, Parapets, Horizontal Grooves And Other Conspicuous Lines	---	1/4"	1/2"
DRAWING DIMENSIONS	Position of Linear Building Lines, Columns, Walls, And Partitions	---	1/2"	1"
	Size And Location of Sleeves, Floor Openings And Wall Openings	---	---	$\pm 1/4$ "
	Cross Section of Columns, Beams, Slabs, And Walls	---	---	+1/2", -1/4"
	Footings* in Plan	---	---	+2", -1/2"
	Footing Misplacement or Eccentricity in Direction of Error (The Lesser Of)	---	---	2% OF WIDTH OR 2"
	Footing Thickness Decrease	---	---	5%
	Footing Thickness Increase	---	---	NO LIMIT
	Step Rise in Flight of Stairs	---	---	$\pm 1/8$ "
	Step Tread in Flight of Stairs	---	---	$\pm 1/4$ "
	Consecutive Step Rise	---	---	$\pm 1/16$ "
	Consecutive Step Tread	---	---	$\pm 1/8$ "

* Footing tolerances apply to concrete dimensions only, not to positioning of vertical reinforcing steel, dowels, or embedded items.

** Includes water and wastewater process structures.

TABLE 03100B
TOLERANCES FOR FORMED SURFACES
CONCRETE IN BRIDGES, WHARVES AND MARINE STRUCTURES

VARIATION FROM	VARIATION IN	MAXIMUM
PLUMB OR SPECIFIED BATTER	Surfaces of columns, piers and walls	1/2" in 10'
LEVEL OR SPECIFIED GRADE	Top surfaces of slabs	See Section 03345
	Top surfaces of curbs and railings	3/16" in 10'
DRAWING DIMENSIONS	Cross section of columns, caps, walls, beams and similar members	+1/2", -1/4"
	Thickness of deck slabs	+1/4", - 1/8"
	Size and location of slab and wall openings	± 1/2"
	Footings in plans	+2", -1/2"
	Footing misplacement or eccentricity in direction of error (the lesser of)	2% of Width or 2"
	Footing thickness decrease	5%
	Footing thickness increase	No Limit
	Step rise in flight of stairs	±1/8"
	Step tread in flight of stairs	±1/4"
	Consecutive step rise	±1/16"
	Consecutive step tread	±1/8"

END OF SECTION

Section 03300
CAST-IN-PLACE CONCRETE

1.0 GENERAL**1.01 SECTION INCLUDES**

- A. Cast-in-place concrete building frame members, floors, shear walls, foundation walls, and supported slabs, vaults, manholes and wet wells.
- B. Cast-in-place concrete work for utility construction or rehabilitation, such as slabs on grade, small vaults, site-cast bases for precast units, cast-in-place manholes, including headwalls and miscellaneous small structures.
- C. Floors and slabs on grade.
- D. Concrete seal slabs.
- E. Control, and expansion and contraction joint devices associated with concrete work, including joint sealants.
- F. Design, construction, erection, and removal of structural concrete formwork.
- G. Equipment pads, light pole base, thrust blocks.
- H. References to Technical Specifications:
 - 1. Section 01200 - Measurement and Payment
 - 2. Section 01350 - Submittals
 - 3. Section 01310 - Coordination and Meetings
 - 4. Section 03600 - Structural Grout
 - 5. Section 03310 - Structural Concrete
 - 6. Section 03100 – Concrete Formwork
 - 7. Section 01440 – Inspection Services
 - 8. Section 01450 – Testing Laboratory Services
- I. Reference Standards:
 - 1. American Concrete Institute (ACI)
 - 2. American Society for Testing and Materials (ASTM)
 - 3. Concrete Reinforcing Steel Institute (CRSI)
 - 4. American Welding Society (AWS)
 - 5. Wire Reinforcement Institute (WRI)
 - 6. Encyclopedia of Industrial Chemical Analysis

1.02 UNIT PRICES

- A. Measurement for cast-in-place concrete is on lump-sum basis for each aforementioned item as bid. Payment includes related work performed on these items in accordance with related sections of these Technical Specifications.
- B. Measurement for extra cast-in-place concrete is on cubic-yard basis. Payment includes related work performed in accordance with related sections.
- C. Refer to Section 01200 - Measurement and Payment for unit price procedures.

1.03 DEFINITIONS

- A. Hot Weather: Any combination of high air temperature, low relative humidity and wind velocity tending to impair quality of fresh or hardened concrete or otherwise resulting in abnormal properties. Hot weather concreting shall be in accordance with ACI - 305R.
- B. Cold Weather: Period when, for more than 2 successive days, mean daily temperature is below 40 degrees F. Cold weather concreting shall be in accordance with ACI - 306R.

1.04 SUBMITTALS

- A. Submittals shall conform to the requirements of Section 01350 – Submittals.
- B. Shop Drawings:
 - 1. Submit Shop Drawings detailing reinforcement fabrication, bar replacement location, splices, spacing, bar designation, bar type, length, size, bending, number of bars, bar support type, and other pertinent information, including dimensions. Provide sufficient detail for placement of reinforcement without use of Plans. Information shall correspond directly to data listed on bill of materials.
 - 2. Use of reproductions of Plans by Contractor, Subcontractor, erector, fabricator or material supplier in preparation of Shop Drawings (or in lieu of preparation of Shop Drawings) signifies acceptance by that party of information shown thereon as correct, and acceptance of obligation to pay for any job expense, real or implied, arising due to errors that may occur thereon. Remove references to Design Engineer, including seals, when reproductions of Plans are used as Shop Drawings.
 - 3. Detail Shop Drawings in accordance with ACI 315, Figure 6.

4. Submit Shop Drawings showing location of proposed additional construction joints, and obtain approval of the Engineer, prior to submitting reinforcing steel Shop Drawings.
- C. Bill of Materials: Submit with Shop Drawings.
- D. Product Data:
1. Mechanical Bar Splices: Submit manufacturer's technical literature, including specifications and installation instructions.
 2. Epoxy grout proposed for anchoring reinforcing dowels to hardened concrete: Submit manufacturer's technical literature including recommended installation procedures.
 3. Provide data on joint devices, attachment accessories and admixtures.
- E. Certificates:
1. Submit steel manufacturer's certificates of mill tests giving properties of steel proposed for use. List of manufacturer's test number, heat number, chemical analysis, yield point, tensile strength, and percentage of elongation. Identify proposed location of steel in work.
 2. Foreign-manufactured reinforcing bars shall be tested for conformance to ASTM requirements by a certified independent testing laboratory located in United States. Certification from any other source is not acceptable. Submit test reports for review. Do not begin fabrication of reinforcement until material has been approved.

1.05 PROJECT RECORD DOCUMENTS

- A. Submit under provisions of Section 01350-Submittals.
- B. Accurately record actual locations of embedded utilities and components which are concealed from view.

1.06 QUALITY ASSURANCE

- A. Perform Work in accordance with ACI 301-99:Specifications for Structural Concrete - IP.
- B. Acquire cement and aggregate from same source for all work.
- C. Conform appropriately to ACI 305R-99:Hot Weather Concreting or ACI 306R.1-90:Standard Specification for Cold Weather Concreting.

1.07 COORDINATION

- A. Coordinate Work under provisions of Section 01310 – Coordination and Meetings.
- B. Coordinate the placement of joint devices with erection of concrete formwork and placement of form accessories.

2.0 PRODUCTS**2.01 CONCRETE MATERIALS**

- A. Cement: ASTM - C150, Type I - Normal Portland Type II - Moderate Sulphate resistance Portland type.
- B. Fine and Coarse Aggregates: ASTM - C33.
- C. Use coarse limestone aggregate and crushed limestone for fine aggregate. The product of concrete alkalinity (A, as equivalent calcium carbonate) times the thickness of cover over the reinforcing steel (Z, in inches) shall not be less than 0.54, i.e. concrete shall have an AZ factor greater than or equal to 0.54. Provide a minimum concrete cover of 2" over reinforcing steel on the inside of the structures.
- D. Water: Clean and not detrimental to concrete.

2.02 ADMIXTURES

- A. Air Entrainment: ASTM - C260.
- B. Chemical: ASTM - C494, Type A - Water Reducing Type D - Water Reducing and Retarding Type E - Water Reducing and Accelerating admixture.

2.03 ACCESSORIES

- A. Bonding Agent: Two component modified epoxy resin.
- B. Vapor Barrier: 6 mil clear polyethylene film type recommended for below grade application.
- C. Non-Shrink Grout: Premixed compound consisting of non-metallic aggregate, cement, water reducing and plasticizing agents; capable of developing minimum compressive strength of 2,400 psi in 48 hours and 7,000 psi in 28 days.

2.04 JOINT DEVICES AND FILLER MATERIALS

- A. Joint Filler Type C: ASTM - D1752; Premolded sponge rubber, fully compressible with recovery rate of minimum 95 percent.

- B. Sealant: ASTM - D1190; synthetic rubber.

2.05 CONCRETE MIX

- A. Mix and deliver concrete in accordance with ASTM - C94, Alternative No. 3. A minimum of 5.75 bags of cement per cubic yard of concrete shall be used. For Concrete in Contact with sewage use Portland Type II, ASTM - C150, Cement.
- B. Provide concrete to the following criteria:
 - 1. Compressive Strength 7 days: 2400 psi
 - 2. Compressive Strength 28 days: 4000 psi
 - 3. Slump: 3 to 4 inches for concrete cast against earth in slabs and footings and where used as a topping. 5 to 6 inches for concrete in supported slabs, beams, columns and walls.
 - 4. Maximum Water/Cement Ratio: 0.50.
- C. Use accelerating admixtures in cold weather only when approved by Engineer. Use of admixtures will not relax cold weather placement requirements.
- D. Use set retarding admixtures during hot weather only when approved by Engineer.
- E. Add air entraining agent to normal weight concrete mix for work exposed to temperature lower than 40 degrees F. Air content shall be 3 percent maximum for concrete with trowel finished surfaces and 3-5 percent for other concrete.

2.06 FORM MATERIAL

- A. Smooth Forms: New plywood, metal, plastic, tempered concrete-form hardboard, dressed lumber faced with plywood or lining, or metal-framed plywood-faced panel material, to provide continuous, straight, smooth surfaces. Form material shall be free of raised grain, torn surfaces, worn edges, patches, dents or other defects. Furnish material in largest practical sizes to minimize number of joints and, when indicated on Plans, conform to joint system indicated. Form material shall have sufficient strength and thickness to withstand pressure of newly placed concrete without bow or deflection.
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- E. Edge Forms and Intermediate Screed Strips: Type and strength compatible with the screed equipment and methods used.
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- G. Metal Pan Joist Forms: Removable type; fabricated of minimum 14-gage steel; one piece between end closures. Adjustable forms not allowed. Taper sides 1 inch per foot to facilitate removal.
- H. Earth Cuts for Forms:
 - 1. Use earth cuts for forming unexposed sides of grade beams cast monolithically with slabs on grade.
 - 2. Where sides of excavations are stable enough to prevent caving or sloughing, following surfaces may be cast against neat-cut excavations:
 - a. Sides of footings.
 - b. Inside face of perimeter grade beams not monolithic with slab on grade. When inside face is cast against earth, increase beam width indicated on Plans by 1 inch.
 - c. Both faces of interior grade beams not monolithic with slab on grade. When grade beam is cast against earth, increase beam width indicated on Plans by 2 inches.
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 - 1. Corrugated fiberboard carton forms, when called for, are intended to form a void space beneath pile-supported and pier-supported slabs and other structural elements as shown.
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 - 4. Seal cuts and ends of each form section by dipping in waterproof wax, unless liners and flutes are completely impregnated with waterproofing.

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1. Use commercially-manufactured ties, hangers and other accessories for embedding in concrete. Do not use wire not commercially fabricated for use as a form accessory.
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 3. Provide waterstop feature for form ties used on liquid-containing structures and on concrete walls which will have earth backfill on one side.
 4. Removable ties: Taper ties may be used when approved by the Engineer. In the hole left by the removal of the taper tie, insert a preformed neoprene or polyurethane plug sized to seat at the center of the wall.
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- O. Chamfer Strips: Unless otherwise indicated on Plans, provide 3/4 inch chamfer strips in corners of forms to produce beveled edges where required by this Section, 3.0 "Execution".
- P. Form Gaskets: Polyethylene rod, closed cell, 1-inch diameter.

2.07 DESIGN OF FORMWORK

- A. Conform to ACI 117, ACI 347 and building codes, unless more restrictive requirements are specified or shown on Plans. Contractor shall design and engineer concrete formwork, including shoring and bracing. Design formwork for applicable gravity loads, lateral pressure, wind loads and allowable stresses. Camber formwork to compensate for anticipated deflection during placement of concrete required to maintain specified tolerances. Design formwork to be readily removed without impact, shock or damage to concrete surfaces and adjacent materials.
- B. Slip Forming: Permitted on written approval of the Engineer. Contractor shall demonstrate suitability of method proposed.

2.08 REINFORCING MATERIAL

- A. Reinforcing Bars: Deformed bars conforming to ASTM - A615, grade as indicated on Plans, except column spirals and those shown on Plans to be smooth bars. Where grade is not shown on Plans, use Grade 60.
- B. Smooth Bars: Where indicated on Plans, use smooth bars conforming to ASTM - A36; ASTM - A615, Grade 60; or ASTM - A675, Grade 70.
- C. Column Spirals: Bars conforming to ASTM - A615, Grade 60, or wire conforming to ASTM - A82.
- D. Epoxy-Coated Deformed Bars, Column Spirals and Smooth Bars: Conform to ASTM - A775/A775M.
- E. Welded Wire Fabric:
 - 1. Welded Smooth Wire Fabric: Conform to ASTM - A185.
 - 2. Welded Deformed Wire Fabric: Conform to ASTM - A497.
 - 3. Provide wire size, type and spacing as shown. Where type is not shown on Plans, use welded smooth wire fabric.
 - 4. Furnish welded wire fabric in flat sheets only.
- F. Tie Wire: 16-1/2 gage or heavier annealed steel wire. Use plastic-coated tie wire with epoxy-coated reinforcing steel.
- G. Bar Supports: Provide chairs. Use bar supports and accessories of sizes required to provide required concrete cover. Where concrete surfaces are exposed to weather, water or wastewater, provide plastic accessories only; do not use galvanized or plastic-tipped metal in such locations. Provide metal bar supports and accessories rated Class 1 or 2 conforming to CRSI Manual of Standard Practice. Use epoxy-coated bar supports with epoxy-coated reinforcing bars.

- H. Slabs on Grade: Provide chairs with sheet metal bases or provide precast concrete bar supports 3 inches wide, 6 inches long, and thick enough to allow required cover. Embed tie wires in 3-inch by 6-inch side.
- I. Mechanical Bar Splices:
 - 1. Conform to ACI 318-05:Building Code Requirements for Structural Concrete and Commentary; use where indicated on Plans.
 - a. Compression splices shall develop ultimate stress of reinforcing bar.
 - b. Tension splices shall develop 125 percent of minimum yield point stress of reinforcing bar.
 - 2. Regardless of chemical composition of steel, any heat effect shall not adversely affect performance of reinforcing bar.
- J. Welded Splices:
 - 1. Provide welded splices where shown and where approved by the Engineer. Welded splices of reinforcing steel shall develop a tensile strength exceeding 125 percent of the yield strength of the reinforcing bars connected.
 - 2. Provide materials for welded splices conforming to AWS D1.4 – Structural Welding Code-Reinforcing Steel.
- K. Epoxy Grout: High-strength rigid epoxy adhesive, conforming to ASTM - C881, Type IV, manufactured for purpose of anchoring dowels into hardened concrete and the moisture condition, application temperature and orientation of the hole to be filled. Unless otherwise shown, depth of embedment shall be as required to develop the full tensile strength (125 percent of yield strength) of dowel, but not less than 12 diameters.

2.09 FABRICATION OF REINFORCING

- A. Bending: Fabricate bars to shapes indicated on Plans by cold bending. Bends shall conform to minimum bend diameters specified in ACI 318-05:Building Code Requirements for Structural Concrete and Commentary. Do not straighten or bend bars. Fabricate epoxy-coated reinforcing steel to required shapes in a manner that will not damage epoxy coating. Repair any epoxy coating with patching material conforming to Item 4.4 of ASTM - A775/A775M.
- B. Splices:
 - 1. Locate splices as indicated on Plans. Do not locate splices at other locations without approval of the Engineer. Use minimum number of splices located at points of minimum stress. Stagger splices in adjacent bars.
 - 2. Length of lap splices: As shown on Plans.

3. Prepare ends of bars at mechanical splices in accordance with splice manufacturer's requirements.
- C. Construction Joints: Unless otherwise shown, continue reinforcing through construction joints.
- D. Bar Fabrication Tolerances: Conform to tolerances listed in ACI 315, Figures 4 and 5.
- E. Standard Hooks: Conform to the requirements of ACI 318-05:Building Code Requirements for Structural Concrete and Commentary.
- F. Marking: Clearly mark bars with waterproof tags showing number of bars, size, mark, length, and yield strength. Mark steel with same designation as member in which it occurs.

2.10 FINISHING MATERIALS

- A. Sealer/Dustproofer (VOC Compliant): Water-based acrylic sealer; non-yellowing under ultraviolet light after 200-hour test in accordance with ASTM - D4587. Conform to local, state and federal solvent emission requirements.
- B. Epoxy Floor Topping: Two-component epoxy resin meeting ASTM - C881 Type III, resistant to wear, staining and chemical attack, blended with granite, sand, trap rock or quartz aggregate, trowel-applied over concrete floor. Topping thickness shall be 1/8 inch. Color shall be gray.
- C. Abrasive Aggregate for Nonslip Finish: Fused aluminum oxide grit, or crushed emery aggregate containing not less than 40 percent aluminum oxide and not less than 25 percent ferric oxide. Material shall be factory graded, packaged, rustproof and nonglazing, and unaffected by freezing, moisture and cleaning materials.
- D. Epoxy Penetrating Sealer: Low-viscosity, two-component epoxy system designed to give maximum penetration into concrete surfaces. Sealer shall completely seal concrete surfaces from penetration of water, oil and chemicals; prevent dusting and deterioration of concrete surfaces caused by heavy traffic; and be capable of adhering to floor surfaces subject to hydrostatic pressure from below. Color shall be transparent amber or gray. Surface shall be non-slip.
- E. Latex Bonding Agent: Non-redisersable latex base liquid conforming to ASTM - C1059. When used in water and wastewater treatment structures, bonding agent shall be suitable for use under continuously submerged conditions. Conformance and suitability certification by manufacturer is required.
- F. Bonding Grout: Prepare bonding grout by mixing approximately one part cement to one part fine sand meeting ASTM - C144 but with 100 percent passing No. 30 mesh sieve. Mix with water to consistency of thick cream. At Contractor's option, a commercially-prepared bonding agent used in accordance with manufacturer's

recommendations and instructions may be used. When used in water and wastewater treatment structures, bonding agent shall be suitable for use under continuously submerged conditions. Conformance and suitability certification by manufacturer is required. Submit manufacturer's technical information on proposed bonding agent.

- G. Patching Mortar:
1. Make patching mortar of same materials and of approximately same proportions as concrete, except omit coarse aggregate. Substitute white Portland cement for part of gray Portland cement on exposed concrete in order to match color of surrounding concrete. Determine color by making trial patch. Use minimum amount of mixing water required for handling and placing. Mix patching mortar in advance and allow to stand. Mix frequently with trowel until it has reached stiffest consistency that will permit placing. Do not add water.
 2. Proprietary compounds for adhesion or specially formulated cementitious repair mortars may be used in lieu of or in addition to foregoing patching materials provided that properties of bond and compressive strength meet or exceed the foregoing and color of surrounding concrete can be matched where required. Use such compounds according to manufacturer's recommendations. When used in water and wastewater treatment structures, material shall be suitable for use under continuously submerged conditions. Conformance and suitability certification by manufacturer is required.
- H. Epoxy Adhesive: Two-component, 100 percent solids, 100 percent reactive compound developing 100 percent of strength of concrete, suitable for use on dry or damp surfaces. Epoxy used to inject cracks and as a binder in epoxy mortar shall meet ASTM - C881, Type VI. Epoxy used as a bonding agent for fresh concrete shall meet ASTM - C881, Type V.
- I. Non-shrink Grout: See Section 03600 - Structural Grout.
- J. Spray-Applied Coating: Acceptable products are Thoro System Products "Thorseal Plaster Mix" or approved equal. Color: Gray.
- K. Concrete Topping: Class H concrete with 3/8-inch maximum coarse aggregate size, as specified in this Section.
- L. Concrete Fill: Class H concrete with 3/8-inch maximum coarse aggregate size, (Class C where fill thickness exceeds 3 inches throughout a placement), as specified in Section 03310 - Structural Concrete.
- M. Evaporation Retardant: Confilm, manufactured by Master Builders; Eucobar, manufactured by Euclid Chemical Company; or equal.

2.11 CONCRETE CURING MATERIALS

- A. Membrane-forming Curing Compound: Conform to ASTM - C309, Type 1D, and following requirements.
 - 1. Minimum solids content: 30 percent.
 - 2. Compound shall not permanently discolor concrete. When used for liquid-containing structures, curing compound shall be white-pigmented.
 - 3. When used in areas that are to be coated, or that will receive topping or floor covering, material shall not reduce bond of coating, topping, or floor covering to concrete. Curing compound manufacturer's technical information shall state conditions under which compound will not prevent bond.
 - 4. Conform to local, state and federal solvent emission requirements. Conform to local, state and federal solvent emission requirements.
 - 5. White pigmented concrete curing compound shall be sprayed on in one even coat with a hand or power sprayer as soon as the surface water disappears from concrete surface.
- B. Clear Curing and Sealing Compound (VOC Compliant): Conform to ASTM - C309, Type 1, Class B, and the following requirements: 30 percent solids content minimum; non-yellowing under ultraviolet light after 500-hour test in accordance with ASTM - D4587. Sodium silicate compounds are not permitted. Conform to local, state and federal solvent emission requirements.
- C. Sheet Material for Curing Concrete: ASTM - C171; waterproof paper, polyethylene film or white burlap-polyethylene sheeting.
- D. Curing Mats (for use in Curing Method 2): Heavy shag rugs or carpets, or cotton mats quilted at 4 inches on center; 12 ounce per square yard minimum weight when dry.
- E. Water for curing: Clean and potable.

3.0 EXECUTION

3.01 EXAMINATION

- A. Verify requirements for concrete cover over reinforcement.
- B. Verify that anchors, seats, plates, reinforcement and other items to be cast into concrete are accurately placed, positioned securely, and will not cause hardship in placing concrete.

3.02 PREPARATION

- A. Prepare previously placed concrete by cleaning with steel brush and applying bonding agent in accordance with manufacturer's instructions.
- B. In locations where new concrete is dowelled to existing work, drill holes in existing concrete, insert steel dowels and pack solid with non-shrink grout.

3.03 PREPARATION OF SURFACES FOR CONCRETING

- A. Earth Surfaces:
 - 1. Under interior slabs on grade, install vapor barrier. Lap joints at least 6 inches and seal watertight with tape, or sealant applied between overlapping edges and ends. Repair vapor barrier damaged during placement of reinforcing and inserts with vapor barrier material; lap over damaged areas at least 6 inches and seal watertight.
 - 2. Other Earth Surfaces: Thoroughly wet by sprinkling prior to placing concrete, and keep moist by frequent sprinkling up to time of placing concrete thereon. Remove standing water. Surfaces shall be free from standing water, mud and debris at the time of placing concrete.
- B. Construction Joints:
 - 1. Definition: Concrete surfaces upon or against which concrete is to be placed, where the placement of the concrete has been interrupted so that, in the judgment of the Engineer, new concrete cannot be incorporated integrally with that previously placed.
 - 2. Interruptions: When placing of concrete is to be interrupted long enough for the concrete to take a set, use forms or other means to shape the working face to secure proper union with subsequent work. Make construction joints only where acceptable to the Engineer.
 - 3. Preparation: Give horizontal joint surfaces a compacted, roughened surface for good bond. Except where the Plans call for joint surfaces to be coated, clean joint surfaces of laitance, loose or defective concrete and foreign material by hydroblasting or sandblasting (exposing aggregate), roughen surface to expose aggregate to a depth of at least 1/4 inch and wash thoroughly. Remove standing water from the construction joint surface before new concrete is placed.
 - 4. After surfaces have been prepared cover approximately horizontal construction joints with a 3-inch lift of a grout mix consisting of Class A concrete batched without coarse aggregate; place and spread grout uniformly. Place wall concrete on the grout mix immediately thereafter.

- C. Set and secure reinforcement, anchor bolts, sleeves, inserts and similar embedded items in the forms where indicated on Plans, Shop Drawings and as otherwise required. Obtain the Engineer's acceptance before concrete is placed. Accuracy of placement is the sole responsibility of the Contractor.
- D. Unless otherwise approved by Engineer, place no concrete until at least 4 hours after formwork, inserts, embedded items, reinforcement and surface preparation have been completed and accepted by the Engineer. Clean surfaces of forms and embedded items that have become encrusted with grout or previously-placed concrete before placing adjacent concrete.
- E. Casting New Concrete Against Old: Where concrete is to be cast against old concrete (any concrete which is greater than 60 days of age), thoroughly clean and roughen the surface of the old concrete by hydro-blasting or sandblasting (exposing aggregate). Coat joint surface with epoxy bonding agent following manufacturer's written instructions, unless indicated otherwise. Unless noted otherwise, this provision does not apply to vertical wall joints where waterstop is installed.
- F. Protection from Water: Place no concrete in any structure until water entering the space to be filled with concrete has been properly cut off or diverted and carried out of the forms, clear of the work. Deposit no concrete underwater. Do not allow still water to rise on any concrete until concrete has attained its initial set. Do not allow water to flow over the surface of any concrete in a manner and at a velocity that will damage the surface finish of the concrete. Pumping, dewatering and other necessary operations for removing ground water, if required, are subject to the Engineer's review.
- G. Corrosion Protection: Position and support pipe, conduit, dowels and other ferrous items to be embedded in concrete construction prior to placement of concrete so there is at least a 2 inch clearance between them and any part of the concrete reinforcement. Do not secure such items in position by wiring or welding them to the reinforcement.
- H. Where practicable, provide for openings for pipes, inserts for pipe hangers and brackets, and setting of anchors during placing of concrete.
- I. Accurately set anchor bolts and maintain in position with templates while they are being embedded in concrete.
- J. Cleaning: Immediately before concrete is placed, thoroughly clean dirt, grease, grout, mortar, loose scale, rust and other foreign substances from surfaces of metalwork to be in contact with concrete.

3.04 FORMWORK INSTALLATION

- A. Formwork Construction
 - 1. Construct and maintain formwork so that it will maintain correct sizes of members, shape, alignment, elevation and position during concrete placement and until concrete has gained sufficient strength. Provide for required

openings, offsets, sinkages, keyways, recesses, moldings, anchorages, and inserts.

2. Construct forms for easy removal without damage to concrete surfaces.
3. Make formwork sufficiently tight to prevent leakage of cement paste during concrete placement. Solidly butt joints and provide backup material at joints as required to prevent leakage and fins. Provide gaskets for wall forms to prevent concrete paste leakage at their base.
4. Place chamfer strips in forms to bevel edges and corners permanently exposed to view, except top edges of walls, and slabs which are indicated on Plans to be tooled. Do not bevel edges of formed joints and interior corners unless indicated on Plans. Form beveled edges for vertical and horizontal corners of equipment bases. Unless otherwise indicated on Plans, make bevels 3/4 inch wide.
5. Provide temporary openings at bases of column and wall forms and other points as required for observation and cleaning immediately before concrete is placed.
6. Where runways are required for moving equipment, support runways directly on the formwork or structural members. Do not allow runways or supports to rest on reinforcing steel.
7. Use smooth forms on formed concrete surfaces required to have smooth form finish or rubbed finish.
8. Rough forms may be used on formed concrete surfaces indicated to have rough form finish.

B. Forms for Surfaces Requiring Smooth Form Finish:

1. Drill forms to suit ties used and to prevent leakage of concrete mortar around tie holes. Uniformly space form ties and align in horizontal and vertical rows. Install taper ties, if used, with the large end on the wet face of the wall.
2. Provide sharp, clean corners at intersecting planes, without visible edges or offsets. Back up joints with extra studs or girts to maintain true, square intersections.
3. Form molding shapes, recesses and projections with smooth-finish materials and install in forms with sealed joints to prevent displacement.
4. Form exposed corners of beams and columns to produce square, smooth, solid, unbroken lines.

5. Provide exterior exposed edges with 3/4-inch chamfer or 3/4-inch radius.
 6. Arrange facing material in orderly and symmetrical fashion. Keep number of joints to practical minimum. Support facing material adequately to prevent deflection in excess of allowable tolerances.
 7. For flush surfaces exposed to view in completed structure, overlap previously-placed hardened concrete with form sheathing by approximately 1 inch. Hold forms against hardened concrete to maintain true surfaces, preventing offsets or loss of mortar.
- C. Forms for Surfaces Requiring Rubbed Finish: Provide forms as specified in this Section, 3.04B “Forms for Surfaces Requiring Smooth Form Finish”. Use smooth plywood linings or forms, in as large sheets as practicable, and with smooth, even edges and close joints.
- D. Edge Forms and Screed Strips for Slabs: Set edge forms or bulkheads and intermediate screed strips for slabs to obtain required elevations and contours in finished slab surface. Provide and secure supports for types of screeds required.
- E. Circular Forms: Set forms in one piece for full height of member.
- F. Surfaces to Receive Membrane Waterproofing: Coordinate surface finish, anchors, reglets, and similar requirements with membrane waterproofing applicator.
- G. Fireproofing Steel Member: Construct forms to provide not less than the concrete thickness necessary, measured from face of steel member, to provide the required fire rating. Forms for concealed surfaces may be unlined.
- H. Tolerances:
1. Unless noted otherwise on Plans, construct formwork so concrete surfaces will conform to tolerance limits listed in Tables 03100A and 03100B at end of this Section.
 2. Establish sufficient control points and bench marks as references for tolerance checks. Maintain these references in undisturbed condition until final completion and acceptance of the Work.
- I. Adjustment of Formwork:
1. Use wedges or jacks to provide positive adjustment of shores and struts. After final inspection and before concrete placement, fasten in position wedges used for final adjustment of forms.
 2. Brace forms securely against lateral deflections. Prepare to compensate for settling during concrete placement.

3. For wall openings, construct wood forms that facilitate necessary loosening to counteract swelling of forms.
- J. Corrugated Fiberboard Carton Forms:
1. Place on smooth firm bed of suitable material to prevent vertical displacement; set tight to prevent horizontal displacement. Exercise care to avoid buckling of forms. Install in accordance with manufacturer's directions and recommendations.
 2. Fit carton forms tightly around piles and piers; completely fill the space between subgrade and concrete placement with carton forms to form a void space.
 3. Protect carton forms from moisture and maintain in a dry condition until concrete is placed on them. If they become wet before placement of concrete, allow them to dry and carefully inspect for strength before concrete is placed.
 4. Before concrete placement, replace damaged or deteriorated forms which are incapable of supporting concrete dead load plus construction live loads.

3.05 PREPARATION OF FORM SURFACES

- A. Clean surfaces of forms and embedded materials before placing concrete. Remove accumulated mortar, grout, rust and other foreign matter.
- B. Coat forms for exposed or painted concrete surfaces with form oil or form-release agent before placing reinforcement. Cover form surfaces with coating material in accordance with manufacturer's printed instructions. Do not allow excess coating material to accumulate in forms or to contact hardened concrete against which fresh concrete will be placed. Remove coating material from reinforcement before placing concrete.
- C. Forms for unexposed surfaces, other than retained-in-place metal forms, may be wet with water immediately before concrete placement in lieu of coating. When possibility of freezing temperatures exists, however, the use of coating is mandatory.

3.06 INSTALLATION OF REINFORCEMENT

- A. Placement Tolerances: Place reinforcement within tolerances of Table 03210A at the end of this Section. Bend tie wire away from forms to maintain the specified concrete coverage.
- B. Interferences: Maintain 2-inch clearance from embedded items. Where reinforcing interferes with location of other reinforcing steel, conduit or embedded items, bars may be moved within specified tolerances or one bar diameter, whichever is greater. Where

greater movement of bars is required to avoid interference, notify the Engineer. Do not cut reinforcement to install inserts, conduit, mechanical openings or other items without approval of the Engineer.

- C. Concrete Cover: Provide clear cover measured from reinforcement to face of concrete as listed in Table 03210B at the end of this Section, unless otherwise indicated on Plans.
- D. Placement in Forms: Use spacers, chairs, wire ties and other accessory items necessary to assemble, space, and support reinforcing properly. Provide accessories of sufficient number, size and strength to prevent deflection or displacement of reinforcement due to construction loads or concrete placement. Use appropriate accessories to position and support bolts, anchors and other embedded items. Tie reinforcing bars at each intersection, and to accessories. Blocking reinforcement with concrete or masonry is prohibited.
- E. Placement for Concrete on Ground: Support bar and wire reinforcement on chairs with sheet metal bases or precast concrete blocks spaced at approximately 3 feet on centers each way. Use minimum of one support for each 9 square feet. Tie supports to reinforcing bars and wires.
- F. Vertical Reinforcement in Columns: Offset vertical bars by at least one bar diameter at splices. Provide accurate templates for column dowels to ensure proper placement.
- G. Splices:
 - 1. Do not splice bars, except at locations indicated on Plans or reviewed Shop Drawings, without approval of the Engineer.
 - 2. Lap Splices: Unless otherwise shown or noted, Class B, conforming to ACI 318-89, Section 12.15.1. Tie securely with wire prior to concrete placement, to prevent displacement of splices during concrete placement.
 - 3. Mechanical Bar Splices: Use only where indicated on Plans or approved by the Engineer. Install in accordance with manufacturer's instructions.
 - a. Couplers located at a joint face shall be of a type which can be set either flush or recessed from the face as shown. Seal couplers prior to concrete placement to completely eliminate concrete or cement paste from entering.
 - b. Couplers intended for future connections: Recess 1/2 inch minimum from concrete surface. After concrete is placed, plug coupler and fill recess with sealant to prevent contact with water or other corrosive materials.
 - c. Unless noted otherwise, match mechanical coupler spacing and capacity to that shown for the adjacent reinforcing.

4. Construction Joints: Place reinforcing continuous through construction joints, unless noted otherwise.
- H. Welded Wire Fabric: Install wire fabric in as long lengths as practicable. Unless otherwise indicated on Plans, lap adjoining pieces at least 6 inches or one full mesh plus 2 inches, whichever is larger. Lace splices with wire. Do not make end laps midway between supporting beams, or directly over beams of continuous structures. Offset end laps in adjacent widths to prevent continuous laps. Conform to WRI - Manual of Standard Practice for Welded Wire Fabric.
- I. Field Bending: Shape reinforcing bent during construction operations to conform to Plans. Bars shall be cold-bent; do not heat bars. Closely inspect reinforcing for breaks. When reinforcing is damaged, replace, Cadweld, or otherwise repair, as directed by the Engineer. Do not bend reinforcement after it is embedded in concrete.
- J. Epoxy-coated Reinforcing Steel: Install in accordance this Section, 3.06J "Field Bending", and in a manner that will not damage epoxy coating. Repair damaged epoxy coating with patching material as specified in Paragraph 2.09 A - Bending.
- K. Field Cutting: Cut reinforcing bars by shearing or sawing. Do not cut bars with cutting torch.
- L. Welding of reinforcing bars is prohibited, except where shown on Plans.

3.07 GROUTING OF REINFORCING AND DOWEL BARS

- A. Use epoxy grout for anchoring reinforcing and dowel steel to existing concrete in accordance with epoxy manufacturer's instructions. Drill hole not more than 1/4 inch larger than steel bar diameter (including height of deformations for deformed bars) in existing concrete. Just before installation of steel, blow hole clean of all debris using compressed air. Partially fill hole with epoxy, using enough epoxy so when steel bar is inserted, epoxy grout will completely fill hole around bar. Dip end of steel bar in epoxy and twist bar while inserting into partially-filled hole.

**TABLE 03210A
REINFORCEMENT PLACEMENT TOLERANCES**

Placement	Tolerances (in inches)
Clear Distance - To formed soffit: To other formed surfaces: Minimum spacing between bars	-1/4 ±1/4 -1/4
Clear distance from unformed surface to top reinforcement - Members 8 inches deep or less: Members more than 8 inches deep but less than 24 inches deep: Members 24 inches deep or greater: Uniform spacing of bars (but the required number of bars shall not be reduced): Uniform spacing of stirrups and ties (but the required number of stirrups and ties shall not be reduced):	±1/4 -1/4, +1/2 -1/4, +1 ±2 ±1
Longitudinal locations of bends and ends of reinforcement - General: Discontinuous ends of members: Length of bar laps:	±2 ±1/2 -1 1/2
Embedded length - For bar sizes No. 3 through 11: For bar sizes No. 14 and 18:	-1 -2

**TABLE 03210B
MINIMUM CONCRETE COVER FOR REINFORCEMENT**

Surface	Minimum Cover (in inches)
Slabs and Joists - Top and bottom bars for dry conditions – No. 14 and No. 18 bars: No. 11 bars and smaller:	1 1/2 1
Formed concrete surfaces exposed to earth, water, or weather, over, or in contact with, sewage; and for bottoms bearing on work mat, or slabs supporting earth cover - No. 5 bars and smaller: No. 6 through No. 18 bars:	1 1/2 2
Beams and Columns - For dry conditions - Stirrups, spirals and ties: Principal reinforcement: Exposed to earth, water, sewage or weather Stirrups and ties: Principal reinforcement:	1 1/2 2 2 2 1/2
Walls - For dry conditions - No. 11 bars and smaller: No. 14 and No. 18 bars: Formed concrete surfaces exposed to earth, water, sewage or weather, or in contact with ground- Circular tanks with ring tension: All others:	1 1 1/2 2 2
Footings and Base Slabs - At formed surfaces and bottoms bearing on concrete work mat: At unformed surfaces and bottoms in contact with earth: Over top of piles: Top of footings - - same as slabs	2 3 2

3.08 HANDLING, TRANSPORTING AND PLACING CONCRETE

- A. Conform to applicable requirements of this Section and Chapter 8 of ACI 301- 99: Specifications for Structural Concrete – IP, Chapter 8. Use no aluminum materials in conveying concrete.
- B. Rejected Work: Remove concrete found to be defective or non-conforming in materials or workmanship. Replace rejected concrete with concrete meeting requirements of Contract Documents, at no additional cost to the Owner.
- C. Unauthorized Placement: Place no concrete except in the presence of the Engineer. Notify the Engineer in writing at least 24 hours before placement of concrete.
- D. Placement in Wall Forms:
 - 1. Do not drop concrete through reinforcing steel.
 - 2. Do not place concrete in any form so as to leave an accumulation of mortar on form surfaces above the concrete.
 - 3. Pump concrete or use hoppers and, if necessary, vertical ducts of canvas, rubber or metal (other than aluminum) for placing concrete in forms so it reaches the place of final deposit without separation. Free fall of concrete shall not exceed 4 feet below the ends of pump hoses, ducts, chutes or buggies. Uniformly distribute concrete during depositing.
 - 4. Do not displace concrete in forms more than 6 feet in horizontal direction from place where it was originally deposited.
 - 5. Deposit in uniform horizontal layers not deeper than 2 feet; take care to avoid inclined layers or inclined construction joints except where required for sloping members.
 - 6. Place each layer while the previous layer is still soft.
 - 7. Provide sufficient illumination in form interior so concrete at places of deposit is visible from the deck or runway.
- E. Conveyors and Chutes: Design and arrange ends of chutes, hopper gates and other points of concrete discharge in the conveying, hoisting and placing system so concrete passing from them will not fall separated into whatever receptacle immediately receives it. Conveyors, if used, shall be of a type acceptable to the Engineer. Do not use chutes longer than 50 feet. Slope chutes so concrete of specified consistency will readily flow. If a conveyor is used, it shall be wiped clean by a device operated in such a manner that none of the mortar adhering to the belt will be wasted. All conveyors and chutes shall be covered.

- F. Placement of Slabs: In hot or windy weather, conducive to plastic shrinkage cracks, apply evaporation retardant to slab after screeding in accordance with manufacturer's instructions and recommendations. Do not use evaporation retardant to increase water content of the surface cement paste. Place concrete for sloping slabs uniformly from the bottom of the slab to the top, for the full width of the placement. As work progresses, vibrate and carefully work concrete around slab reinforcement. Screed the slab surface in an up-slope direction.
- G. When adverse weather conditions affect quality of concrete, postpone concrete placement. Do not mix concrete when the air temperature is at or below 40 degrees F and falling. Concrete may be mixed when temperature is 35 degrees F and rising. Take temperature readings in the shade, away from artificial heat. Protect concrete from temperatures below 32 degrees F until the concrete has cured for a minimum of 3 days at 70 degrees F or 5 days at 50 degrees F.

When concrete temperature is 85 degrees F or above, do not exceed 60 minutes between introduction of cement to the aggregates and discharge. When the weather is such that the concrete temperature would exceed 90 degrees F, employ effective means, such as pre-cooling of aggregates and mixing water, using ice or placing at night, as necessary to maintain concrete temperature, as placed, below 90 degrees F.

3.09 PUMPING OF CONCRETE

- A. If pumped concrete does not produce satisfactory results, in the judgment of the Engineer, discontinue pumping operations and proceed with the placing of concrete using conventional methods.
- B. Pumping Equipment: Use a 2-cylinder pump designed to operate with only one cylinder if one is not functioning, or have a standby pump on site during pumping.
- C. The minimum hose (conduit) diameter: Comply with ACI 304.2R-96:Placing Concrete by Pumping Methods.
- D. Replace pumping equipment and hoses (conduits) that do not function properly.
- E. Do not use aluminum conduits for conveying concrete.
- F. Field Quality Control: Take samples for slump, air content and test cylinders at the placement (discharge) end of the line.

3.10 CONCRETE PLACEMENT SEQUENCE

- A. Place concrete in a sequence acceptable to the Engineer. To minimize effects of shrinkage, place concrete in units bounded by construction joints shown. Place alternate units so each unit placed has cured at least 7 days for hydraulic structures, or 3 days for other structures, before contiguous unit or units are placed, except do not

place corner sections of vertical walls until the 2 adjacent wall panels have cured at least 14 days for hydraulic structures and 7 days for other structures.

- B. Level the concrete surface whenever a run of concrete is stopped. To ensure straight and level joints on the exposed surface of walls, tack a wood strip at least 3/4-inch thick to the forms on these surfaces. Carry concrete about 1/2 inch above the underside of the strip. About one hour after concrete is placed, remove the strip, level irregularities in the edge formed by the strip with a trowel and remove laitance.

3.11 TAMPING AND VIBRATING

- A. Thoroughly settle and compact concrete throughout the entire depth of the layer being consolidated, into a dense, homogeneous mass; fill corners and angles, thoroughly embed reinforcement, eliminate rock pockets and bring only a slight excess of water to the exposed surface of concrete during placement. Use ACI 309R-96:Guide for Consolidation of Concrete, Group 3, immersion-type high-speed power vibrators (8,000 to 12,000 rpm) in sufficient number and with sufficient (at least one) standby units. Use Group 2 vibrators only when accepted by the Engineer for specific locations. Do not transport concrete by vibrating.
- B. Use care in placing concrete around waterstops. Carefully work concrete by rodding and vibrating to make sure air and rock pockets have been eliminated. Where flat-strip type waterstops are placed horizontally, work concrete under waterstops by hand, making sure air and rock pockets have been eliminated. Give concrete surrounding the waterstops additional vibration beyond that used for adjacent concrete placement to assure complete embedment of waterstops in concrete.
- C. Concrete in Walls: Internally vibrate, ram, stir, or work with suitable appliances, tamping bars, shovels or forked tools until concrete completely fills forms or excavations and closes snugly against all surfaces. Do not place subsequent layers of concrete until previously-placed layers have been so worked. Provide vibrators in sufficient numbers, with standby units as required, to accomplish the results specified within 15 minutes after concrete of specified consistency is placed in the forms. Keep vibrating heads from contact with form surfaces. Take care not to vibrate concrete excessively or to work it in any manner that causes segregation of its constituents.

3.12 PLACING MASS CONCRETE

- A. Observe the following additional restrictions when placing mass concrete.
 - 1. Use specified superplasticizer.
 - 2. Maximum temperature of concrete when deposited: 70 degrees F.
 - 3. Place in lifts approximately 18 inches thick. Extend vibrator heads into previously-placed layer.

4. Refer to Section 03310 - Structural Concrete for Mass Concreting.

3.13 CONCRETE FINISHING

3.14 FINISHING OF FORMED SURFACES

- A. Unfinished Surfaces: Finish is not required on surfaces concealed from view in completed structure by earth, ceilings or similar cover, unless indicated otherwise on Plans.
- B. Rough Form Finish:
 1. No form facing material is required on rough form finish surfaces.
 2. Patch tie holes and defects. Chip off fins exceeding 1/4 inch in height.
 3. Rough form finish may be used on concrete surfaces which will be concealed from view by earth in completed structure, except concealed surfaces required to have smooth form finish, as shown on Plans.
- C. Smooth Form Finish:
 1. Form facing shall produce smooth, hard, uniform texture on concrete. Use plywood linings or forms in as large sheets as practicable, and with smooth, even edges and close joints.
 2. Patch tie holes and defects. Rub fins and joint marks with wooden blocks to leave smooth, unmarred finished surface.
 3. Provide smooth form finish on the wet face of formed surfaces of water-holding structures, and of other formed surfaces not concealed from view by earth in completed structure, except where otherwise indicated on Plans. Walls that will be exposed after future construction, at locations indicated on Plans, shall have smooth form finish. Smooth form finish on exterior face of exterior walls shall extend below final top of ground elevation. Exterior face of all perimeter grade beams shall have smooth form finish for full depth of grade beam.
- D. Rubbed Finish:
 1. Use plywood linings or forms in as large sheets as practicable, and with smooth, even edges and close joints.
 2. Remove forms as soon as practicable, repair defects, wet surfaces, and rub with No. 16 carborundum stone or similar abrasive. Continue rubbing sufficiently to bring surface paste, remove form marks and fins, and produce smooth, dense

surface of uniform color and texture. Do not use cement paste other than that drawn from concrete itself. Spread paste uniformly over surface with brush. Allow paste to reset, then wash surface with clean water.

3. Use rubbed finish at locations indicated on Plans, except where rubbed finish is indicated for a wall which will be containing a liquid, use spray-applied coating.
- E. Spray-applied Coating: At Contractor's option, in lieu of rubbed finish, spray-applied coating may be applied after defects have been repaired and fins removed. Remove form oil, curing compound and other foreign matter that would prevent bonding of coating. Apply coating in uniform texture and color in accordance with coating manufacturer's instructions.
- F. Related Unformed Surfaces: Tops of piers, walls, bent caps, and similar unformed surfaces occurring adjacent to formed surfaces shall be struck smooth after concrete is placed. Float unformed surfaces to texture reasonably consistent with that of formed surfaces. Continue final treatment on formed surfaces uniformly across unformed surfaces.

3.15 HOT WEATHER FINISHING

- A. When hot weather conditions exist, as defined in the Section, 1.03A "Hot Weather", and as judged by the Engineer, apply evaporation retardant to the surfaces of slabs, topping and concrete fill placements immediately after each step in the finishing process has been completed.

3.16 FINISHING SLABS AND SIMILAR FLAT SURFACES TO CLASS A, B AND C TOLERANCES

- A. Apply Class A, B and C finishes at locations indicated on Plans. Class B or better finish shall be applied if not shown otherwise by the Plans.
- B. Shaping to Contour: Use strike-off templates or approved compacting-type screeds riding on screed strips or edge forms to bring concrete surface to proper contour. See Section 03100 - Concrete Formwork for edge forms and screeds.
- C. Consolidation and Leveling: Concrete to be consolidated shall be as stiff as practicable. Thoroughly consolidate concrete in slabs and use internal vibration in beams and girders of framed slabs and along bulkheads of slabs on grade. Consolidate and level slabs and floors with vibrating bridge screeds, roller pipe screeds or other approved means. After consolidation and leveling, do not permit manipulation of surfaces prior to finishing operations.
- D. Tolerances for Finished Surfaces: Check tolerances by placing straightedge of specified length anywhere on slab. Gap between slab and straightedge shall not exceed tolerance listed for specified class.

Class	Straightedge Length in Feet	Tolerance in Inches
A	10	1/8
B	10	1/4
C	2	1/4

- E. Raked Finish: After concrete has been placed, struck off, consolidated and leveled to Class C tolerance, roughen surface before final set. Roughen with stiff brushes or rakes to depth of approximately 1/4 inch. Notify the Engineer prior to placing concrete requiring initial raked surface finish so that acceptable raked finish standard may be established for project. Protect raked, base-slab finish from contamination until time of topping. Provide raked finish for following:
1. Surfaces to receive bonded concrete topping or fill.
 2. Steep ramps, as noted on Plans.
 3. Additional locations as noted on Plans.
- F. Float Finish:
1. After concrete has been placed, struck off, consolidated and leveled, do not work further until ready for floating. Begin floating when water sheen has disappeared, or when mix has stiffened sufficiently to permit proper operation of power-driven float. Consolidate surface with power-driven floats. Use hand floating with wood or cork-faced floats in locations inaccessible to power-driven machine and on small, isolated slabs.
 2. After initial floating, re-check tolerance of surface with 10-foot straightedge applied at not less than two different angles. Cut down high spots and fill low spots to Class B tolerance. Immediately re-float slab to a uniform, smooth, granular texture.
 3. Provide float finish at locations not otherwise specified and not otherwise indicated on Plans.
- G. Trowel Finish:
1. Apply float finish as previously specified. After power floating, use power trowel to produce smooth surface which is relatively free of defects but which may still contain some trowel marks. Do additional troweling by hand after surface has hardened sufficiently. Do final troweling when ringing sound is produced as trowel is moved over surface. Thoroughly consolidate surface by hand troweling operations.
 2. Produce finished surface free of trowel marks, uniform in texture and appearance and conforming to Class A tolerance. On surfaces intended to

support floor coverings, remove defects which might show through covering by grinding.

3. Provide trowel finish for floors which will receive floor covering and additional locations indicated on Plans.

H. Broom or Belt Finish:

1. Apply float finish as previously specified. Immediately after completing floated finish, draw broom or burlap belt across surface to give coarse transverse scored texture.
2. Provide broom or belt finish at locations indicated on Plans.

3.17 FINISHING SLABS AND SIMILAR FLAT SURFACES TO "F-NUMBER SYSTEM" FINISH

- A. Shaping to Contour: Use strike-off templates or approved compacting-type screeds riding on screed strips or edge forms to bring concrete surface to proper contour. Edge forms and screeds: Conform to Section 03100 - Concrete Formwork.
- B. Consolidation and Leveling: Concrete to be consolidated shall be as dry as practicable. Thoroughly consolidate concrete in slabs and use internal vibration in beams and girders of framed slabs and along bulkheads of slabs on grade. Consolidate and level slabs and floors with vibrating bridge screeds, roller pipe screeds or other approved means. After consolidation and leveling, do not manipulate surfaces prior to finishing operations.
- C. Tolerances for Finished Surfaces: Independent testing laboratory will check floor flatness and levelness in accordance with this Section, 3.23F "Field Quality Control".
- D. Float Finish:
 1. After concrete has been placed, struck off, consolidated and leveled, do not work further until ready for floating. Begin floating when water sheen has disappeared, or when mix has stiffened sufficiently to permit proper operation of power-driven float. Consolidate surface with power-driven floats. Use hand floating with wood or cork-faced floats in locations inaccessible to power-driven machine and on small, isolated slabs.
 2. Check tolerance of surface after initial floating with a 10-foot straightedge applied at not less than two different angles. Cut down high spots and fill low spots. Immediately refloat slab to uniform, smooth, granular texture to F_F20/F_L17 tolerance, unless shown otherwise on Plans.
 3. Provide "F-Number System" float finish at locations indicated on Plans.

- E. Trowel Finish:
1. Apply float finish as previously specified. After power floating, use power trowel to produce smooth surface which is relatively free of defects but which may still contain some trowel marks. Do additional trowelings by hand after surface has hardened sufficiently. Do final troweling when ringing sound is produced as trowel is moved over surface. Thoroughly consolidate surface by hand troweling operations.
 2. Produce finished surface free of trowel marks, uniform in texture and appearance and conforming to an F_F25/F_L20 tolerance for slabs on grade and F_F25/F_L17 for elevated slabs, unless shown otherwise on Plans. On surfaces intended to support floor coverings, remove defects, which might show through covering, by grinding.
 3. Provide "F-Number System" trowel finish at locations indicated on Plans.

3.18 BONDED CONCRETE TOPPING AND FILL

- A. Surface Preparation:
1. Protect raked, base-slab finish from contamination until time of topping. Mechanically remove oil, grease, asphalt, paint, clay stains or other contaminants, leaving clean surface.
 2. Prior to placement of topping or fill, thoroughly dampen roughened slab surface and leave free of standing water. Immediately before topping or fill is placed, scrub coat of bonding grout into surface. Do not allow grout to set or dry before topping or fill is placed.
- B. Concrete Fill:
1. Where concrete fill intersects a wall surface at an angle steeper than 45 degrees from vertical, provide a 1.5-inch deep keyway in the wall at the point of intersection; size keyway so that no portion of the concrete fill is less than 1.5 inches thick. Form keyway in new walls; create by saw cutting the top and bottom lines and chipping in existing walls.
 2. Apply wood float finish to surfaces of concrete fill.
 3. Provide concrete fill at locations shown on Plans.
- C. Bonded Concrete Topping in Bottom of Clarifiers and Thickeners:
1. Minimum thickness of concrete topping: 1 inch. Maximum thickness when swept in by clarifier and thickener equipment: 3 inches.

2. Compact topping and fill by rolling or tamping, bring to established grade, and float. Topping grout placed on sloping slabs shall proceed uniformly from the bottom of the slab to the top, for the full width of the placement. Coat surface with evaporation retardant as needed between finishing operations to prevent plastic shrinkage cracks.
3. Screed topping to true surface using installed equipment. Protect equipment from damage during sweeping-in process. Perform sweeping-in process under supervision of equipment manufacturer's factory representative. After topping has been screeded, apply wood float finish. During finishing, do not apply water, dry cement or mixture of dry cement and sand to the surface.
4. As soon as topping or fill finishing is completed, coat surface with curing compound. After the topping is set and sufficiently hard in clarifiers and where required by the Engineer, fill the tank with sufficient water to cover the entire floor for 14 days.
5. Provide bonded concrete topping in bottom of all clarifiers and thickeners.

3.19 EPOXY PENETRATING SEALER

- A. Surfaces to receive epoxy penetrating sealer: Apply wood float finish. Clean surface and apply sealer in compliance with manufacturer's instructions.
- B. Rooms with concrete curbs or bases: Continue application of floor coating on curb or base to its juncture with masonry wall. Rooms with solid concrete walls or wainscots: Apply minimum 2-inch-high coverage of floor coating on vertical surface.
- C. Mask walls, doors, frames and similar surface to prevent floor coating contact.
- D. When coving floor coating up vertical concrete walls, curbs, bases or wainscots, use masking tape or other suitable material to keep a neat level edge at top of cove.
- E. Provide epoxy penetrating sealer at locations indicated on Plans.

3.20 EPOXY FLOOR TOPPING

- A. Surfaces to receive epoxy floor topping: Apply wood float finish unless recommended otherwise by epoxy floor topping manufacturer. Clean surface and apply epoxy floor topping in compliance with manufacturer's recommendations and instructions. Thickness of topping: 1/8 inch.
- B. Rooms with concrete curbs or bases: Continue application of floor coating on curb or base to its juncture with masonry wall. Rooms with solid concrete walls or wainscots: apply 2-inch-high coverage of floor coating on vertical surface.

- C. Mask walls, doors, frames and similar surfaces to prevent floor coating contact.
- D. When coving floor coating up vertical concrete walls, curbs, bases or wainscots, use masking tape or other suitable material to keep a neat level edge at top of cove.
- E. Finished surface shall be free of trowel marks and dimples.
- F. Provide epoxy floor topping at locations indicated on Plans.

3.21 SEALER/DUSTPROOFER

- A. Where sealer or sealer/dustproofers is indicated on Plans, just prior to completion of construction, apply coat of specified clear sealer/dustproofing compound to exposed interior concrete floors in accordance with manufacturer's instructions.

3.22 NONSLIP FINISH

- A. Apply float finish as specified. Apply two-thirds of required abrasive aggregate by method that ensures even coverage without segregation and re-float. Apply remainder of abrasive aggregate at right angles to first application, using heavier application of aggregate in areas not sufficiently covered by first application. Re-float after second application of aggregate and complete operations with troweled finish. Perform finishing operations in a manner that will allow the abrasive aggregate to be exposed and not covered with cement paste.
- B. Provide nonslip finish at locations indicated on Plans.

3.23 FIELD QUALITY CONTROL

- A. Field inspection and testing will be performed in accordance with ACI 301-99: Specifications for Structural Concrete - IP and under provisions of Sections 01440 – Inspection Services and Section 01450 – Testing Laboratory Services.
- B. Provide free access to Work and cooperate with appointed firm.
- C. Submit proposed mix design to inspection and testing firm for review prior to commencement of Work.
- D. Tests of cement and aggregates may be performed to ensure conformance with specified requirements.
- E. Three concrete test cylinders will be taken for every 50 cu yds or less of concrete or as directed by the Engineer.
- F. One additional test cylinder will be taken during cold weather concreting, cured on job site under same conditions as concrete it represents.

- G. One slump test will be taken for each set of test cylinders taken.
- H. Provide the results of alkalinity tests of concrete used in sanitary structures. Provide one test for each structure. These tests shall be performed by an independent testing laboratory. Perform the test on the concrete covering reinforcing steel on the inside of the pipe or structure. Alkalinity tests are to be in accordance with Encyclopedia of Industrial Chemical Analysis, Vol. 15, Page 230, Interscience Publishers Division, John Wiley and Sons.

3.24 PATCHING

- A. Allow Engineer to inspect concrete surfaces immediately upon removal of forms.
- B. Excessive honeycomb or embedded debris in concrete is not acceptable. Notify Engineer upon discovery.
- C. Patch imperfections in accordance with ACI 301-99: Specifications for Structural Concrete - IP.

3.25 DEFECTIVE CONCRETE

- A. Defective Concrete: Concrete not conforming to required lines, details, dimensions, tolerances or specified requirements.
- B. Repair or replacement of defective concrete will be determined by the Engineer.
- C. Do not patch, fill, touch-up, repair, or replace exposed concrete except upon express direction of Engineer for each individual area.

3.26 CURING

- A. Comply with ACI 308.1-98: Standard Specifications for Curing Concrete. Cure by preventing loss of moisture, rapid temperature change and mechanical injury for a period of 7 curing days when Type II or IP cement has been used and for 3 curing days when Type III cement has been used. Start curing as soon as free water has disappeared from the concrete surface after placing and finishing. A curing day is any calendar day in which the temperature is above 50 degrees F for at least 19 hours. Colder days may be counted if air temperature adjacent to concrete is maintained above 50 degrees F. In continued cold weather, when artificial heat is not provided, removal of forms and shoring may be permitted at the end of calendar days equal to twice the required number of curing days. However, leave soffit forms and shores in place until concrete has reached the specified 28-day strength, unless directed otherwise by the Engineer.
- B. Cure formed surfaces not requiring rub-finished surface by leaving forms in place for the full curing period. Keep wood forms wet during the curing period. Add water as

needed for other types of forms. Or, at Contractor's option, forms may be removed after 2 days and curing compound applied.

C. Rubbed Finish:

1. At formed surfaces requiring rubbed finish, remove forms as soon as practicable without damaging the surface.
2. After rub-finish operations are complete, continue curing formed surfaces by using either approved curing/sealing compounds or moist cotton mats until normal curing period is complete.

D. Unformed Surfaces: Cure by membrane curing compound method.

1. After concrete has received a final finish and surplus water sheen has disappeared, immediately seal surface with a uniform coating of approved curing compound, applied at the rate of coverage recommended by manufacturer or as directed by the Engineer. Do not apply less than 1 gallon per 180 square feet of area. Provide satisfactory means to properly control and check rate of application of the compound.
2. Thoroughly agitate the compound during use and apply by means of approved mechanical power pressure sprayers equipped with atomizing nozzles. For application on small miscellaneous items, hand-powered spray equipment may be used. Prevent loss of compound between nozzle and concrete surface during spraying operations.
3. Do not apply compound to a dry surface. If concrete surface has become dry, thoroughly moisten surface immediately prior to application. At locations where coating shows discontinuities, pinholes or other defects, or if rain falls on a newly coated surface before film has dried sufficiently to resist damage, apply an additional coat of compound at the specified rate of coverage.

3.27 CURING MASS CONCRETE

A. Observe the following additional restrictions when curing mass concrete.

1. Minimum curing period: 2 weeks.
2. When ambient air temperature falls below 32 degrees F, protect surface of concrete against freezing.
3. Do not use steam or other curing methods that will add heat to concrete.
4. Keep forms and exposed concrete continuously wet for at least the first 48 hours after placing, and whenever surrounding air temperature is above 90 degrees F during final curing period.

5. During 2-week curing period, provide necessary controls to prevent ambient air temperature immediately adjacent to concrete from falling more than 30 degrees F in 24 hours.

3.28 REMOVAL OF FORMS

A. Time Limits:

1. When repair of surface defects or finishing is required before concrete is aged, forms on vertical surfaces may be removed as soon as concrete has hardened sufficiently to resist damage from removal operations.
2. Remove top forms on sloping surfaces of concrete as soon as concrete has attained sufficient stiffness to prevent sagging. Loosen wood forms for wall openings as soon as this can be accomplished without damage to concrete. Leave formwork for water-retaining structures in place for at least 2 days. Formwork for non-water-retaining columns, walls, sides of beams and other formwork components not supporting weight of concrete may be removed after 12 hours, provided concrete has hardened sufficiently to resist damage from removal operations, and provided removal of forms will not disturb members supporting weight of concrete.
3. Forms and shoring supporting weight of concrete or construction loads: Leave in place until concrete has reached minimum strength specified for removal of forms and shoring. Do not remove such forms in less than 4 days.

B. Circular Paper or Spiral Tube Forms: Follow manufacturer's directions for form removal. Take necessary precautions to prevent damage to concrete surface. When removal is done before completion of curing time, replace form, tie in place, and seal to retard escape of moisture.

C. Removal Strength:

1. Control Tests: Suitable strength-control tests will be required as evidence that concrete has attained specified strength for removal of formwork or shoring supporting weight of concrete in beams, slabs and other structural members. Furnish test cylinders and data to verify strength for early formremoval.
 - a. Field-cured Test Cylinders: When field-cured test cylinders reach specified removal strength, formwork or shoring may be removed from respective concrete placements.
 - b. Laboratory-cured Test Cylinders: When concrete has been cured as specified for structural concrete for same time period required by laboratory-cured cylinders to reach specified strength, formwork or shoring may be removed from respective concrete placements.

Determine length of time that concrete has been cured by totaling the days or fractions of days, not necessarily consecutive, during which air temperature surrounding concrete is above 50 degrees F and concrete has been damp or thoroughly sealed against evaporation and loss of moisture.

2. Compressive Strengths: The minimum concrete compressive strength for removal of formwork supporting weight of concrete is 75 percent of specified minimum 28-day strength for class of concrete involved.

3.29 RESHORING

- A. When reshoring is permitted, plan operations in advance and obtain the Engineer's approval of such operations. While reshoring is under way, keep live load off new construction. Do not permit concrete in any beam, slab, column or other structural member to be subjected to combined dead and construction loads in excess of loads permitted for developed concrete strength at time of reshoring.
- B. Place reshores as soon as practicable after form-stripping operations are complete but in no case later than end of day on which stripping occurs. Tighten reshores to carry required loads without over stressing construction. Leave reshores in place until tests representative of concrete being supported have reached specified strength at time of removal of formwork supporting weight of concrete.
- C. Floors supporting shores under newly-placed concrete: Leave original supporting shores in place, or re-shore. Locate reshores directly under shore position above. Extend reshoring over a sufficient number of stories to distribute weight of newly-placed concrete, forms and construction live loads in such manner that design superimposed loads of floors supporting shores are not exceeded.

3.30 FORM REUSE

- A. Do not reuse forms that are worn or damaged beyond repair. Thoroughly clean and recoat forms before reuse. For wood and plywood forms to be used for exposed smooth finish, sand or otherwise dress concrete contact surface to original condition or provide form liner facing material. For metal forms, straighten, remove dents and clean to return forms to original condition.

**TABLE 03100A
TOLERANCES FOR FORMED SURFACES CONCRETE IN BUILDINGS****

Variation From	Variation In	For any 10-foot length	For any 20-foot length or any bay	Maximum for Entire Dimension
Plumb or Specified Batter	Lines and Surfaces of Columns, Piers, Walls and Arrises	1/4"	---	1"
	Exposed Corner Columns, Control Joint Grooves, and Other Conspicuous Lines	---	1/4"	1/2"
Level of Specified Grade	Slab Soffits, Ceilings, Beam Soffits, and Arrises (measured before removal of shores),	1/4"	3/8"	3/4"
	Exposed Lintels, Sills, Parapets, Horizontal Grooves and Other Conspicuous Lines	---	1/4"	1/2"
Drawing Dimensions	Position of Linear Building Lines, Columns, Walls and Partitions	---	1/2"	1"
	Size and Location of Sleeves, Floor Openings and Wall Openings	---	---	±1/4"
	Cross Section of Columns, Beams, Slabs, and Walls	---	---	+1/2", -1/4"
	Footings* in Plan	---	---	+2", -1/2"
	Footing Misplacement or Eccentricity in Direction of Error (the lesser of)	---	---	2% of Width or 2"
	Footing Thickness Decrease	---	---	5%
	Footing Thickness Increase	---	---	No Limit
	Step Rise in Flight of Stairs	---	---	±1/8"
	Step Tread in Flight of Stairs	---	---	±1/4"
	Consecutive Step Rise	---	---	±1/16"
	Consecutive Step Tread	---	---	±1/8"

*Footing tolerances apply to concrete dimensions only, not to positioning of vertical reinforcing steel, dowels, or embedded items

**Includes water and wastewater process structures

**TABLE 03100B
TOLERANCE FOR FORMED SURFACES
CONCRETE IN BRIDGES, WHARVES AND MARINE STRUCTURES**

Variation From	Variation In	Maximum
Plumb of Specified Batter	Surfaces of columns, piers and walls	1/2" in 10'
Level or Specified Grade	Top surfaces of slabs	See Section 03345
	Top surfaces of curbs and railings	3/16" in 10'
Drawing Dimensions	Cross section of columns, caps, walls, beams, and similar members	±1/2", -1/4"
	Thickness of deck slabs	±1/4", -1/8"
	Size and location of slab and wall openings	±1/2"
	Footings in plan	+2, -1/2"
	Footing misplacement or eccentricity in direction of error (the lesser of)	2% of width or 2"
	Footing thickness decrease	5%
	Footing thickness increase	No limit
	Step rise in flight of stairs	±1/8"
	Step tread in flight of stairs	±1/4"
	Consecutive step rise	±1/16"
Consecutive step tread	±1/8"	

3.31 PROTECTION

- A. Protect concrete against damage until final acceptance by the Owner.
- B. Protect fresh concrete from damage due to rain, hail, sleet or snow. Provide such protection while the concrete is still plastic and whenever such precipitation is imminent or occurring.
- C. Do not backfill around concrete structures or subject them to design loadings until all components of the structure needed to resist the loading are complete and have reached the specified 28-day compressive strength, except as authorized otherwise by the Engineer.

END OF SECTION

SECTION 03310**STRUCTURAL CONCRETE****1.0 GENERAL****1.01 SECTION INCLUDES**

- A. Cast-in-place normal-weight structural concrete and mass concrete.
- B. References to Technical Specifications:
 - 1. Section 00300 – Bid Proposal
 - 2. Section 01200 – Measurement
 - 3. Section 01350 – Submittals
 - 4. Section 01450 – Testing Laboratory Services
 - 5. Section 03300 – Cast-in-Place Concrete

1.02 MEASUREMENT AND PAYMENT

- A. Measurement for structural concrete is on an each basis for each structure as bid. Payment includes related work performed on these structures in accordance with related sections of these Specifications.
- B. If Extra Structural Concrete is allowed, based on the Engineer's direction, and indicated in Section 00300 – Bid Proposal as an Extra Item, measurement will be on a cubic-yard basis, measured in place. Payment includes related work performed in accordance with related sections of these Specifications.
- C. Refer to Section 01200 – Measurement and Payment for unit price procedures.
- D. No provisions shall be provided for temperature controlled curing of test cylinder. Test cylinder(s) shall be cured in identical environment until picked up by lab.

1.03 DEFINITIONS

- A. Mass Concrete: Concrete sections 4 feet or more in least dimension.
- B. Hot Weather: Any combination of high air temperature, low relative humidity and wind velocity tending to impair quality of fresh or hardened concrete or otherwise resulting in abnormal properties. Hot weather concreting shall be done in accordance with ACI - 305R.
- C. Cold Weather: Period when, for more than 2 successive days, mean daily temperature is below 40 degrees F. Cold weather concreting shall be done in accordance with ACI - 306R.

1.04 SUBMITTALS

- A. Conform to Section 01350 – Submittals.
- B. Mill Certificates: Required for bulk cement.
- C. Design Mixes:
 - 1. Submit test data on proposed design mixes for each type of concrete in the Work, including each class, and variations in type, source or quantity of material. Include type, brand and amount of cementitious materials; type, brand and amount of each admixture; slump; air content; aggregate sources, gradations, specific gravity and absorption; total water (including moisture in aggregate); water/cement ratio; compressive strength test results for 7 and 28 days; and shrinkage tests for Class C and D concrete at 21 or 28 days of drying.
 - 2. Submit abrasion loss and soundness test results for limestone aggregate.
 - 3. Testing of aggregates, including sieve analysis, shall be performed by a certified independent testing laboratory. Tests shall have been performed no earlier than 3 months before Notice to Proceed.
 - 4. Provide standard deviation data for plant producing concrete. Data shall include copies of laboratory test results and standard deviation calculated in accordance with ACI 318, Item 5.3.1. Laboratory tests shall have been performed within past 12 months. When standard deviation data is not available, comply with ACI 318, Table 5.3.2.2.
 - 5. Review and acceptance of mix design does not relieve Contractor of responsibility to provide concrete of quality and strength required by these Specifications.
- D. Admixtures: Submit manufacturer's technical information, including following:
 - 1. Air-Entraining Admixture: Give requirements to control air content under all conditions, including temperature variations and presence of other admixtures.
 - 2. Chemical Admixtures: Give requirements for quantities and types to be used under various temperatures and job conditions to produce uniform, workable concrete mix. Submit evidence of compatibility with other admixtures and cementitious materials proposed for use in design mix.
- E. High-Range Water Reducer (Superplasticizer): When proposed for use, submit manufacturer's technical information and instructions for use of superplasticizer. State whether superplasticizer will be added at ready-mix plant or job site. When superplasticizer will be added at job site, submit proposed plan for measuring and adding superplasticizer to concrete mix at job site, and establish dosing area on site with holding tanks and metering devices. When superplasticizer is to be added at

ready-mix plant, submit contingency plans for adding additional superplasticizer at job site when required due to delay in placing concrete. Identify portions of Work on which superplasticizer is proposed for use.

- F. Hot and Cold Weather Concreting: Submit, when applicable, proposed plans for hot and cold weather concreting. Review and acceptance of proposed procedure will not relieve Contractor of responsibility for quality of finished product.
- G. Project Record Drawings: Accurately record actual locations of embedded utilities and components that are concealed from view.

1.05 QUALITY ASSURANCE

- A. Provide necessary controls during evaluation of materials, mix designs, production and delivery of concrete, placement and compaction to assure that the Work will be accomplished in accordance with Contract Documents. Maintain records of concrete placement. Record dates, locations, quantities, air temperatures, and test samples taken.
- B. Code Requirements: Concrete construction for buildings shall conform to ACI 318. Concrete construction for water and wastewater treatment and conveying structures shall conform to ACI 318 with modifications by ACI 350R, Item 2.6. Where this Specification conflicts with ACI 318 or ACI 350R, this Specification governs.
- C. Testing and Other Quality Control Services:
 - 1. Concrete testing required in this section, except concrete mix design, limestone aggregate test data, and testing of deficient concrete, will be performed by an independent commercial testing laboratory employed and paid by the Owner in accordance with Section 01450 – Testing Laboratory Services.
 - 2. Provide material for and cooperate fully with Owner's testing laboratory technician in obtaining samples for required tests.
 - 3. Standard Services: The following testing and quality control services will be provided by Owner in accordance with Section 01450 – Testing Laboratory Services:
 - a. Verification that plant equipment and facilities conform to NRMCA "Certification of Ready-Mix Concrete Production Facilities".
 - b. Testing of proposed materials for compliance with this Specification.
 - c. Review of proposed mix design submitted by Contractor.

- d. Obtaining production samples of materials at plants or stockpiles during work progress and testing for compliance with this Specification.
- e. Strength testing of concrete according to following procedures:
 - 1) Obtaining samples for field test cylinders from every 100 cubic yards and any portion less than 100 cubic yards for each mix design placed each day, according to ASTM C172, with each sample obtained from a different batch of concrete on a representative, random basis. Selecting test batches by any means other than random numbers chosen before concrete placement begins is not allowed.
 - 2) Molding four specimens from each sample according to ASTM C31, and curing under standard moisture and temperature conditions as specified in Sections 7(a) and (b) of ASTM C31.
 - 3) Testing two specimens at 7 days and two specimens at 28 days according to ASTM C39, reporting test results averaging strengths of two specimens. However, when one specimen evidences improper sampling, molding or testing, it will be discarded and remaining cylinder considered test result. When high-early-strength concrete is used, specimens will be tested at 3 and 7 days.
- f. Air content: For each strength test, determination of air content of normal weight concrete according to ASTM C231.
- g. Slump: For each strength test, and whenever consistency of concrete appears to vary, conducting slump test in accordance with ASTM C143.
- h. Temperature: For each strength test, checking concrete temperature in accordance with ASTM C1064.
- i. Lightweight concrete: For each strength test, or more frequently when requested by the Engineer, determination of air content by ASTM C567 and unit weight by ASTM C567.
- j. Monitoring of current and forecasted climatic conditions to determine when rate of evaporation, as determined by Figure 2.1.5 of ACI 305R, will produce loss of 0.2 pounds of water, or more, per square foot per hour. Testing lab representative will advise Contractor to use hot weather precautions when such conditions will exist during concrete placement, and note on concrete test reports when Contractor has been advised that hot weather conditions will exist.

- k. Class A and D Concrete Shrinkage Tests: Performance of drying shrinkage tests for trial batches as follows:
- 1) Preparation and Testing of Specimens: Compression and drying shrinkage test specimens will be taken in each case from the same concrete sample; shrinkage tests will be considered a part of the normal compression tests for the project. 4-inch by 4-inch by 11-inch prisms with an effective gage length of 10 inches, fabricated, cured, dried and measured in accordance with ASTM C157, modified as follows:
 - (a). Wet curing: Remove specimens from molds at an age of 23 hours ± 1 hour after trial batching and immediately immerse in water at 70 degrees F ± 3 degrees F for at least 30 minutes;
 - (b). Measure within 30 minutes after first 30 minutes of immersion to determine original length (not to be confused with "base length");
 - (c). Then submerge in saturated limewater, at 73 degrees F ± 3 degrees F, for 7 days;
 - (d). Then measure at age 7 days to establish "base length" for drying shrinkage calculations ("zero" days drying age);
 - (e). Calculate expansion (base length expressed as a percentage of original length);
 - (f). Immediately store specimens in a temperature and humidity controlled room maintained at 73 degrees F, ± 3 degrees, and 50 percent relative humidity, ± 4 percent, for the remainder of the test.
 - (g). Measure to determine shrinkage, expressed as percentage of base length. Compute the drying shrinkage deformation of each specimen as the difference between the base length (at "zero" days drying age) and the length after drying at each test age. Compute the average drying shrinkage deformation of the specimens to the nearest 0.0001 inch at each test age. If the drying shrinkage of any specimen departs from the average of that test age by more than 0.0004 inch, disregard the results obtained from that specimen.

Report results of shrinkage tests to the nearest 0.001 percent of shrinkage.

- (h). Report shrinkage separately for 7, 14, 21, and 28 days of drying after 7 days of moist curing.
4. Additional Testing and Quality Control Services: The following will be performed by an independent commercial testing laboratory employed and paid by the Owner in accordance with Section 01450, Testing Laboratory Services, when requested by the Engineer.
 - a. Checking of batching and mixing operations.
 - b. Review of manufacturer's report of each cement shipment and conducting laboratory tests of cement.
 - c. Molding and testing reserve 7-day cylinders or field cylinders.
 - d. Conducting additional field tests for slump, concrete temperature, and ambient temperature.
 - e. Alkalinity Tests: For concrete used in sanitary structures, one test for each structure. Perform alkalinity tests on concrete covering reinforcing steel on the inside of the pipe or structure in accordance with "Encyclopaedia of Industrial Chemical Analysis," Vol. 15, page 230.
5. Contractor shall provide the following testing and quality control services:
 - a. Employ an independent commercial testing laboratory, acceptable to Owner, to prepare and test design mix for each class of concrete for which material source has been changed.
 - b. Notify commercial testing laboratory employed by Owner 24 hours prior to placing concrete.
6. Testing of deficient concrete in place:
 - a. When averages of three consecutive strength test results fail to equal or exceed specified strength, or when any individual strength test result falls below specified strength by more than 500 psi, strength of concrete shall be considered potentially deficient and core testing, structural analysis or load testing may be required by the Engineer.
 - b. When concrete in place proves to be deficient, Contractor shall pay costs, including costs due to delays, incurred in providing additional

- testing and analysis services provided by the Engineer, or the independent commercial testing laboratory selected by the Owner.
- c. Replace concrete work judged inadequate by core tests, structural analysis or load tests at no additional cost to the Owner.
 - d. Core Tests:
 - 1) Obtain and test cores in accordance with ASTM C42. Where concrete in structure will be dry under service conditions, air dry cores (temperature 60 to 80 degrees F, relative humidity less than 60 percent) for 7 days before test; test dry. Where concrete in structure will be more than superficially wet under service conditions, test cores after moisture conditioning in accordance with ASTM C42.
 - 2) Take at least three representative cores from each member or area of concrete in place that is considered potentially deficient. Location of cores shall be determined by the Engineer so as to least impair strength of structure. When, before testing, one or more cores shows evidence of having been damaged during or after removal from structure, replace the damaged cores.
 - 3) Concrete in area represented by core test will be considered adequate when average strength of cores is equal to at least 85 percent of specified strength, and when no single core is less than 75 percent of specified strength.
 - 4) Patch core holes in accordance with Section 03300 – Cast-in-Place Concrete, Paragraph 3.13.
 - e. Structural Analysis: When core tests are inconclusive or impractical to obtain, the Engineer may perform additional structural analysis at Contractor's expense to confirm safety of structure.
 - f. Load Tests: When core tests and structural analysis do not confirm safety of structure, load tests may be required, and their results evaluated, in accordance with ACI 318.
 - g. Testing by impact hammer, sonoscope, probe penetration tests (Windsor probe), or other nondestructive device may be permitted by the Engineer to determine relative strengths at various locations in structure, to evaluate concrete strength in place, or for selecting areas to be cored. However, such tests, unless properly calibrated and correlated with other test data, shall not be used as basis for acceptance or rejection of structure's safety.

1.06 STORAGE AND HANDLING OF MATERIALS

- A. Cement: Store cement in weather tight buildings, bins or silos to provide protection from dampness and contamination and to minimize warehouse set. When there is any doubt as to the expansive potential of shrinkage-compensating cements because of method or length of storage and exposure, laboratory test cement before use.
- B. Aggregate: Arrange and use aggregate stockpiles to avoid excessive segregation or contamination with other materials or with other sizes of like aggregates. Build stockpiles in successive horizontal layers not exceeding 3 feet in thickness. Complete each layer before next is started.
- C. Fine Aggregate: Before using, allow fine aggregate to drain until uniform moisture content is reached.
- D. Admixtures: Store admixtures to avoid contamination, evaporation or damage. For those used in form of suspensions or non-stable solutions, provide suitable agitating equipment to assure uniform distribution of ingredients. Protect liquid admixtures from freezing and other temperature changes which would adversely affect their characteristics.
- E. Lightweight Aggregates: Uniformly pre-dampen lightweight aggregates as necessary to prevent excessive variations in moisture content. Allow pre-dampened aggregates to remain in stockpiles, under continuous fog spray, for minimum of 24 hours before use. Provide adequate drainage in stockpile areas to eliminate excess water and accumulation of contaminated fines.

2.0 PRODUCTS

2.01 MATERIALS

- A. Cement:
 - 1. Use same brand of cement used in concrete mix design. Use only one brand of each type in each structure, unless otherwise indicated on Drawings.
 - 2. Portland Cement: ASTM C150, Type I or Type II, gray in color. Use Type III only when specifically authorized by the Engineer in writing. Use Type II, including the requirements of Table 2, in construction of liquid-containing structures and cooling towers, unless shown otherwise on Drawings.
- B. Admixtures:
 - 1. Do not use calcium chloride, thiocyanate or admixtures containing more than 0.05 percent chloride ions.
 - 2. Air-Entraining Admixtures: ASTM C260, compatible with other admixtures used.

3. Chemical Admixtures: Polymer type, non-staining, chloride-free admixtures conforming to ASTM C494, Type A, C, D or E.
 4. High-Range Water Reducer (Superplasticizer): ASTM C494, Type F or G, compatible with and by the same manufacturer as other admixtures.
- C. Mixing Water: Use clean, potable water, free from harmful amounts of oils, acids, alkalis or other deleterious substances, meeting requirements of ASTM C94.
- D. Aggregates: Use coarse aggregate from only one source and fine aggregate from only one source, for exposed concrete in any single structure.
1. Coarse Aggregate: Gravel, crushed gravel or crushed limestone conforming to ASTM C33.
 2. Fine Aggregate: Natural sand complying with ASTM C33.
 3. Limestone aggregate shall conform to ASTM C33 and the following additional requirements:
 - a. Clean, hard, strong and durable particles free of chemicals and coatings of silt, clay, or other fine materials that may affect hydration and bond of cement paste.
 - b. Select crushed limestone: High-calcium limestone (minimum 95 percent CaCO_3 and maximum 3.5 percent MgCO_3) with maximum Los Angeles Abrasion loss of 38 percent, when tested in accordance with ASTM C131 or ASTM C535.
 - c. Test aggregate for soundness in accordance with ASTM C88; maximum loss shall not exceed 18 percent after 5 cycles of magnesium sulfate test.
 4. Maximum size of coarse aggregate:
 - a. Normal weight concrete, except as noted below: 1-1/2 inches.
 - b. Formed members 6 inches or less in least dimension: 1/5 least dimension.
 - c. Slabs: 1/3 depth of slab.
 - d. Drilled shafts: 1/3 clearance between reinforcing steel, but not greater than 3/4 inch.
 - e. Concrete fill, seal slabs and bonded concrete topping in clarifiers: 3/8 inch.

5. Coarse aggregate for lightweight concrete: ASTM C330. Grading limits: 3/4 inch to No. 4.
 6. Abrasive Aggregate: Conform to requirements of Section 03300 – Cast-in-Place Concrete, Paragraph 3.13.
- E. Calcium Chloride: Not permitted.
- F. Evaporation Retardant: Masterbuilders "Confilm", Euclid "Eucobar", or equal.
- G. Miscellaneous Materials:
1. Bonding Agent: Two-component modified epoxy resin.
 2. Vapor barrier: 6-mil clear polyethylene film of type recommended for below-grade application.
 3. Non-shrink grout: premixed compound consisting of non-metallic aggregate, cement and water-reducing and plasticizing agents; capable of developing minimum compressive strength of 2,400 psi in 48 hours and 7,000 psi in 28 days.

2.02 CONCRETE MIX

- A. Objective: Select proportions of ingredients to produce concrete having proper placability, durability, strength, appearance and other specified properties.
- B. Mix Design: Employ and pay an independent commercial testing laboratory, acceptable to Owner, to prepare and test mix designs for each type of concrete specified. Proportion mix design ingredients by weight. Submit mix designs and test results for approval.
1. During the trial batches, aggregate proportions may be adjusted by the testing laboratory using two coarse aggregate size ranges to obtain the required properties. If one size range produces an acceptable mix, a second size range need not be used. Such adjustments shall be considered refinements to the mix design and shall not be the basis for extra compensation to the Contractor. Concrete shall conform to the requirements of this Section, whether the aggregate proportions are from the Contractor's preliminary mix design, or whether the proportions have been adjusted during the trial batch process. Prepare trial batches using the aggregates, cement and admixtures proposed for the project. Make trial batches large enough to obtain 3 drying shrinkage test specimens and 6 compression test specimens from each batch. Shrinkage testing is required only for Class A and D concrete.

2. Determine compressive strength by testing 6-inch diameter by 12-inch high cylinders, made, cured and tested in accordance with ASTM C192 and ASTM C39. Test 3 compression test cylinders at 7 days and 3 at 28 days. Average compressive strength for the 3 cylinders tested at 28 days for any given trial batch shall be not less than 125 percent of the specified compressive strength.
3. Perform sieve analysis of the combined aggregate for each trial batch according to of ASTM C136. Report percentage passing each sieve.
4. In mix designs for Class A and D concrete, fine aggregate shall not exceed 41 percent of total aggregate by weight.

C. Shrinkage Limitations, Class A and D Concrete

1. Maximum concrete shrinkage for specimens cast in the laboratory from the trial batch: 0.036 percent as measured at 21-day drying age or 0.042 percent at 28-day drying age. Use for construction only mix designs that meet trial batch shrinkage requirements. Shrinkage limitations apply only to Class A and D concrete.
2. Maximum concrete shrinkage for specimens cast in the field shall not exceed the trial batch maximum shrinkage requirement by more than 25 percent.
3. If the required shrinkage limitation is not met during construction, take any or all of the following actions, at no additional cost to the Owner, for securing the specified shrinkage requirements: Changing the source or aggregates, cement or admixtures; reducing water content; washing of aggregate to reduce fines; increasing the number of construction joints; modifying the curing requirements; or other actions designed to minimize shrinkage or its effects.

D. Selecting Ingredient Proportions for Concrete:

1. Proportion concrete mix according to ACI 301, Chapter 3.
2. Establish concrete mix design by laboratory trial batches prepared by independent testing laboratory, or on basis of previous field experience in accordance with provisions of ACI 318, Item 5.3; however, minimum cement content for each class of concrete shall not be less than specified.
3. Concrete mix design data submitted for review shall have average 28-day compressive strength calculated in accordance with ACI 318, Item 5.3.2.1. When data is not available to determine standard deviation in accordance with ACI 318, Item 5.3.1, average 28-day strength of mix design shall conform to ACI 318, Table 5.3.2.2.

E. Water-Cement Ratios:

1. Maximum allowable water-cement ratios shall be as follows:

- a. Concrete for liquid-containing structures: 0.45.
 - b. Concrete subjected to brackish water, salt spray or deicers: 0.40.
 - c. All other concrete: 0.55.
2. Superplasticizer may be added to maintain specified maximum water-cement ratios. Include free water in aggregate in water-cement ratio computations.
- F. Adjustment of Mix Proportions: After sufficient data becomes available during construction, mix may be adjusted upon approval of the Engineer, in accordance with ACI 318, Item 5.5; however, minimum cement content for each class of concrete shall not be less than specified.
- G. Entrained Air: Air-entrain all concrete except drilled shafts. Total air content in accordance with ASTM C173: 4 to 6 percent.
- H. Consistency, Workability, and Slump:
- 1. The quantity of water in a batch of concrete shall be just sufficient, with a normal mixing period, to produce concrete which can be worked properly into place without segregation, and which can be compacted by vibratory methods as specified, to give the desired strength, density, impermeability and smoothness of surface. Change the quantity of water as necessary, with variations in the nature or moisture content of the aggregates, to maintain uniform production of a desired consistency. Determine the consistency of the concrete in successive batches by slump tests in accordance with ASTM C 143. Slumps shall be as follows:

Concrete Type	Minimum Slump	Maximum Slump
Portland Cement Concrete	2"	4"
Concrete to be dosed with superplasticizer:	1"	3"
Normal Weight Concrete after dosing with superplasticizer	4"	9"
Lightweight Concrete after dosing with superplasticizer	4"	7"
Drilled Shaft Concrete:	4"*	8"

* Minimum slump where drilled shafts are cast in temporary casings: 5 inches

- 2. Specified slump shall apply at time when concrete is discharged at job site. Perform slump tests to monitor uniformity and consistency of concrete delivered to job site; however, do not use as basis for mix design. Do not exceed water-cement ratios specified.

- I. Admixtures: Proportion admixtures according to manufacturer's recommendations. Use of accelerator is permitted when air temperature is less than 40 degrees F. Use of retarder is permitted when temperature of placed concrete exceeds 65 degrees F.
- J. High-Range Water Reducers (Superplasticizers): Use superplasticizer to improve workability of concrete or delay hydration of cement, in accordance with requirements and recommendations of product manufacturer and approved submittals.
- K. Concrete Classification and Strength:
 - 1. Strength: Conform to values for class of concrete indicated on Drawings for each portion of Work. Requirements are based on 28-day compressive strength. If high early-strength concrete is allowed, requirements are based on 7-day compressive strength.

2. Classification:

Class (Normal-weight)	Minimum 28-day Compressive Strength (psi)	Minimum Cement Content Pounds per Cubic Yard
Concrete for Structures Containing Water or Wastewater		
A	4,000	564 (6 sacks)
B	1,500	329 (3 ½ sacks)
C	3,000	470 (5 sacks)
D	5,000	658 (7 sacks)
H	3,000	611 (6 ½ sacks)
Concrete for Buildings, Slabs on Grade and Miscellaneous Structures		
AB	4,000	Not Applicable
BB	1,500	Not Applicable
CB	3,000	Not Applicable
DB	5,000	Not Applicable

Class (Light-weight)	Minimum 28-day Compressive Strength (psi)	Minimum Cement Content Pounds per Cubic Yard
E	3,000	Not Applicable
F	4,000	Not Applicable
G	5,000	Not Applicable

- 3. Maximum size aggregate for Class H concrete: 3/8 inch. Maximum size aggregate for all other normal-weight concrete: 1-1/2 inches, except as specified in Paragraph 2.01D.4.
- 4. When required strength is not obtained with minimum cement content as specified, add cement, lower water-cement ratio or provide other aggregates as necessary.

5. In addition to conforming to specified strength, lightweight concrete must be within specified unit weight limits. Maximum air-dry unit weight is 118 pounds per cubic foot; minimum is 110 pounds per cubic foot unless shown otherwise on Drawings. Determine air-dry unit weight in accordance with ASTM C567. Correlate air-dry unit weight with fresh unit weight of the same concrete as a basis for acceptance during construction.
- L. Use of Classes of Concrete:
1. Use classes of concrete as indicated on the Drawings and in other specifications.
 2. Liquid-containing structures: If not otherwise indicated, use the following classes for structures containing water or wastewater and for utility applications in the locations described:
 - a. Class A: All reinforced concrete and where not otherwise defined.
 - b. Class B: Unreinforced concrete used for plugging pipes, seal slabs, thrust blocks, and trench dams, unless indicated otherwise.
 - c. Class H: Fill and topping. Where concrete fill thickness exceeds 3 inches in the majority of a placement and is not less than 1.5 inches thick, Class A concrete may be used.
 3. All other structures: If not otherwise indicated, use the following classes in the locations described:
 - a. Class AB: All reinforced concrete and where not otherwise defined.
 - b. Class CB: Duct banks; see Section 16402 – Underground Duct Banks for additional requirements.
 - c. Class BB: Unreinforced concrete fill under structures.

2.03 MIXING NORMAL WEIGHT CONCRETE

- A. Conform to ACI 301, Chapter 7.
- B. Ready-Mixed Concrete:
 1. Measure, batch, mix and transport ready-mixed concrete according to ASTM C94. Plant equipment and facilities shall conform to NRMCA "Certification of Ready Mixed Concrete Production Facilities".

2. Provide batch tickets with information specified in ASTM C94. Deliver batch ticket with concrete and give to Owner's on-site testing laboratory representative.
- C. Batch Mixing at Site:
1. Mix concrete in batch mixer conforming to requirements of CPMB "Concrete Plant Mixer Standards". Use mixer equipped with suitable charging hopper, water storage tank and water measuring device. Batch mixer shall be capable of mixing aggregates, cement and water into uniform mass within specified mixing time, and of discharging mix without segregation. Operate mixer according to rated capacity and recommended revolutions per minute printed on manufacturer's rating plate.
 2. Charge batch into mixer so some water will enter before cement and aggregates. Keep water running until one-fourth of specified mixing time has elapsed. Provide controls to prevent discharging until required mixing time has elapsed. When concrete of normal weight is specified, provide controls to prevent addition of water during mixing. Discharge entire batch before mixer is recharged.
 3. Mix each batch of 2 cubic yards or less for not less than 1 minute and 30 seconds. Increase minimum mixing time 15 seconds for each additional cubic yard or fraction of cubic yard.
 4. Keep mixer clean. Replace pick-up and throw-over blades in drum when they have lost 10 percent of original depth.
- D. Admixtures:
1. Charge air-entraining and chemical admixtures into mixer as solution using automatic dispenser or similar metering device. Measure admixture to accuracy within ± 3 percent. Do not use admixtures in powdered form.
 2. Two or more admixtures may be used in same concrete, provided that admixtures in combination retain full efficiency and have no deleterious effect on concrete or on properties of each other. Inject admixtures separately during batching sequence.
 3. Add retarding admixtures as soon as practicable after addition of cement.
- E. Temperature Control:
1. When ambient temperature falls below 40 degrees F, keep as-mixed temperature above 55 degrees F to maintain concrete above minimum placing temperature.

2. When water or aggregate has been heated, combine water with aggregate in mixer before cement is added. Do not add cement to mixtures of water and aggregate when temperature of mixture is greater than 100 degrees F.
3. In hot weather, maintain temperature of concrete below maximum placing temperature. When necessary, temperature may be lowered by cooling ingredients, cooling mixer drum by fog spray, using chilled water or well-crushed ice in whole or part for added water, or arranging delivery sequence so that time of transport and placement does not generate unacceptable temperatures.
4. Submit hot weather and cold weather concreting plans for approval.

2.04 MIXING LIGHTWEIGHT CONCRETE

- A. Determining Absorption of Aggregates: Mixing procedures vary according to total absorption by weight of lightweight aggregates. Determine total absorption by weight before pre-dampening in accordance with ASTM C127.
- B. Ten Percent or Less Absorption: Follow same requirements as for mixing normal-weight concrete when preparing concrete made with low-absorptive lightweight aggregates having 10 percent or less total absorption by weight. To be low-absorptive, aggregates must absorb less than 2 percent additional water in first hour after mixing.
- C. More Than 10 Percent Absorption: Batch and mix concrete made with lightweight aggregates having more than 10 percent total absorption by weight, as follows:
 1. Place approximately 80 percent of mixing water in mixer.
 2. If aggregates are pre-dampened, add air-entraining admixture and all aggregates. Mix for minimum of 30 seconds, or 5 to 10 revolutions of truck mixer.
 3. When aggregates have not been pre-dampened, mix aggregates and water for minimum of 1 minute and 30 seconds, or 15 to 30 revolutions of truck mixer. Then add air-entraining admixture and mix for additional 30 seconds.
 4. Then, in the following sequence, add specified or permitted admixtures (other than air-entraining agent), all cement, and mixing water previously withheld.
 5. Complete mixing using procedures for normal-weight concrete.

2.05 MASS CONCRETE

- A. Do not use high early-strength cement (Type III) or accelerating admixtures.

- B. Use high-range water-reducing admixture (superplasticizer) to minimize water content and cement content.
- C. Specified water-reducing retarding admixture may be required to prevent coldjoints when placing large quantities of concrete, to permit revibration of concrete, to offset effects of high temperature in concrete or weather, and to reduce maximum temperature or rapid temperature rise.

2.06 EQUIPMENT

- A. Select equipment of size and design to ensure continuous flow of concrete at delivery end. Conform to following equipment and operations requirements.
- B. Truck mixers, agitators and manner of operation: Conform to ASTM C94. Use of non-agitating equipment for transporting concrete is not permitted.
- C. Belt conveyors: Configure horizontally, or at a slope causing no segregation or loss. Use approved arrangement at discharge end to prevent separation. Discharge long runs without separation into hopper.
- D. Chutes: Metal or metal-lined (other than aluminum). Arrange for vertical-to-horizontal slopes not more than 1 to 2 or less than 1 to 3. Chutes longer than 20 feet or not meeting slope requirements may be used if concrete is discharged into hopper before distribution.
- E. Do not use aluminum or aluminum-alloy pipe or chutes for conveying concrete.

3.0 EXECUTION

3.01 SPECIAL CONSIDERATIONS

- A. **Concreting Under Water:** Not permitted except where shown otherwise on Drawings or approved by the Engineer. When shown or permitted, deposit concrete under water by methods acceptable to the Engineer so fresh concrete enters mass of previously-placed concrete from within, causing water to be displaced with minimum disturbance at surface of concrete.
- B. **Protection from Adverse Weather:** Unless adequate protection is provided or the Engineer's approval is obtained, do not place concrete during rain, sleet, snow or freezing weather. Do not permit rainwater to increase mixing water or to damage surface finish. If rainfall occurs after placing operations begin, provide adequate covering to protect Work.

3.02 PREPARATION OF SURFACES FOR CONCRETING

- A. **Earth Surfaces:**

1. Under interior slabs on grade, install vapor barrier. Lap joints at least 6 inches and seal watertight with tape, or sealant applied between overlapping edges and ends. Repair vapor barrier damaged during placement of reinforcing and inserts with vapor barrier material; lap over damaged areas at least 6 inches and seal watertight.
 2. Other Earth Surfaces: Thoroughly wet by sprinkling prior to placing concrete, and keep moist by frequent sprinkling up to time of placing concrete thereon. Remove standing water. Surfaces shall be free from standing water, mud and debris at the time of placing concrete.
- B. Construction Joints:
1. Definition: Concrete surfaces upon or against which concrete is to be placed, where the placement of the concrete has been interrupted so that, in the judgment of the Engineer, new concrete cannot be incorporated integrally with that previously placed.
 2. Interruptions: When placing of concrete is to be interrupted long enough for the concrete to take a set, use forms or other means to shape the working face to secure proper union with subsequent work. Make construction joints only where acceptable to the Engineer.
 3. Preparation: Give horizontal joint surfaces a compacted, roughened surface for good bond. Except where the Drawings call for joint surfaces to be coated, clean joint surfaces of laitance, loose or defective concrete and foreign material by hydroblasting or sandblasting (exposing aggregate), roughen surface to expose aggregate to a depth of at least 1/4 inch and wash thoroughly. Remove standing water from the construction joint surface before new concrete is placed.
 4. After surfaces have been prepared cover approximately horizontal construction joints with a 3-inch lift of a grout mix consisting of Class A concrete batched without coarse aggregate; place and spread grout uniformly. Place wall concrete on the grout mix immediately thereafter.
- C. Set and secure reinforcement, anchor bolts, sleeves, inserts and similar embedded items in the forms where indicated on Contract Drawings, shop drawings and as otherwise required. Obtain the Engineer's acceptance before concrete is placed. Accuracy of placement is the sole responsibility of the Contractor.
- D. Place no concrete until at least 4 hours after formwork, inserts, embedded items, reinforcement and surface preparation have been completed and accepted by the Engineer. Clean surfaces of forms and embedded items that have become encrusted with grout or previously-placed concrete before placing adjacent concrete.

- E. Casting New Concrete Against Old: Where concrete is to be cast against old concrete (any concrete which is greater than 60 days of age), thoroughly clean and roughen the surface of the old concrete by hydroblasting or sandblasting (exposing aggregate). Coat joint surface with epoxy bonding agent following manufacturer's written instructions, unless indicated otherwise. Unless noted otherwise, this provision does not apply to vertical wall joints where waterstop is installed.
- F. Protection from Water: Place no concrete in any structure until water entering the space to be filled with concrete has been properly cut off or diverted and carried out of the forms, clear of the work. Deposit no concrete underwater without special methods. Do not allow still water to rise on any concrete until concrete has attained its initial set. Do not allow water to flow over the surface of any concrete in a manner and at a velocity that will damage the surface finish of the concrete. Pumping, dewatering and other necessary operations for removing ground water, if required, are subject to the Engineer's review.
- G. Corrosion Protection: Position and support pipe, conduit, dowels and other ferrous items to be embedded in concrete construction prior to placement of concrete so there is at least a 2 inch clearance between them and any part of the concrete reinforcement. Do not secure such items in position by wiring or welding them to the reinforcement.
- H. Where practicable, provide for openings for pipes, inserts for pipe hangers and brackets, and setting of anchors during placing of concrete.
- I. Accurately set anchor bolts and maintain in position with templates while they are being embedded in concrete.
- J. Cleaning: Immediately before concrete is placed, thoroughly clean dirt, grease, grout, mortar, loose scale, rust and other foreign substances from surfaces of metalwork to be in contact with concrete.

3.03 HANDLING, TRANSPORTING AND PLACING CONCRETE

- A. Conform to applicable requirements of Chapter 8 of ACI 301 and this Section. Use no aluminum materials in conveying concrete.
- B. Rejected Work: Remove concrete found to be defective or non-conforming in materials or workmanship. Replace rejected concrete with concrete meeting requirements of Contract Documents, at no additional cost to the Owner.
- C. Unauthorized Placement: Place no concrete except in the presence of the Engineer. Notify the Engineer in writing at least 24 hours before placement of concrete.
- D. Placement in Wall Forms:
 - 1. Do not drop concrete through reinforcing steel that will not be covered by current pour.

2. Do not place concrete in any form so as to leave an accumulation of mortar on form surfaces above the concrete.
 3. Pump concrete or use hoppers and, if necessary, vertical ducts of canvas, rubber or metal (other than aluminum) for placing concrete in forms so it reaches the place of final deposit without separation. Free fall of concrete shall not exceed 4 feet below the ends of pump hoses, ducts, chutes or buggies. Uniformly distribute concrete during depositing.
 4. Do not displace concrete in forms more than 6 feet in horizontal direction from place where it was originally deposited. Do not transport concrete with vibrators.
 5. Deposit in uniform horizontal layers not deeper than 2 feet; take care to avoid inclined layers or inclined construction joints except where required for sloping members.
 6. Place each layer while the previous layer is still soft. Rate of placement shall not exceed 5 feet of vertical rise per hour.
 7. Provide sufficient illumination in form interior so concrete at places of deposit is visible from the deck or runway.
- E. Conveyors and Chutes: Design and arrange ends of chutes, hopper gates and other points of concrete discharge in the conveying, hoisting and placing system so concrete passing from them will not fall separated into whatever receptacle immediately receives it. Conveyors, if used, shall be of a type acceptable to the Engineer. Do not use chutes longer than 50 feet. Slope chutes so concrete of specified consistency will readily flow. If a conveyor is used, it shall be wiped clean by a device operated in such a manner that none of the mortar adhering to the belt will be wasted. All conveyors and chutes shall be covered.
- F. Placement of Slabs: In hot or windy weather, conducive to plastic shrinkage cracks, apply evaporation retardant to slab after screeding in accordance with manufacturer's instructions and recommendations. Do not use evaporation retardant to increase water content of the surface cement paste. Place concrete for sloping slabs uniformly from the bottom of the slab to the top, for the full width of the placement. As work progresses, vibrate and carefully work concrete around slab reinforcement. Scream the slab surface in an up-slope direction.
- G. When adverse weather conditions affect quality of concrete, postpone concrete placement. Do not mix concrete when the air temperature is at or below 40 degrees F and falling. Concrete may be mixed when temperature is 35 degrees F and rising. Take temperature readings in the shade, away from artificial heat. Protect concrete from temperatures below 32 degrees F until the concrete has cured for a minimum of 3 days at 70 degrees F or 5 days at 50 degrees F.

- H. When concrete temperature is 85 degrees F or above, do not exceed 60 minutes between introduction of cement to the aggregates and discharge. When the weather is such that the concrete temperature would exceed 90 degrees F, employ effective means, such as pre-cooling of aggregates and mixing water, using ice or placing at night, as necessary to maintain concrete temperature, as placed, below 90 degrees F.

3.04 PUMPING OF CONCRETE

- A. If pumped concrete does not produce satisfactory results, in the judgment of the Engineer, discontinue pumping operations and proceed with the placing of concrete using conventional methods.
- B. Pumping Equipment: Use a 2-cylinder pump designed to operate with only one cylinder if one is not functioning, or have a standby pump on site during pumping.
- C. The minimum hose (conduit) diameter: Comply with ACI 304.2R.
- D. Replace pumping equipment and hoses (conduits) that do not function properly.
- E. Do not use aluminum conduits for conveying concrete.
- F. Field Control: Take samples for slump, air content and test cylinders at the placement (discharge) end of the line.

3.05 CONCRETE PLACEMENT SEQUENCE

- A. Place concrete in a sequence acceptable to the Engineer. To minimize effects of shrinkage, place concrete in units bounded by construction joints shown. Place alternate units so each unit placed has cured at least 7 days for hydraulic structures, or 3 days for other structures, before contiguous unit or units are placed, except do not place corner sections of vertical walls until the 2 adjacent wall panels have cured at least 14 days for hydraulic structures and 7 days for other structures.
- B. Level the concrete surface whenever a run of concrete is stopped. To ensure straight and level joints on the exposed surface of walls, tack a wood strip at least 3/4-inch thick to the forms on these surfaces. Carry concrete about 1/2-inch above the underside of the strip. About one hour after concrete is placed, remove the strip, level irregularities in the edge formed by the strip with a trowel and remove laitance.

3.06 TAMPING AND VIBRATING

- A. Thoroughly settle and compact concrete throughout the entire depth of the layer being consolidated, into a dense, homogeneous mass; fill corners and angles, thoroughly embed reinforcement, eliminate rock pockets and bring only a slight excess of water to the exposed surface of concrete during placement. Use ACI 309R Group 3 immersion-type high-speed power vibrators (8,000 to 12,000 rpm) in sufficient number and with

sufficient (at least one) standby units. Use Group 2 vibrators only when accepted by the Engineer for specific locations.

- B. Use care in placing concrete around waterstops. Carefully work concrete by rodding and vibrating to make sure air and rock pockets have been eliminated. Where flat-strip type waterstops are placed horizontally, work concrete under waterstops by hand, making sure air and rock pockets have been eliminated. Give concrete surrounding the waterstops additional vibration beyond that used for adjacent concrete placement to assure complete embedment of waterstops in concrete.
- C. Concrete in Walls: Internally vibrate, ram, stir, or work with suitable appliances, tamping bars, shovels or forked tools until concrete completely fills forms or excavations and closes snugly against all surfaces. Do not place subsequent layers of concrete until previously-placed layers have been so worked. Provide vibrators in sufficient numbers, with standby units as required, to accomplish the results specified within 15 minutes after concrete of specified consistency is placed in the forms. Keep vibrating heads from contact with form surfaces. Take care not to vibrate concrete excessively or to work it in any manner that causes segregation of its constituents.

3.07 PLACING MASS CONCRETE

- A. Observe the following additional restrictions when placing mass concrete.
 - 1. Use specified superplasticizer.
 - 2. Maximum temperature of concrete when deposited: 70 degrees F.
 - 3. Place in lifts approximately 18 inches thick. Extend vibrator heads into previously-placed layer.

3.08 REPAIRING SURFACE DEFECTS AND FINISHING

- A. Conform to Section 03300 - Cast-in-Place Concrete.

3.09 CURING

- A. Conform to Section 03300 - Cast-in-Place Concrete.

3.10 PROTECTION

- A. Protect concrete against damage until final acceptance by the Owner.
- B. Protect fresh concrete from damage due to rain, hail, sleet or snow. Provide such protection while the concrete is still plastic and whenever such precipitation is imminent or occurring.

- C. Do not backfill around concrete structures or subject them to design loadings until all components of the structure needed to resist the loading are complete and have reached the specified 28-day compressive strength, except as authorized otherwise by the Engineer.

END OF SECTION

SECTION 03600

STRUCTURAL

GROUT

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Non-shrink grout used wherever grout is shown in the Documents, unless another type is specifically referenced. Two classes of non-shrink grout (Class I and II) and areas of application are specified.

1.02 UNIT PRICES

- A. Include the cost for grout in the lump sum for each structure in which it will be used. No separate payment will be made for grout.
- B. Measurement for extra grout (Class I and II) is on cubic foot basis. Payment includes associated work performed in accordance with related sections included in the Contract Documents.

1.03 SUBMITTALS

- A. Conform to all provisions and sections of these specifications.
- B. Quality Control:
 - 1. The Contractor shall submit manufacturer's literature certifying compliance with the specified properties for Class I and II grouts.
 - 2. The Contractor shall submit manufacturer's literature containing instructions and recommendations on the mixing, handling, placement and appropriate uses for each type of grout used in the work.
- C. The Contractor shall submit manufacturer's written warranty as specified.

1.04 QUALITY ASSURANCE

- A. Field Tests:
 - 1. Compression test specimens will be taken during construction from the first placement of each type of grout, and at intervals thereafter as selected by the Engineer to ensure continued compliance with these Specifications. The specimens will be made by the Owner's Representative or its representative.
 - 2. Compression tests and fabrication of specimens for non-shrink grout will be

performed as specified in ASTM C109 at intervals during construction as selected by the Owner's Representative. A set of three specimens will be

made for testing at 7 days, 28 days, and each additional time period as appropriate.

- 3. Grout already placed which fails to meet the requirements of these Specifications is subject to removal and replacement no additional cost to the Owner.
- 4. The cost of laboratory tests on grout will be borne by the Owner, but the Contractor shall assist the Owner’s Representative obtaining specimens for testing. However, the Contractor shall be charged for the cost of any additional tests and investigation on work performed which does not meet the Specifications. The Contractor shall supply materials necessary for fabricating the test specimens.

B. Warranty:

- 1. Provide 1-year warranty for work provided under this Section.
- 2. Manufacturer's warranty shall not contain a disclaimer limiting responsibility to only the purchase price of products or materials furnished.
- 3. Manufacturer shall warrant participation with Contractor in replacing or repairing grout found to be defective due to faulty materials, as determined by industry standard test methods.

PART 2 PRODUCTS

2.01 APPLICATION

- A. The following is a listing of typical applications and the corresponding type of grout which is to be used. Unless indicated otherwise, grouts shall be provided as listed below whether or not called for on the Drawings.

Application:	Type of Grout
Structural member base plates	Non-shrink Class II
Storage tanks and other equipment	Non-shrink Class I
Filling blockout spaces for embedded items such as railing posts, gate guide frames, etc.	Non-shrink Class II (Class I where placement time exceeds 15 minutes)
Under precast concrete elements	Non-shrink Class I

Toppings and concrete fill less than 3 inches thick	Concrete Topping per Section 03310 and Section 03345
Toppings and concrete fill greater than 3 inches thick	Concrete Fill per Section 03310 and Section 03345
Any application not listed above, where grout is called for on the Drawing.	Non-shrink Class I, unless noted otherwise

2.02 PREPACKAGED GROUTS

A. Basic Requirements for Cementitious Non-Shrink Grout

1. Provide prepackaged non-shrink grout that is inorganic, flowable, non-gas-liberating, non-metallic, and cement-based, requiring only the addition of water.
2. Deliver grout in original packaging with manufacturer's instructions printed on each container.
3. Select the specific formulation for each class of non-shrink grout specified to conform to that recommended by the manufacturer for the particular application.
4. Compressive strength at 28 days: 7000 psi minimum.
5. Do not use a grout for which the non-shrink property is based on a chemically generated gas or gypsum expansion.

B. Class I Non-Shrink Grout:

1. Supply Class I Grout conforming to these specifications and to CRD-C621 and ASTM C1107 Grade C and B (as modified below) when tested using the amount of water needed to achieve the following properties:
 - a. Fluid consistency (20 to 30 seconds) per CRD-C611 at initial testing.
 - b. Fluid consistency (45 seconds) per CRD-C611 at 30 minutes after mixing.
 - c. At temperatures of 45, 73.4, and 95 degrees F.

2. To satisfy non-shrink requirements, the length change from placement to time of final set shall not have a shrinkage greater than the amount of expansion measured after final set at 3 and 14 days. The expansion at 3 and 14 days shall not exceed the 28-day expansion.
 3. Fluid grout shall pass through the flow cone, with a continuous flow, 1 hour after mixing.
 4. Demonstrate in tests that grout maintains contact with the base plate to provide a minimum effective bearing area of 95 percent of the gross contact area after final set.
 5. The grout packaging shall list weight, maximum amount of mixing water to be used, maximum usable working time (pot life) at flowable consistency, and temperature restrictions for preparation and placement within which grout will meet specified requirements.
- C. Class II Non-Shrink Grout:
1. Supply Class II Grout confirming to ASTM C1107 and the following requirements when tested using the amount of water needed to achieve the following properties:
 - a. Flowable consistency: 140 percent flow on ASTM C230, five drops in 30 seconds.
 - b. Fluid working time: 15 minutes, minimum.
 - c. Flowable duration: 30 minutes, minimum.
 2. When tested, the grout shall not bleed at maximum allowed water.

2.03 CURING MATERIALS

- A. Curing materials: As specified in Section 03370 - Concrete Curing and as recommended by the manufacturer of prepackaged grouts.

2.04 CONSISTENCY

- A. Mix grouts to the consistency necessary to completely fill the space to be grouted. Dry pack consistency is such that the grout is plastic and moldable but will not flow. Where "dry pack" is called for in the Contract Documents, it shall mean a grout of that consistency; the type of grout to be used shall be as specified herein for the particular application.

PART 3 EXECUTION

3.01 PREPARATION

- A. Verify that base concrete or masonry has attained design strength before grout is placed.
- B. When cementitious grouts are used on concrete surfaces, saturate the concrete surface with water for 24 hours prior to placement of cement-based grout. Upon completion of saturation period remove excess water prior to grouting.

3.02 GROUTING PROCEDURES

- A. Prepackaged Grouts: Perform mixing, surface preparation, handling, placing, consolidation, curing, and other means of execution for prepackaged grouts according to the written instructions of the manufacturer. Use prepackaged materials in the quantities and proportions as directed by the manufacturer unless there is certified test data verifying that the specified properties are attained by modified mix.

3.03 CONSOLIDATION

- A. Place grout in such a manner, for the consistency necessary for each application, so as to assure that the space to be grouted is completely filled.

END OF SECTION