

SECTION 03100
CONCRETE FORMWORK

PART 1 GENERAL

1.01. SECTION INCLUDES

- A. Formwork for cast-in-place concrete.
- B. **Architectural form liners.**
- C. Controlled permeability form liners.
- D. Form hardware, ties, etc.
- E. Form removal; coordinate with rub finish requirements.
- F. Camber requirements for beams and slabs.

Add. #6

1.02. RELATED SECTIONS

- A. Section 03250 - CONCRETE JOINTS AND ACCESSORIES
- B. Section 03350 - CONCRETE FINISHES
- C. Section 03370 - CONCRETE CURING AND PROTECTION
- D. Section 05531 - GRATING AND FLOOR PLANK: Embedded frames.

1.03. REFERENCES

- A. The publications listed below form a part of these specifications.
 - 1. ACI 117 - Specification for Tolerances in Concrete Construction and Materials
 - 2. ACI 301 - Specifications for Structural Concrete
 - 3. ACI 347 - Recommended Practice for Concrete Formwork
 - 4. ACI SP-4 - Formwork for Concrete
 - 5. ASTM A653 - Steel Sheet, Zinc Coated

1.04. SUBMITTALS

- A. Submit single-page catalog cuts showing the types of form ties with and without waterstops to be used.
- B. Submit single-page catalog cuts showing all the types of formwork systems to be utilized for the project. (Do not include Contractor's design of formwork system.)

C. **For Architectural Form Liners**

Add. #6

1. **Submit catalog cuts for available finishes and styles that can be selected by the Owner.**
2. **Upon request, submit 2-foot square samples of form liners selected by the Owner to be reviewed for final approval.**

D. Submit catalog cuts for controlled permeability form liners.

E. **Provide a field constructed sample panel utilizing an architectural form liner in accordance with Section 03350, Concrete Finishes.**

Add. #6

1.05. COORDINATION

- A. Coordinate the installation of all cast-in (embedded) items that need to be included in the formwork.
- B. Design, engineering, and construction of formwork shall be the responsibility of the Contractor and must achieve the desired end results.

1.06. DELIVERY, STORAGE, AND HANDLING

- A. Deliver form and accessory materials to site in an undamaged condition. Defective or damaged materials shall not be used.

PART 2 PRODUCTS

2.01. MATERIALS

- A. Form materials shall be new wood, new plywood, or steel.

Do not use poor quality or used forms that will make a rubbed finish difficult to produce. Reference Section 03350. Therefore, worn, used forms will not be allowed on exposed work.

B. **Architectural Form Liners**

Add. #6

1. **Style (pattern and texture) shall be selected by the Owner.**
2. **All form liners shall be composed of durable materials that are not easily damaged.**

C. Controlled permeability form liners (CPL) shall be provided for all liquid containment structures. Provide "Zemdrain MD" by MaxFrank Inc. **(distributed by Dupont)**; "Formtex" by Fibertex Nonwovens LLC **(distributed by Dayton Superior)**; or equal.

Add. #4

D. Chamfer forming strips for exposed edges of concrete.

1. Exposed edges and outside corners of concrete shall be formed with 3/4-inch by 3/4-inch chamfer forming strips.
2. Downstream side of weir plates shall formed with 3-inch by 3-inch chamfer forming strips unless indicated otherwise.

E. Rustication (Reveal) Strips

1. **Rustication (reveal) strips shall be constructed of wood, beveled approximately 1/4-inch each side to facilitate removal, unless indicated otherwise on the Contract Drawings. These wood strips shall be sealed with a clear wood sealer prior to the application of form release agent.**
2. **Locations and profiles of rustication (reveal) strips shall as indicated on the Contract Drawings. Where the profiles are not indicated, provide 1 x 2 beveled strips.**

F. Reveal Strips

1. Reveal strips shall be provided as shown in the patterns and sizes indicated on the Contract Drawings for particular exposed concrete structures.
2. Reveal strips shall generally be 1 x 2 wood (or as indicated otherwise on the Contract Drawings), beveled approximately 1/4-inch each side to facilitate removal. The strips shall be sealed with a clear wood sealer prior to the application of form release agent.

G. Forms shall be coated with a release agent which will not stain concrete, absorb moisture, reduce the bonding characteristics of additional concrete coatings, or negatively affect the rubbed finish process. Use Euclid Chemical "Euco Super Slip," BASF Building Systems "Cast Off," or equal.

H. Form Ties

1. Form ties shall leave no metal closer than 1-inch to the surface of the finished concrete. The ends of the form ties shall create cone-shaped tie holes for sealing with plug mortar per Section 03350.
2. Ties used for watertight and below-grade structures shall have a waterstop.
3. Snap ties without cone-shaped ends can only be used at unexposed portions of frost walls, retaining walls, and grade beams.

I. Joint forming materials for interruptions in concrete placement shall be per Section 03250.

PART 3 EXECUTION**3.01. ERECTION INSTALLATION APPLICATION**

- A. Form surfaces shall be smooth and shall be removable in sections, such that no prying against the faces of the new concrete is necessary.
- B. Earth cut forms shall not be used. All footings, slab edges, etc. shall be formed unless specifically shown otherwise on the Contract Drawings.
- C. Soffit forms for beams and slabs shall be constructed to produce a built-in camber equal to 1/8 inch per 5 feet of span length unless indicated otherwise.
- D. Erected forms shall be substantial and rigid, sufficiently tight to prevent leakage of laitance and properly braced and tied to maintain position and shape under the weight and pressure of the newly placed concrete.

All joints between adjacent form panels shall be backed by a waler or stud. Seal formwork by gasketing and caulking to prevent leakage on the preceding placement below or adjacent.

- E. Inspection and cleanout openings shall be provided as required.
- F. Provide formed openings where required for items to be embedded in or passing through concrete work.

Locate and set in place embedded items which will be cast directly into concrete.

Coordinate work of other sections in forming and placing openings, slots, reglets, recesses, chases, sleeves, bolts, anchors, embedded frames, and other inserts.

- G. Install chamfer forming strips on formwork at edges, outside corners, and at weir locations.
- H. Apply form release agent in accordance with manufacturer's recommendations. Apply prior to placement of reinforcing steel, anchoring devices, and embedded items. Do not apply form release agent where concrete surfaces will receive special finishes which are affected by agent.

I. **Controlled Permeability Form Liners (CPL)**

Add. #6

- 1. **CPLs shall be provided for all liquid containment structures. As a minimum, they shall be used to form all surfaces that will be in contact with liquid (other than groundwater).**
- 2. CPLs shall be used only for one application. They may only be used for a second application dependent on being in an acceptable condition, approved by the Engineer.

J. **Architectural Form Liners**

Add. #6

- 1. **Selected architectural form liners shall be used where indicated on the Contract Drawings.**
- 2. **Placement of form liners shall be such that the embossed pattern and texture is continuous along the entire surface of the concrete face.**
- 3. **The form liners shall be secured to the backup formwork to ensure they do not slip during placement of concrete.**
- 4. **Damaged form liners that have been rejected by the Engineer shall be replaced at the Contractor's expense.**

K. Form Hardware

- 1. Form tie layout shall be in a neat pattern when finished concrete is exposed.
- 2. Form ties shall not be located within 6 inches from top of concrete placement.
- 3. No snap ties shall be broken off until the concrete is at least three days old and will not damage the concrete surface.

- L. Tolerances for finish formed surfaces and variations in dimensions shall be in accordance with the following table:

TOLERANCES FOR FORMED SURFACES*

1. Variation from plumb:	
a. In the lines and surfaces of columns, piers, walls, etc.:	
• In any 10 feet of height	1/4 inch
• Maximum for the entire height if >40 feet	1 inch
b. For exposed corners of columns, wall corners, construction/ control joint grooves, and other conspicuous vertical lines:	
• In any 20 feet of height	1/4 inch
• Maximum for the entire height if >20 feet	1/2 inch
2. Variation from level or from grades specified:	
a. In slab soffits, ceilings and beam soffits, measured before removal of supporting shores:	
• In any 10 feet of length	1/4 inch
• In any bay or in any 20 feet of length	3/8 inch
• Maximum for the entire length if >40 feet	3/4 inch
b. At top of walls, sills, and parapets; and along construction joint grooves and other conspicuous horizontal lines:	
• In any bay or in 20 feet of length	1/4 inch
• Maximum for the entire length if >40 feet	1/2 inch
3. Variation of the linear building lines or lines of structure from position in plan and related position of columns, walls, and partitions:	
• In any bay	1/2 inch
• In any 20 feet of length	1/2 inch
• Maximum for the entire length	1 inch
4. Additional Tolerances for Biological Aerated Filters: Refer to Kruger shop drawings and requirements (see Drawing 1435735 –Sheet 6 of 7, Drawing 1436039 –Sheet 8 of 9, and Drawing 1436039 – Sheet 8 of 9)	
5. Variation in the sizes and location of sleeves, floor openings, and wall openings:	±1/4 inch
6. Variation in cross-sectional dimensions of columns and beams and in the thickness of slabs and walls:	-1/4 inch +1/2 inch
7. Footings and Thickened Edges of Slabs:	
a. Variations in dimensions in plan:	-1/2 inch +2 inches
b. Misplacement or eccentricity:	
• 2 percent of the footing width in the direction of misplacement but not more than 2 inches	
c. Thickness:	
• Decrease in specified thickness	5 percent
• Increase in specified thickness:	No limit but increased thickness must be maintained for minimum 5-foot length

Add. #4

*Tolerances apply to concrete dimensions only, not to positioning reinforcing steel or embedded items.

3.02. FIELD QUALITY CONTROL

- A. Prior to placing concrete, inspect erected formwork, shoring, and bracing to ensure that work is in accordance with formwork design. Verify that all supports, fastenings, wedges, ties, and items are secure.
- B. Clean and vacuum formed cavities of debris prior to placing concrete.

Flush with water or use compressed air to remove remaining foreign matter. Ensure that water and debris drain to exterior of formwork through cleanout ports.
- C. During cold weather, remove ice and snow from within forms. Do not use water to clean out forms, unless formwork and concrete construction proceed within heated enclosure. De-icing salts will not be permitted. (Reference Section 03370.)
- D. Damaged or previously used form liners shall not be used and shall be replaced at Contractor's expense.

3.03. FORM REMOVAL

- A. The Contractor shall assume full responsibility for the strength of all components from which forms are removed.
- B. Forms and supports shall remain undisturbed until the concrete has attained sufficient strength to support its own weight in addition to any collateral loads (temporary or permanent) that may be placed upon it during subsequent work. In no event shall any forms be loosened or removed prior to 24 hours' wet cure time.
- C. Non-structural vertical forms such as beam side forms, column forms, and wall forms may be removed at any time after 24 hours, provided that stripping does not damage surfaces and such action does not endanger any part of the structure. Coordinate timing of form removal with rub finish requirements specified in Section 03350.
- D. No structural forms and shoring supporting underside of slabs or beams shall be removed prior to concrete attaining at least 80 percent of the required design strength and no less than 14 days after placing concrete. Field-cured cylinders (paid by the Contractor) can be taken for consideration to remove the structural forms sooner than 14 days.

During cold weather conditions, do not remove structural forms sooner than 21 days after placing concrete. Reference Section 03370 for cold weather requirements.
- E. Immediately reshore all concrete required to support formwork for subsequent concrete placement. Any slab to be cast shall be shored downward.

END OF SECTION

SECTION 03200
CONCRETE REINFORCEMENT

PART 1 GENERAL

1.01. SECTION INCLUDES

- A. Reinforcing bars.
- B. Welded wire reinforcement.
- C. Galvanized reinforcing bars.
- D. Fiber reinforcement.
- E. Threaded rebar splicing system.
- F. Mechanical rebar splicing system.
- G. Bar supports and bolsters.

1.02. RELATED SECTIONS

- A. Section 01420 - SPECIAL INSPECTIONS
- B. Section 03250 - CONCRETE JOINTS AND ACCESSORIES
- C. Section 03300 - CAST-IN-PLACE CONCRETE
- D. Section 04300 - UNIT MASONRY SYSTEM

1.03. REFERENCES

The publications listed below form a part of these specifications.

- A. American Concrete Institute
 - 1. ACI 301 - Specifications for Structural Concrete
 - 2. ACI 315 - Details and Detailing of Concrete Reinforcement
 - 3. ACI 315R - Manual of Engineering and Placing Drawings for Reinforced Concrete Structures
 - 4. ACI 318 - Building Code Requirements for Structural Concrete
 - 5. ACI 350 - Code Requirements for Environmental Engineering Concrete Structures
 - 6. ACI 530 - Building Code Requirements for Masonry Structures
- B. American Society for Testing and Materials
 - 1. ASTM A185 - Steel Welded Wire Reinforcement, Plain, for Concrete

2. ASTM A497 - Steel Welded Wire Reinforcement, Deformed, for Concrete
 3. ASTM A615 - Deformed and Carbon-Steel Bars for Concrete Reinforcement
 4. ASTM A767 - Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
 5. ASTM A780 - Standard Practice for Repair of Damaged Hot-Dip Galvanized Coatings
 6. ASTM A970 - Specification for Welded or Forged Headed Bars for Concrete Reinforcement
 7. ASTM C1116 - Specification for Fiber-Reinforced Concrete and Shotcrete
 8. ASTM E329 - Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction
- C. Concrete Reinforcing Steel Institute (CRSI) - Placing Reinforcing Bars
- D. American Welding Society (AWS) - AWS D12.1, Reinforcing Steel Welding Code for Reinforcing Steel.

1.04. SUBMITTALS

- A. Reinforcement Shop Drawing - Submit shop drawings in accordance with ACI 301, ACI 315, ACI 315R, and as modified below.
1. Shop drawings shall be clear enough so that every reinforcing bar in the structure can be located and shall be complete with all dimensions of the structure without the need to refer to the Contract Drawings.
 2. A reinforcing bar layout plan shall be provided for each slab or walkway level, and an elevation view reinforcing bar layout shall be provided for each wall.
 3. Shop drawings shall clearly indicate all construction joints, expansion joints, and control joints. Contractor shall coordinate with the reinforcement detailer so that all reinforcement interruptions and/or all splices can be shown and accounted for in the detailing.
 4. Reinforcement shall be shown as bent where needed to clear waterstops and/or maintain uniform cover. Bars with bends shall be indicated schematically on the plan and elevation views.
 5. All openings and pipe penetrations in walls and slabs shall be indicated on the reinforcement shop drawings (coordinated by Contractor). Formed openings larger than 1.25 times the rebar spacing in any direction shall be detailed with additional reinforcement around the opening in accordance with the Standard Detail on the Contract Drawings.
 6. Photocopies of Contract Drawings, in whole or in part, will not be acceptable.
 7. All re-submittals of shop drawings shall have all revisions/corrections clearly highlighted to the Engineer (e.g. labeled, clouded, etc.)

8. Final corrected copies of shop drawings (for file and to be used in the field) shall be submitted a minimum of 14 days prior to start of installation.
 9. No reinforcing bar fabrication shall commence until shop drawings are approved.
 10. All reinforcing bars shall be shop fabricated. No reinforcing bars shall be field bent.
- B. Mill test reports showing physical and chemical analysis shall be provided for Engineer's records.
 - C. Submit catalog cut for threaded rebar splicing system.
 - D. Submit catalog cut for mechanical rebar splicing system.
 - E. Submit catalog cuts, clearly marked to indicate reinforcing bar supports and bolsters to be used for walls and slabs.

1.05. COORDINATION

- A. All construction joints, expansion joints, and control joints must be coordinated by the Contractor so that all reinforcement interruptions and/or splices can be shown.
- B. Contractor shall locate all wall/slab openings and pipe penetrations on the shop drawings prior to Engineer's review and approval.
- C. Required adjustments to reinforcing bars to accommodate cast-in (embedded) items shall be shown and detailed on the shop drawings.
- D. Contractor shall coordinate the supply of all bar supports and bolsters.

1.06. QUALITY ASSURANCE

- A. Reinforcement work shall conform to the applicable requirements of ACI 301, ACI 315, ACI 318, and CRSI referenced publications.
- B. All reinforcing bars shall have the manufacturer's mill marking rolled into the bar which shall indicate the producer, size, type, and grade.
- C. All reinforcing bars shall be neatly bundled and tagged for placement when delivered to the job site. Bundles shall be properly identified for coordination with mill test reports.

1.07. DELIVERY, STORAGE, AND HANDLING

- A. Deliver reinforcing bars and accessory materials to the site in an undamaged condition.
- B. Reinforcement shall not be stored in direct contact with earth and shall be kept free of mud.
- C. Bundles of bars may be loaded in or on structures, providing the Contractor avoids premature loading or overloading of the structure. Surface protection from rust stains or damage shall be provided by the Contractor.
- D. Equipment for handling galvanized reinforcing bars shall have protected contact areas. Bundles of coated bars shall be lifted at multiple pick-up points to minimize bar-to-bar abrasion from sags in the bundles. Coated bars shall be stored on protective cribbing.

PART 2 PRODUCTS

2.01. MATERIALS

- A. Deformed Reinforcing Bars - ASTM A615, Grade 60.
- B. Welded Wire Reinforcement (WWR) - ASTM A185 for plain wire and ASTM A497 for deformed wire, supplied in flat sheets only.
- C. Galvanized (Zinc-Coated) Reinforcing Bars - ASTM A767, Grade 60 deformed bars with Class I coating, galvanized after fabrication.
- D. Fiber Reinforcement - ASTM C1116, polypropylene fibers. Fibers shall be manufactured by Fibermesh Company, Grace Construction Products, or equal.
- E. Bar Supports and Bolsters
 - 1. Bar supports and bolsters shall be a non bleeding and non staining material where concrete surfaces remain exposed. Plastic, plastic tipped, or stainless steel bar supports shall be used for uncoated reinforcing bars. Galvanized reinforcing bars shall utilize bar supports and bolsters that are galvanized, coated with epoxy or another polymer, or made of plastic.
 - 2. Bar supports bearing on grade, insulation, or soft material shall be continuous runner type supplied with continuous welded on plates. Individual high chair supports will not be considered adequate.

Alternatively, minimum 4000 psi precast concrete blocks specifically cast for proper support of reinforcing bars can be utilized. The use of pavers, brick, or concrete masonry units (CMU) to support reinforcement shall not be permitted.
- F. Expansion joint slip dowel and sleeve system shall be as specified in Section 03250.
- G. Threaded rebar splicing system shall be a fabricated assembly with a flanged threaded mechanical splice capable of developing 125 percent of the specified yield strength (75 ksi for Grade 60 bars). Provide galvanized-coated flanged threaded rebar splicing systems where specifically indicated in the Contract Documents. Use Barsplice Products, Inc. "BPI Barsplicer System," ERICO "Lenton Form Saver," Dayton Superior "Threaded Splicing Systems," or equal.
- H. Mechanical bar splicing system for deformed rebar shall consist of lock-tightened shear bolts and special grip rails to mechanically splice rebar.

Use BarSplice Products, Inc. Zap Screwlok Type 2 (#3 bars or larger), SL Series (#4 bars or larger), or Transition (splice of different sized bars); Lenton Lock S or B Series (#4 bars or larger); Dayton Superior Bar Lock Splicing System D250SCA Bar Lock S/CA or L Series Couplers.
- I. Headed device in headed deformed bars shall conform to ASTM A970 including Annex A1 requirements for Class HA head dimensions. Use ButtonHead BNH System by BarSplice Products, Inc. or equal.

2.02. SOURCE QUALITY CONTROL

- A. Shop Inspection - The Engineer reserves the right to inspect the manufacturer's facilities while fabrication of reinforcing bars for this project is being performed.

PART 3 EXECUTION

3.01. ERECTION INSTALLATION APPLICATION

- A. Placement of reinforcement shall be in accordance with ACI and CRSI referenced publications.
- B. Reinforcing bars shall be spaced as shown on the approved shop drawings. Deviations with bars spaced up to 1.25 times the required spacing, necessary because of interference with inserts, conduits, piping, small openings for ducts, etc., are allowable as long as four consecutive bars average out to the required spacing.
- C. Where larger openings are encountered and reinforcing bars must be cut, equivalent splice bars (rounded bars) must be placed at each side of the opening plus #5 diagonal bars enveloping the opening at each corner (reference Standard Detail on Contract Drawings).
- D. Reinforcing bars shall be accurately located in forms and held in place before and during concreting by using supports of adequate strength and black annealed tie wire (#16 gage or heavier), to prevent bar displacement.
- E. Tie wires shall be bent into the wall or slab so as to not intrude into the reinforcement concrete cover space.
- F. Install bar supports and bolsters as specified in Part 2. Pavers, brick, or CMU supports shall not be permitted. Additional bar supports shall be installed to eliminate deflection of reinforcement.
- G. The minimum distance between non-lap spliced, parallel bars shall be two times the bar diameter, but in no case shall be less than 1 1/2 inches.

3.02. COVER

- A. Clear concrete cover shall conform to ACI 318 and ACI 350 unless noted otherwise.
- B. For structures exposed to earth, water, or weather (such as wet wells, channels, tanks, foundation walls, etc.), the clear cover shall be 2 inches (for severe exposure).
- C. The reinforcing bars of footings, base slabs, and other members in which concrete is deposited against the ground shall have 3 inches of concrete cover between it and the ground contact surface.
- D. Ends of reinforcing bars shall extend up to 2 inches from the outside face of the members into which they frame or terminate.

3.03. WELDED WIRE REINFORCEMENT

- A. Welded wire reinforcement shall be adequately supported, anchored, and tied integrally with the framework system to assure its final location in the slab. Lap the ends/edges of each sheet in accordance with CRSI procedures, but shall be lapped a minimum of 6 inches.

- B. The practice of "walking in" and placing the mats of reinforcement in freshly placed concrete will not be permitted.

3.04. FIBER REINFORCEMENT

- A. Concrete reinforced with fibers shall be used in concrete as indicated. Provide minimum 2 lbs. fibers per cubic yard of concrete unless indicated otherwise.
- B. If requested by the Engineer, the fiber manufacturer shall provide the services of a qualified representative for a pre-job meeting and initial job startup.

3.05. GALVANIZED REINFORCING BARS

- A. Galvanized reinforcing bars shall be fastened with galvanized, nylon, epoxy, or plastic-coated tie wire or other approved materials.
- B. Galvanized reinforcing bars supported from formwork shall rest on or be held in place with wire bar supports that are galvanized, coated with epoxy or another polymer, or made of plastic.
- C. Coating damage due to loading, shipment, and placing shall not exceed 2 percent of surface area. Damaged area greater than 2 percent of surface area shall deem the reinforcing bar unacceptable for use.
 - 1. Damaged areas shall be prepared and repaired with galvanized repair paint in accordance with ASTM A780.
 - 2. Repair field cut ends with zinc-rich coating used in accordance with manufacturer's recommendations.
- D. Galvanized reinforcing bars shall not be spliced or placed in direct contact with uncoated reinforcing bars.

3.06. DEVELOPMENT AND SPLICE LENGTHS

- A. All splicing of reinforcing bars shall be lap-spliced with bars placed in contact with each other and wired securely.
- B. Minimum lap splice or development length for reinforcing bars shall be as indicated on Contract Drawing S901. Special splices shown on the Contract Drawings, however, shall be lapped for the lengths indicated.
- C. Attention is directed to the fact that the top bars in beams or grade beams are required to extend one third of the span into the adjacent span (see typical bar placing diagram for beams). These top bars are not intended as splice bars, but are full value top reinforcement. The preferred placement is to have the required minimum space between all top bars. Bundling in pairs will be allowed if all the rules for bundled bars (per ACI 318) are met.
- D. Splices shall not be placed at points of maximum stress. However, in instances where they are unavoidable, the splice location in every second parallel bar shall be offset by alternating at least one and a half times the splice length.
- E. Base mat bottom bar splices shall not coincide with wall dowel locations. Offset adjacent bottom bar splices to avoid reinforcing bar congestion.

- F. Welding of reinforcing bars shall not be allowed unless specifically approved by the Engineer.
- G. Mechanical splice connections may be used for compression members (columns, etc.) only at locations approved by the Engineer and where new reinforcing bars are spliced with reinforcing bars in existing structures as indicated on the Contract Drawings. Square sawn ends are required for direct contact stress transfer in these devices.
- H. Observe the rules for staggering splices in accordance with ACI and CRSI.

3.07. FIELD QUALITY CONTROL

- A. The Contractor shall advise the Engineer of his intentions to place concrete at least 48 hours prior to concrete placement to allow for Special Inspections (as required) and observation of installed reinforcement and embedded accessories, including waterstops, keyways, and other items.
- B. Any repairs, corrections, cleaning, removal of debris, etc., shall be accomplished prior to start of concrete being placed.
- C. Reinforcement installed within wall forms and in any deep formwork shall be checked by the Contractor and verified by the Engineer before closing the form, as well as immediately prior to placing concrete.
- D. Prior to concrete deposition, reinforcement shall be free from mortar (concrete splash from previous placement), mud, loose mill and rust scale, grease, oil or any other coatings, including ice, that would reduce bond with the concrete.
- E. Where there is a delay in depositing concrete, reinforcement shall be rechecked and cleaned when necessary. Cleaning shall be done by whatever mechanical means is necessary to return it to an acceptable condition.

END OF SECTION

SECTION 03300

CAST-IN-PLACE CONCRETE

PART 1 GENERAL

1.01. SCOPE OF WORK

- A. It is the intent of these specifications to produce high quality, dense, durable, watertight (if applicable) concrete. The Contractor will be responsible for the final in-place concrete quality. Care shall be taken in development of mix designs and during mixing, placing, curing, and finishing to achieve the desired end result. The Contractor will be responsible to repair leaks (if applicable), cracks, unsound concrete, and poor finishes to the satisfaction of the Owner, at no additional cost.
- B. Section includes:
 - 1. Concrete mix design requirements.
 - 2. Placement and care of concrete.
 - 3. Restrictions regarding embedments in concrete.
 - 4. Concrete testing.
 - 5. Concrete repair (of newly cast concrete).

1.02. RELATED SECTIONS

- A. Section 01420 - SPECIAL INSPECTIONS
- B. Section 03100 - CONCRETE FORMWORK
- C. Section 03200 - CONCRETE REINFORCEMENT
- D. Section 03250 - CONCRETE JOINTS AND ACCESSORIES
- E. Section 03301 - LIQUID TIGHTNESS TEST FOR CONCRETE STRUCTURES
- F. Section 03350 - CONCRETE FINISHES
- G. Section 03370 - CONCRETE CURING AND PROTECTION
- H. Section 03600 - GROUT
- I. Section 03732 - CONCRETE REPAIR

1.03. REFERENCES

The publications listed below form a part of this specification.

- A. American Concrete Institute (ACI)
 - 1. ACI 201.1 - Guide for Conducting a Visual Inspection of Concrete in Service

2. ACI 211.1 - Selecting Proportions for Normal, Heavyweight, and Mass Concrete
 3. ACI 301 - Specifications for Structural Concrete
 4. ACI 302.1 - Guide for Concrete Floor and Slab Construction
 5. ACI 304 - Measuring, Mixing, Transporting and Placing Concrete
 6. ACI 305R - Hot Weather Concreting
 7. ACI 306R - Cold Weather Concreting
 8. ACI 309 - Guide for Consolidation of Concrete
 9. ACI 318 - Building Code Requirements for Structural Concrete
 10. ACI 350R - Code Requirements for Environmental Engineering Concrete Structures
- B. American Society for Testing and Materials (ASTM)
1. ASTM C31 - Making and Curing Concrete Test Specimens in the Field
 2. ASTM C33 - Concrete Aggregates
 3. ASTM C39 - Compressive Strength of Cylindrical Concrete Specimens
 4. ASTM C42 - Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
 5. ASTM C94 - Ready-Mixed Concrete
 6. ASTM C138 - Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
 7. ASTM C143 - Test Method for Slump of Hydraulic-Cement Concrete
 8. ASTM C150 - Portland Cement
 9. ASTM C172 - Sampling Freshly Mixed Concrete
 10. ASTM C231 - Air Content of Freshly Mixed Concrete by the Pressure Method
 11. ASTM C260 - Air-Entraining Admixtures for Concrete
 12. ASTM C295 - Petrographic Examination of Aggregates
 13. ASTM C311 - Sampling and Testing Fly Ash or Natural Pozzolans for Use in Concrete
 14. ASTM C457 - Determination of Air Voids in Concrete
 15. ASTM C494 - Chemical Admixtures for Concrete
 16. ASTM C595 - Specification for Blended Hydraulic Cements
 17. ASTM C618 - Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

18. ASTM C948 - Density, Water Absorption, and Apparent Porosity of Glass-Fiber Reinforced Concrete
19. ASTM C989 - Ground Granulated Blast-Furnace Slag for Use in Concrete
20. ASTM C1116 - Fiber-Reinforced Concrete and Shotcrete
21. ASTM C1218 - Test Method for Water-Soluble Chloride in Mortar and Concrete
22. ASTM C1260 - Test for Alkali Reactivity of Aggregates

1.04. SUBMITTALS

- A. Qualifications statement regarding batch plant certification.
- B. Prior to submittal of concrete mix designs, submit data on all ingredients to be used in the mix designs for pre-approval. All data shall be dated within the last 12 months.
 1. Certified mill tests of cementitious materials (cement, fly ash, and slag).
 2. Certified tests of fine and coarse aggregates meeting requirements in Part 2 of this specification.
 3. Verification of fine and coarse aggregates' potential for alkali-aggregate reactivity provided by one or more of the following:
 - a. Certified testing of aggregates for alkali-aggregate reactivity potential.
 - b. Identification by State DOT for "ASR potential."
 - c. Certified statement from source of aggregates pertaining to history of alkali-aggregate reactivity.
 4. Catalog cuts of concrete admixtures,
- C. Concrete Mix Designs - Concrete mixes used on this project shall be either established mixes verified by "Field Test Data" or new custom laboratory designed "Trial Mixtures." Requirements for either option are as follows.

All test data shall be dated within the last 12 months. Partial submittal will not be reviewed.

1. List amount and sources of mix ingredients:
 - a. Cement.
 - b. Pozzolans (fly ash and slag).
 - c. Fine aggregate.
 - d. Coarse aggregate.
 - e. Water.
 - f. Admixtures.

- g. Fibers (if required).
- 2. Strength Test Reports - The average strengths shall be higher than the required average compressive strengths (f'_{cr}) as per ACI 301, paragraph 4.2.3.3. Concrete supplier shall perform calculations validating proposed concrete strengths.
- 3. Typed letter signed by an official from concrete supplier stating that all materials for proposed mix are identical (from the same source and of the same amounts) as materials used for concrete mix in the submitted strength test reports.
- 4. Certified test for amount of water-soluble chloride ion (CL-) in concrete.
- D. Submit catalog cut for retarding admixture.
- E. Submit catalog cut for surface-applied hot weather evaporation reducer.
- F. Submit a filled-in sample batch plant ticket prior to the first concrete placement. Reference batch ticket requirements in Part 3 of this specification.
- G. Submit special requests for embedment of conduit, etc. Reference restrictions in Part 3 of this specification.
- H. If concrete repairs are needed for newly cast concrete as indicated in Part 3 of this specification, the Contractor shall submit proposed repair products and procedures specified in Section 03732.

1.05. COORDINATION

- A. Coordinate all concrete placements with work (general, site/civil, architectural, structural, electrical, HVAC, instrumentation, mechanical, plumbing, etc.) indicated in all specifications and on all Contract Drawings.
- B. Coordinate concrete placement with rock blasting restrictions.
- C. Coordinate installation of all cast-in (embedded) items (i.e., grating frames, hatches, anchor rods, etc.) prior to start of concrete placement. Post-installation of cast-in items into new hardened concrete is not allowed.
- D. Coordinate all concrete placements with testing and inspection requirements specified herein and identified in Section 01420.
- E. Obtain approval on Contractor's proposed curing and protection plan prior to placement of any concrete. Reference Section 03370.

1.06. QUALIFICATIONS

- A. The concrete batch plant providing concrete to this project shall be certified by the State DOT.

PART 2 PRODUCTS

2.01. CONCRETE

A. Concrete Classes and Their Use

1. Mix A - All general uses not otherwise specified or provided for below.
2. Mix B - Liquid Containment Structures - All structural reinforced concrete in contact with process water.
3. Mix C - Concrete fill/topping (average thickness greater than 3 inches), pipe supports and encasements, and ductbanks.
4. Mix CF - Concrete topping with fiber reinforcing (average thickness less than 3 inches).
5. Mix D - Concrete thrust blocks (below grade), and fill concrete below structures.
6. Mix E - Exterior slabs, platforms, walkways, sidewalks, road curbs, and truck unloading containment pads. Secant pile cap beams and BAF liner.

Mix	28-Day Compressive Strength (psi)	Coarse Aggregate Size per ASTM C33	Minimum Total Cementitious Content (lbs/CY)	Maximum Water/Cement Ratio (w/c) ⁽¹⁾	Air Content % ⁽²⁾	Maximum Water-Soluble Chloride Ion (CL ⁻)
A	4,500	#57	575	0.44	6.0	0.30
B	4,500	#57	575 ⁽³⁾	0.42	6.0	0.10
C, CF ⁽⁴⁾	4,000	#7	550	0.45	7.0	0.15
D	3,000	#467	425	0.50	6.0	0.30
E	5,000	#57	600	0.40	6.0	0.15

- (1) These maximum water/cement ratios shall be considered for selection of supplier's mix designs. The water/cement ratio specified in the approved mix designs shall be the maximum used in production.
- (2) Tolerance for air content is +1-1/2 percent.
- (3) Fly ash content shall be 15 to 25 percent of total cementitious content. As an alternate to fly ash, use slag at 30 to 50 percent of total cementitious content. Maximum total cementitious content shall not exceed 660 lbs/CY.
- (4) Provide two mix designs; with and without fibers.

B. Air Entrainment Requirements

1. All concrete exposed to weather or liquid shall be air-entrained as specified in the above chart.
2. For interior concrete, where finishes require a lower air content than specification requires, the air content shall be adjusted accordingly with the approval of the Engineer.

C. Concrete Slump

1. Without plasticizers, concrete slump for flatwork shall not exceed 3 inches. Wall concrete, columns, and deep beams (without plasticizers) shall be placed with a maximum slump of 4 inches.
2. Concrete with superplasticizer shall be designed for a target slump of 6 inches. Mixed concrete with a slump greater than 8 inches shall not be placed on this project.

2.02. MATERIALS

A. Cement

1. Cement shall be Portland cement Type I or Type II and shall meet the requirements of ASTM C150.

If aggregates are susceptible to alkali-silica reactivity (ASR), cement shall be low alkali containing less than 0.60 percent of equivalent alkalies ($\text{Na}_2\text{O} + 0.658\text{K}_2\text{O}$) per ASTM C150, Table 2 unless other approved measures are included to mitigate ASR. Low alkali cement shall be tested frequently during construction, as outlined in Part 3, to monitor alkali levels.

2. If Type II cement is available, use for below-grade construction and for liquid containment structures or when air temperatures at the time of placement are expected to exceed 80 degrees F.
3. High early-strength cement (Type III with a maximum tri-calcium aluminate (C3A) content of 8 percent) shall only be used with advance written approval by the Engineer. Note that Type III cement would not be allowed for Mix B concrete.

B. Pozzolans

1. Mix B concrete and all concrete mixes utilizing aggregates with ASR potential shall contain pozzolans. (Reference the mix design chart above.)
2. Fly ash shall meet the requirements of ASTM C618 Class F except as modified below:
 - a. Loss of Ignition, Maximum - 5.0 percent.
 - b. Maximum Retained on #325 Sieve - 30 percent.
3. Blastfurnace slag material shall meet the requirements of ASTM C989. A blend of Portland cement and blastfurnace slag shall meet the requirements of ASTM C595 and be specifically manufactured to produce higher concrete strengths and provide greater resistance to chloride penetration and sulfate attack.

C. Aggregates

1. Fine Aggregate (Sand)
 - a. Natural or manufactured siliceous sand.
 - b. Quantity of deleterious substances limited by Table 1 of ASTM C33.

- c. Graded within the specified limits of ASTM C33.
- 2. Coarse Aggregate
 - a. Crushed stone or crushed gravel.
 - b. Quantity of deleterious substances limited by Table 3 of ASTM C33 for Class 4S aggregates.
 - c. Graded within the specified limits of ASTM C33.
- 3. Five cycle soundness tests for fine and coarse aggregates shall meet the requirements of ASTM C33.

PERCENT LOSS

	MAGNESIUM SULFATE	SODIUM SULFATE
Fine Aggregate ⁽¹⁾	15	10
Coarse Aggregate ⁽²⁾	18	12

- (1) If provided results of soundness tests exceed these limits, it would be acceptable to provide a certified letter attesting to the favorable performance of the fine aggregates as outlined in ASTM C33, Article 8.
- (2) Soundness tests for coarse aggregates do not need to be provided if they are approved by State DOT for use with concrete. Submit verification of such.
- 4. Source of fine and coarse aggregates shall not have a history pertaining to alkali-aggregate reactivity. In the event that aggregate source with potential alkali-aggregate reactivity is unavoidable, at least two of the following measures shall be taken to minimize this reaction:
 - a. Provide low alkali cement.
 - b. Use fly ash (minimum 20 percent content) or slag.
 - c. Use lithium-based additives (proven to be effective based on testing of concrete).

D. Mixing Water - Clear and potable.

E. Fiber Reinforcement - Concrete toppings reinforced with fibers shall be in accordance with ASTM C948 or C1116. Fibers shall be used in concrete toppings less than 3 inches thick. Reference Section 03200.

2.03. ADMIXTURES, ETC.

A. General Requirements - Admixtures other than those specified may only be used after written approval by the Engineer.

- 1. Admixtures shall be as manufactured by Master Builders Solutions (BASF Chemical Company); Sika Corporation; Euclid Chemical; Grace Construction Products; or equal.

2. All admixtures proposed shall be selected in advance so that the appropriate trial mixes can be made.
 3. After material sources have been established and approved, these sources shall not be changed for the duration of the project.
 4. The Engineer may require that a field representative of the admixture manufacturer provide occasional service in the field or batch plant to assure proper use of the admixture.
- B. Air entrainment admixture shall meet the requirements of ASTM C260.
- C. All concrete mixes shall contain a "water-reducing admixture" that meets the requirements of ASTM C494 Type A or a "high range water-reducing admixture" (superplasticizer) that meets the requirements of ASTM C494 Types F or G. These admixtures shall not contain chlorides.
- D. Retarding Admixture - If air temperatures are expected to exceed 85 degrees F during the placement and/or finishing of any flatwork, a retarding admixture shall be used that meets the requirements of ASTM C494 Type D.
- E. Evaporation Reducer - For all concrete flatwork during hot and/or windy weather conditions, apply to freshly placed concrete prior to finishing. Use BASF Chemical Company "Confilm," L&M Construction Chemicals "E-Con," Conspec (by Dayton Superior) "Aquafilm," or equal.
- F. Acceleration admixtures associated with cold weather concrete shall meet the requirements of ASTM C494 Type C and shall not contain calcium chloride. (Reference Section 03370 for cold weather protection procedures.) Note that acceleration admixtures are not allowed in Mix B for liquid containment structures. Approval from Engineer shall be obtained prior to use.

PART 3 EXECUTION

3.01. BLASTING COORDINATION

- A. Prior to concrete placement, all rock blasting must be completed within a 100-foot radius of any area to receive concrete. After placement of any concrete on the project site, no blasting will be allowed for a minimum of 24 hours.

3.02. PREPARATION, MIXING, AND HANDLING OF CONCRETE

- A. Batch Plant Requirements - Measurement of materials at the batch plant shall be in accordance with ASTM C94.
- B. The batch plant used to supply concrete for this project shall meet the following requirements:
1. Weight Hoppers - The plant shall have separate weight bins for cement and aggregate.
 2. Scales - Shall measure the actual weight within an accuracy of 0.1 percent of full scale or one graduation, whichever is less. Scales shall be sealed annually by the Official Sealer of Weights and Measures.
 3. Heating and Cooling of Materials

- a. In cold weather, the batch plant shall be equipped to heat aggregates and water to produce concrete delivery temperatures at the project site greater than the minimum temperatures indicated below. Aggregates shall not contain ice or have frozen lumps nor shall they be heated to a temperature over 120 degrees F.
 - 1) When ambient air temperature at time of placement is above 30 degrees F, concrete temperature must be at or above 55 degrees F.
 - 2) When ambient air temperature at time of placement is below 30 degrees F, concrete temperature must be at or above 60 degrees F.
 - 3) When ambient air temperature at time of placement is below 0 degrees F, concrete temperature must be at or above 65 degrees F.
 - b. In warm weather, the batch plant shall be equipped to cool water with ice, and cool aggregates by shading and spraying with cool water, to obtain concrete delivery temperatures at the project site of no greater than 95 degrees F. The Contractor shall take into account drive time, slump loss, admixtures, flash set, etc. and reduce delivery temperatures as appropriate.
4. Moisture Content - The automated batch plant shall adjust aggregate weights dispensed based on their moisture content.

C. Mixing Methods

1. All concrete shall be ready mixed and meet the requirements of ASTM C94.

The truck mixer shall be equipped with a water tank for carrying mixing water. Water added to the mixer shall be measured to the nearest gallon by use of a water meter. For all trucks arriving on site without an operating water meter, water shall only be added manually into the back of the truck using a calibrated container. Water carried within the truck water tank shall not be used unmeasured.

Water can be added to the mixer to attain initial slump, but only within the limits of the specified water/cement ratio. After addition of water, the concrete shall be mixed at least 30 revolutions in the mixing speed range.

Mixers shall meet the requirements of the "Truck Mixer and Agitator Standards" Truck Mixer Manufacturer's Bureau and shall bear their certification plate.

Trucks shall be equipped with a revolution counting device.
2. A written delivery slip or ticket, prepared and signed by the plant operator shall be made out at the proportioning plant for each truck load batch. The delivery slip shall be given to the Engineer as soon as the truck arrives at the job site, and each slip shall show the following information, which represents actual quantities of batched materials in each truck:
 - a. Truck number.
 - b. Date and time truck is batched.
 - c. Ticket number.

- d. Mix designation of concrete.
- e. Cubic yards of concrete.
- f. Cement type and weight in pounds.
- g. Weight in pounds of each size and type of aggregate.
- h. Admixtures, weights in pounds and ounce.
- i. Moisture content of fine and coarse aggregates.
- j. Water added to the batch at the plant.
- k. Water added to the batch during transport from plant to job site.
- l. Water added to the batch at the job site.

The driver and/or testing laboratory technician shall record the number of gallons of water added during transport and at the job site. If no additional water is added, this shall be clearly indicated on the batch tickets. In no case shall the water/cement ratio be exceeded.

Any truck delivering concrete to the job site without a delivery slip will be rejected and shall immediately depart from the job site.

- 3. After completion of mixing, discharging may begin immediately, otherwise the mixer shall be revolved at the agitating speed.

The total time interval from when the cement makes contact with the aggregates to the completion of discharge shall not exceed 90 minutes. The Engineer may reduce the total time limit in hot weather or under unusual conditions if unsatisfactory results are obtained.

- 4. Mixing at the Construction Site - If the time limits specified cannot be consistently achieved by mixing at the plant or in transit, concrete shall be mixed completely in the truck mixer following the addition of the mixing water at the point of deposition.

Trucks shall be loaded first with coarse and fine aggregates and admixtures during which time the drum may be revolved or rocked. Cement shall be added last and the drum shall remain stationary after the cement is added until water is added at the project site.

Mixing shall begin at the project site after the addition of water and shall continue for a minimum of 100 revolutions or until a uniform mix has been produced. Mixing time shall not exceed 15 minutes.

The entire load shall be discharged within 30 minutes after mixing has been completed.

3.03. EMBEDMENTS IN CONCRETE

- A. Embed no pipes other than electrical conduit in structural concrete.

- B. Obtain approval from Engineer for any variation from the following requirements unless shown on the Drawings. Make request in writing accompanied by suitable sketch.
1. Do not cut or displace any reinforcement.
 2. Do not place conduit between concrete surfaces and reinforcement.
 3. Restrict O.D. of conduit to 1/4 of slab thickness. Keep within middle half of that thickness.
 4. Any bundle of conduits shall not exceed a diameter equal to 1/4 of slab thickness.
 5. Place unbundled, parallel conduits at least 6 inches apart.
 6. Conduits that cross must be bent such that they cross between 45 and 90 degrees from each other.
 7. Conduits that cross can touch each other, but no more than three conduits (not exceeding total height of 1/3 of slab thickness) can cross at any given location.
 8. Conduits that run parallel with any reinforcement shall be kept a minimum of 2 inches clear from that reinforcement.
 9. Do not embed conduit in beams.
 10. Total conduit cross sectional area embedded in columns shall be less than 4 percent of the gross concrete area of columns.

3.04. CONCRETE PLACEMENT

- A. The Contractor shall notify the Special Inspector (when required), Engineer, and testing lab a minimum of 48 hours in advance of placement to allow sufficient time for scheduling and observation of the work and for any corrective measures which are subsequently required.
- B. Preparation
1. Concrete shall not be placed until all reinforcement is secured in position, nor until the forms have been completely installed and cleaned of debris; coated; form ties retightened; all sleeves, castings, pipe, conduits, anchors, forms for openings have been placed and anchored by the Contractor, nor until all water, snow, and ice have been removed from the space to be occupied by the concrete.
 2. Finishing installation of reinforcing and finalization of formwork concurrent with starting of concrete placement is not acceptable.
- C. All porous soil or concrete surfaces against which new concrete is to be placed shall be wetted down and dampened prior to placement. Spraying from the concrete truck hose immediately prior to placement will not be considered sufficient.
- D. Concrete shall be placed in accordance with ACI 302, ACI 304, and ACI 318.
- E. Concrete shall be conveyed as rapidly as practicable to the point of deposit by methods which prevent the separation or loss of the ingredients.

- F. Any concrete being placed shall not be allowed to free fall more than 5 feet as measured from the point of discharge to the bottom of the formed surface. All distances greater than 5 feet shall utilize elephant trunks with hoppers.
- G. When placing concrete, sufficient illumination shall be provided in the interior of the forms so that the concrete, at places of deposit, is visible.
- H. Concrete shall be placed and vibrated in layers not to exceed 30 inches. Reference ACI 309.
- I. Vibration shall be applied directly to the freshly-placed concrete by successive vertical penetrations of the vibrator. It shall be of sufficient duration to accomplish thorough compaction and complete embedment of reinforcement and fixtures.

"Pencil" vibrators shall be on hand and utilized where required.

Vibration shall be supplemented by forking or spading by hand in the corners of forms.

When vibrating structural slabs, the vibrator must not ride the form supporting the slab.

Since the duration of vibration required is dependent on the frequency, size of vibrator, and slump of concrete, the length of time must be determined in the field.

Vibrators shall not be used to move concrete laterally within the forms.
- J. Place concrete continuously and at full depth of slabs (so as not to permit cold joints) between predetermined expansion, construction, or control joints.

3.05. PUMPING CONCRETE

- A. Pumping Concrete - If the pump operator does not have direct visual contact with the location of concrete placement, two-way radio communications shall be provided.

3.06. EQUIPMENT AND HOUSEKEEPING PADS

- A. The General Contractor shall provide minimum 4-inch high concrete pads for all mechanical, plumbing, HVAC, and electrical equipment. If greater thicknesses are shown on the Contract Drawings or required by the equipment being installed, provide thickness required.
- B. Verify all concrete pad sizes, locations, and anchors with various Contractors. If sizes are not dimensioned on the Contract Drawings, provide concrete pads 6 inches wider than the equipment in each direction.
- C. Prior to placing concrete pads, use a bonding agent.

3.07. CONCRETE TOPPING (TYPE G FINISH, REFERENCE SECTION 03350)

- A. Where concrete toppings are indicated on the Contract Drawings, use Mix C or Mix CF concrete as applicable.
- B. At new construction, finish the slab with a Type A scratched finish. Precede the concrete topping with an application of a bonding agent.
- C. At existing concrete slabs, the slab shall first be abrasive blasted. Apply a bonding agent prior to placement of the concrete topping.

3.08. CONCRETE FINISHING

- A. All flatwork concrete shall be finished immediately after placement per Section 03350.
- B. All formed concrete shall be finished after form removal. Coordinate timing of form removal within the seven-day rubbed finish requirements per Section 03350.

3.09. CONCRETE CURING AND PROTECTION

- A. All concrete shall be cured (and protected from hot or cold weather conditions) for a minimum of seven days. Submittal of proposed procedures is required; follow requirements of Section 03370.

3.10. LIQUID TIGHTNESS TEST

- A. Liquid containment structures shall be tested for liquid tightness per Section 03301.

3.11. INCOMPLETE STRUCTURES

- A. Structures which are incomplete may not be capable of withstanding backfill, hydrostatic, surcharge, storage and other permanent or temporary loading conditions imposed during construction. Control of such loading conditions shall be the sole responsibility of the Contractor.

3.12. TESTING FOR QUALITY ASSURANCE

- A. The Owner will hire and pay for the services of an independent testing laboratory to perform the testing for quality assurance. Field testing shall consist of w/c ratio verification, temperature, slump, air content, density, and tests for the compressive strength. These test results shall be used by the Contractor to assist his control of quality in order to meet specified values. Additional testing for materials verification (including fine and coarse aggregate moisture content and water absorption, etc.) shall be conducted as directed by Engineer.

Contractor shall accept the reported results from this independent testing laboratory. If Contractor is in contention with any of these results, Contractor is allowed to hire their own independent testing laboratory to perform additional testing. Contractor's costs of other independent testing laboratory will not be recompensated, regardless of test results.

- B. Testing will be required for each placement in excess of 5 cubic yards.
- C. Location of Field Tests - All sampling for field tests (cylinders, air content, slump, etc.) shall be performed at the delivery truck to allow proper correlation of the tests.

When concrete is being pumped, additional air content testing shall be performed at the pump discharge to monitor air content changes through the pump and to maintain specified air content at location of concrete placement.

- D. The following field tests will be performed by the testing laboratory for every concrete placement:

- 1. Water/Cement Ratio (Calculated Method)

- a. The water/cement ratio shall be calculated and recorded for each truckload of concrete delivered to the job site. This calculation shall account for all

moisture in the mix including wash water, water added during transport and at the job site, and free moisture in both fine and coarse aggregates.

- b. Concrete which exceeds the water/cement ratio specified in the approved mix design shall not be utilized.
2. Temperature - Shall be recorded by the testing laboratory for each batch of concrete delivered to the project.
3. Slump Test - Slump tests shall be made in the field by the testing laboratory on each batch of concrete produced, in accordance with ASTM C143.
4. Air Content Test (Fresh Concrete)
 - a. Test for entrained air content in accordance with ASTM C231. Concrete which does not contain the proper amount of entrained air shall not be utilized under this contract.
 - b. A minimum of two tests will be required for each day of operations. Also, at least one test shall be made for each 50 cubic yards and each class of concrete placed within a single day.
 - c. If concrete is being pumped, a test shall be performed at both the truck and the end of the pump discharge. These two tests shall be used to monitor the drop in air content due to pumping and to better regulate the air content in forthcoming concrete batches.
 - d. In the event that test results are outside the limits specified, additional tests shall be required to show that concrete meets the specification requirements or the concrete shall not be used on this project. These additional tests shall be paid for by the Contractor.
5. Unit Weight (Density) - The unit weight of the fresh concrete shall be measured in accordance with ASTM C138. The unit weight shall be recorded at the same interval as required for air content testing as stated above.
6. Compressive Strength Test
 - a. Samples of concrete will be taken and tested by the testing laboratory for compressive strength in accordance with ACI 301; ASTM C31, C39, and C172; except as modified herein.

At least one sampling will be taken for each 50 cubic yards of each class of concrete placed within a single day. No more than one sampling may be taken from a single batch to satisfy this requirement.

One sampling shall consist of four 6-inch diameter test cylinders. One cylinder will be tested at 7 days, and 2 cylinders tested at 28 days, and 1 held for testing at 56 days as needed.

Each cylinder will be identified by a tag, furnished by the Contractor, which will be hooked or wired to the side of the container.

It is the Contractor's responsibility that cylinders be stored in a temperature-controlled curing box, provided by the Contractor on the construction site, for

24 hours after they have been molded and held at a temperature between 60 degrees F and 80 degrees F. Provide a high/low thermometer to verify temperature range.

After 24 hours, the testing technician will transport the samples to the laboratory for moist curing until tested.

- b. When field temperatures during the 24 hours immediately preceding the time of concrete placement have exceeded 85 degrees F, or have been less than 40 degrees F, or when freezing, hot weather, or other extraordinary field curing conditions are anticipated, or when requested by the Engineer, four additional cylinders shall be molded at each sampling for field curing.

These additional cylinders shall be located by the Contractor to be cured at the structure as near to the point where the sampled concrete was placed as practicable. These cylinders shall receive the same protection and be subject to the same environmental conditions as that portion of structure for periods of 5, 21, and 49 days from the date of molding.

The additional field-cured cylinders shall thereafter be transported to the laboratory and stored at laboratory room temperature and conditions for additional days until tested. One specimen tested at 7 days, 2 at 28 days, and 1 held for testing at 56 days if needed.

Note: 7- and 28-day laboratory cured specimens continue to be required as control specimens. Field-cured specimens will also be considered for concrete acceptance.

- c. After job site storage, concrete test cylinders shall be transported in rigid boxes specifically sized and constructed to prevent specimens from becoming damaged from tipping, falling, rolling, or bumping.
- d. After a mean value of a ratio between 7-day and 28 day strengths has been established from 10 or more samplings the 7-day strengths shall subsequently be taken as a preliminary indication of the 28-day strengths.

Thereafter, should a 7-day test strength from any sampling (laboratory cured) be more than 10 percent lower than the 7 day strength which corresponds with the specified 28 day compressive strength, the Contractor shall:

- 1) Immediately provide an additional seven days of curing in the affected area from which the deficient test cylinders were taken.
 - 2) Correct the mix for the next concrete placement.
- e. From laboratory cured specimens, the strength level of concrete will be evaluated for acceptance based on criteria in ACI 301, Chapter 17. Concrete is considered satisfactory if all of the following conditions are satisfied:
 - 1) The average of 28-day cylinder tests for any three consecutive sets shall meet or exceed the strength required for the mix specified.
 - 2) No more than 10 percent of the compressive strength test results from individual specimens shall have strengths less than that specified.

- 3) No single set of compressive strength test results falls below the specified strength by more than 500 psi.
 - f. The Contractor can request additional field-cured cylinders to verify adequate concrete strengths for early formwork removal. The Contractor shall reimburse the Owner for the testing of these additional cylinders.
 - g. In the event that the above conditions are not met and there is reason to imply that the low compressive strength results reflect actual concrete strength in the structure, additional tests shall be performed as outlined in Article 3.13.
- E. The following additional tests will be performed by the testing laboratory periodically as indicated, as directed by the Engineer:
1. Aggregate Water Absorption - Prior to the first concrete placement, the testing laboratory shall obtain fine and coarse aggregate samples to determine and report water absorption. Aggregates shall be retested to adjust absorption values every 90 days until 95 percent of project concrete has been placed.
 2. Aggregate Moisture Content - At Engineer's discretion, the testing laboratory shall visit the batch plant and obtain samples of fine and coarse aggregates for the purpose of verifying actual moisture content as reported by the batch plant.
 3. Cement alkalinity (when low-alkali cement is used to mitigate ASR) - Prior to the first concrete placement, the testing laboratory shall obtain a cement sample to test for alkaline content. Testing laboratory shall report acceptability and conformance to requirements of ASTM C150 for ASR mitigation. Unless most current cement mill test reports are provided every 40 days, testing laboratory shall conduct additional sampling every 90 days until 95 percent of project concrete has been placed.
 4. Water/Cement Ratio (Microwave Drying Method)
 - a. At the discretion of the Engineer, water/cement ratio of fresh concrete may be verified by Microwave Drying Method.
 - b. Testing laboratory shall perform a microwave oven drying test every day in which 50 cubic yards or more concrete is scheduled to be placed. Testing shall be repeated throughout the day for every 50 cubic yards that is placed. Concrete discharge from truck and placement will not be held up pending results of initial testing.
 - c. The testing laboratory shall follow AASHTO Standard Test Designation T318-02, "Water Content of Freshly Mixed Concrete Using Microwave Oven Drying," to determine water content and w/c ratio.
 - d. Testing laboratory will provide a sample calculation worksheet to show calculations of water content (WC) and water/cement ratio with absorption of fine and coarse aggregates being taken into account. Testing laboratory shall provide immediate reporting to the Contractor and the Owner's representative, followed by a formal written report.
 - e. Concrete which does not meet specified water/cement ratio shall be rejected. When concrete is determined to not meet specifications, additional testing

will be required on subsequent trucks arriving on site, and discharge will not be permitted until consistent satisfactory results are obtained.

5. Air Content Test (Hardened Concrete)

- a. The testing laboratory shall obtain core samples as directed by Engineer. The Contractor shall promptly assist testing laboratory by providing access, ladders, and/or scaffolding as needed to obtain samples. The testing laboratory shall core drill concrete and provide same-day patching of holes using non-shrink grout.
- b. Samples shall be obtained 14 days after placement (immediately following the 7-day wet cure and 7 day drying out).
- c. Hardened air content shall be determined in accordance with ASTM C457. Should any of these representative core samples show low air content, additional sampling and testing will be required and paid for by the Contractor. The Contractor will be responsible for replacement and/or corrective measures for concrete not meeting specification requirements.
- d. Three cores shall be obtained at each location as specified below. At base slab locations, the three cores shall be obtained at random throughout the slab. At walls, one sample shall be taken near the base of the wall, one at mid-height, and the third near the top of the wall. Wall samples are to be taken from the inside of the tank.

3.13. ADDITIONAL TESTING FOR CONCRETE ACCEPTANCE

- A. When unsatisfactory test results arise, additional tests as outlined below shall be provided and paid for by the Contractor.
- B. Inadequate Compressive Strength - In the event that test results fail to meet the strength requirements as outlined above, the Contractor shall be responsible for costs associated with having concrete core specimens obtained from the affected area and tested.

Three cores shall be taken for each sample in which the strength requirements were not met. The drilled cores shall be obtained and tested in conformance with ASTM C42 by the Owner's independent testing laboratory.

A core specimen shall be taken perpendicular to the concrete surface and shall be taken from near the middle of a unit of deposit when possible and not near formed joints or obvious edges of a unit deposit.

The diameter of core specimens should be at least 4 inches. The length of specimen, when capped, shall be at least twice the diameter of the specimen. Core specimens shall not include reinforcement. On the same day as they are drilled, core holes shall be repaired with non-shrink grout.

The core specimens shall be carefully handled while transported to the laboratory. Cores shall be tested and evaluated in accordance with ASTM C442 and ACI 301, Chapter 1.6.7.

1. The concrete in question will be considered acceptable if the average of three core specimen compressive strength tests meet or exceed 85 percent of the specified strength required for the specific concrete mix. No individual core compressive strength test result shall fall below 75 percent of the specified strength.

2. Load Tests - If compressive strength requirements under the above procedure are not met by the results of core tests, then the Engineer may order load tests pursuant to ACI 318. Such tests shall be at the Contractor's expense.
- C. Non-Compliant Air Content - In the event that concrete placed by the Contractor is suspected of, or is tested and shown to not have proper air content or erratic air test results are obtained as specified above, the Contractor shall engage an independent testing laboratory to obtain and test samples for air content in accordance with ASTM C457 and to recommend modification to mix components or additives. The Contractor will be responsible for remediation to the satisfaction of the Engineer/Owner.

3.14. TEST REPORTS

- A. The testing laboratory shall provide a copy of field notes directly to Owner's on-site representative no later than the following day.
- B. Compressive strength test results shall be submitted to the Owner's on-site representative, Engineer, Contractor, and concrete supplier within 2 business days following 7-, 28-, and 56-day testing.

3.15. REPAIR OF NEWLY CAST CONCRETE

- A. Areas of concrete in which cracking, spalling, or other signs of deterioration develop during initial curing or thereafter until the end of the guarantee period shall be removed and replaced, or repaired in accordance with this Article and Section 03732.

The Contractor may propose to use a specific method most suitable to the situation and have the method approved by the Engineer prior to repair. The Contractor shall submit manufacturer's product data sheets and recommended application procedures to the Engineer for approval prior to performing repairs.

- B. Structural Cracks (as determined by Engineer) - Random shrinkage or structural cracks shall be repaired utilizing a low viscosity, 100 percent solids, two-component epoxy resin injection system as specified in Section 03732.
- C. Leaking and/or Active Cracks (that are not structural cracks) - Leaking and active cracks shall be repaired utilizing a low viscosity, hydrophobic, closed cell polyurethane foam injection system as specified in Section 03732.
- D. Excessive surface cracking in concrete slabs as defined herein shall receive a penetrating epoxy resin sealer to mend and seal the cracks as specified in Section 03732.

Excessive cracking shall be defined as areas containing "craze cracking" or "map cracking" as defined by ACI 201.1. In the event that excessive cracking occurs in isolated areas of a given concrete slab, sealer could only be required in the area of the cracks bounded by construction or control joints pending Engineer approval.

- E. Damaged (spalled, weakened, or disintegrated) concrete and areas of honeycomb shall be removed to sound concrete and shall be repaired in accordance with Section 03732.
- F. Substrength Concrete
 1. Concrete which fails to meet the strength requirements as outlined above in Article 3.13 will be analyzed by the Engineer as to its adequacy based upon design loading and exposure conditions for the particular area of concrete in question.

2. If the concrete in question is found unacceptable based upon this analysis, that portion of the structure shall be strengthened or replaced by the Contractor at his expense. The method of strengthening or extent of replacement shall be as defined by the Engineer.
 3. Concrete not requiring strengthening but still falling below the strength requirements, may be accepted by the Owner in accordance with the General Conditions, specifically the paragraph entitled "Acceptance of Defective Work."
- G. Inadequate Air Content - Concrete which will be exposed to freeze-thaw cycles when in service, and which is found to have inadequate air content, shall be replaced to the extent defined by the Engineer.

END OF SECTION