

**DIVISION 3
CONCRETE**

SECTION 03220.0 REINFORCING STEEL

PART 1: GENERAL

1.01 RELATED SECTIONS:

Refer to the following Sections for related Work:

Section 03300.0 - Cast-in-Place Concrete

Section 03371.0 - Shotcrete

1.02 SECTION INCLUDES:

Work necessary for the detailing, furnishing, cutting, bending, bundling, tagging, mill testing, providing placing drawings, and delivering all reinforcing steel, including dowels, used in the Work.

1.03 REFERENCES:

A. American Concrete Institute (ACI):

1. ACI 315 Details and Detailing of Concrete Reinforcement
2. ACI 318 Building Code Requirements for Reinforced Concrete

B. ASTM International (ASTM):

1. ASTM A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
2. ASTM A 706 Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement

C. Concrete Reinforcing Steel Institute (CRSI):

1. CRSI Manual of Standard Practice

1.04 SUBMITTALS:

CONTRACTOR shall provide the following submittals sufficient to allow evaluation by **ENGINEER OF RECORD**:

- A. Shop Drawings: Prepare and submit detail and placing drawings.
- B. Test Reports: Submit mill test reports as required in paragraph 1.05.B., herein.

1.05 QUALITY ASSURANCE REQUIREMENTS:

- A. All Work shall be constructed, monitored, and tested in accordance with the requirements of the CQA Plan.
- B. Tests of Reinforcing Steel:
 1. Physical and chemical tests shall be performed for deformed bars for each heat of reinforcing in accordance with ASTM A 613.

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2. Copies of certified mill test reports (CMTR's) for the chemical ladle analyses and mill physical tests shall be furnished by **CONTRACTOR** for each heat.
- C. Any Work found unsatisfactory or any Work disturbed by subsequent operations before acceptance is granted shall be corrected by **CONTRACTOR**, at no additional cost to **OWNER**.

1.06 SHIPPING, HANDLING, AND STORAGE:

- A. Shipping and Handling Requirements:
 1. The reinforcing steel shall be free from contamination of grease, oil, dirt, and other foreign matter during fabrication and delivery. Any foreign matter on the reinforcing steel shall be removed prior to shipment.
 2. Bars shall be bundled and tagged for ready identification in the field. A fabrication identification tag shall be placed at one end of each bundle. Tags and tag markings shall be weatherproof and securely attached to each bundle to provide positive identification at delivery. Bundles received without tags shall be returned to the supplier/subcontractor at no expense to the **MANAGER** or **ENGINEER OF RECORD**.
 3. No bundle may include more than one grade, size, and length or configuration of reinforcing steel.
- B. Delivery Requirements:
 1. All reinforcing steel shall be delivered to the jobsite as directed by the **CONTRACTOR** to satisfy the construction schedule.

PART 2: PRODUCTS

2.01 MATERIALS:

- A. Reinforcing Bars:
 1. Reinforcement shall be new deformed reinforcement having a minimum yield strength of 60,000 psi conforming to ASTM A 615, Grade 60 and the supplementary requirements.
 2. Reinforcement that is to be welded as required per the DRAWINGS shall be new and have a minimum yield strength of 60,000 psi and shall conform to ASTM A 706.
- B. Dowel Bars And Expansion Caps:
 1. Dowel bars shall be plain steel bars of the size shown on the DRAWINGS conforming to ASTM A 615 and shall be free from burring or other deformation restricting slippage in the concrete.
 2. Expansion caps for dowel bars shall be metal, PVC, or other type of an approved design to cover two (2) to three (3) inches of the dowel, with a closed end and with a suitable stop to hold the end of the cap at least the width of the joint plus one-quarter (1/4) inch away from the end of the dowel bar. Caps shall be of such design that they will not collapse during construction. The cap shall be fitted on the trailing end of the dowel bar as shown on the DRAWINGS.
- C. Tie wire shall be No. 16 AWG or heavier.
- D. The required mill physical and chemical tests are delineated in paragraph 1.05B., herein.

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PART 3: EXECUTION

3.01 DETAILING AND FABRICATION:

- A. Unless otherwise indicated, all reinforcing steel shall be detailed and fabricated in accordance with ACI 315. The Contractor shall supply placing drawings and bar lists in accordance with ACI 315.
- B. Details of concrete reinforcement not covered in ACI 315 shall be in accordance with the CRSI Manual.

3.02 INSTALLATION:

- A. **CONTRACTOR** shall be responsible for the locations and placement of all reinforcing bars.
- B. Reinforcing steel shall be placed as shown on the DRAWINGS and as specified in Sections 03300.0 and 03371.0.
- C. The use of a torch or heat source for cutting or bending steel shall not be allowed.
- D. Bars shall be free of scale, dirt, grease, or other foreign matter which are detrimental to bond.
- E. Reinforcing bars shall be accurately placed with respect to spacing and clearance, securely tied at intersections, and supported in such a manner as to prevent displacement during placement of concrete.
- F. Where pipe sleeves, inserts, and anchors prevent placement of reinforcing bars in the locations shown, additional reinforcing shall be required, in locations as approved by **ENGINEER OF RECORD**.
- G. Reinforcing bar splices shall be used only in the locations shown on the DRAWINGS.
- H. Welded splices shall not be permitted.
- I. The length of lap for reinforcing bars shall be in accordance with ACI 318, unless otherwise shown.

*** END OF SECTION ***

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SECTION 03300.0 CAST-IN-PLACE CONCRETE

PART 1: GENERAL

1.01 RELATED SECTIONS:

Refer to the following Sections for related Work:

Section 02200.0 – Earthwork
Section 03220.0 – Reinforcing Steel

1.02 SECTION INCLUDES:

Furnishing all labor, equipment, material and services to:

- A. Furnish, unload, handle, assemble, erect, strip, and clean all required formwork, including necessary scaffolding, for placement of concrete, formwork, and reinforcing.
- B. Furnish, unload, handle, store, and properly install all waterstops.
- C. Furnish, store, and install all form materials, curing blankets, form release agents, bar support and centering accessories.
- D. Unload, store, handle, and install all reinforcing steel and fabric including necessary field fabricating and including all accessories for positioning and supporting reinforcement against displacement.
- E. Obtain from an approved source and deliver properly mixed concrete to the required points of placement at the site, in accordance with the requirements of these SPECIFICATIONS.
- F. Furnish, and throughout the duration of the concrete work, certified material test reports for cement used for this project.
- G. Furnish concrete mix design and supporting test data in accordance with paragraph 1.04, herein.
- H. Provide heating of the water and/or aggregates for mixing concrete during cold weather.
- I. Provide cooling of the water and/or aggregates for mixing concrete during hot weather.
- J. Obtain NRMCA certification and submit a copy of the Certificate to the **MANAGER** and **ENGINEER OF RECORD**. Provide periodic equipment checks and recertification as required by the NRMCA program.
- K. Deposit rejected material in an off-site disposal area in accordance with State and local regulations.
- L. Deposit wash water in an on-site disposal area designated by the **MANAGER**.
- M. Maintain proper conditions for working at the site and for placing reinforcing steel and concrete in the dry.
- N. Clean and prepare surfaces of joints as required.
- O. Schedule, order, place, vibrate, finish and cure concrete, including patching, mortar, and bonding paste.
- P. Unload, handle, store and properly install all embedded items.

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1.03 REFERENCES:

- A. American Association of State Highway and Transportation Officials (AASHTO)
 - AASHTO M 182 Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats

- B. American Concrete Institute (ACI):
 - 1. ACI 301 Specifications for Structural Concrete for Buildings
 - 2. ACI 304R Guide for Measuring, Mixing, Transporting, and Placing Concrete
 - 3. ACI 305R Hot Weather Concreting
 - 4. ACI 306R Cold Weather Concreting
 - 5. ACI 309R Guidance for Consolidation of Concrete
 - 6. ACI 318 Building Code Requirements for Reinforced Concrete and Commentary
 - 7. ACI 347 Formwork for Concrete, Fifth Edition

- C. ASTM International (ASTM):
 - 1. ASTM C 33 Specification for Concrete Aggregates
 - 2. ASTM C 94 Specification for Ready-Mixed Concrete
 - 3. ASTM C 150 Specification for Portland Cement
 - 4. ASTM C 171 Specification for Sheet Materials for Curing Concrete
 - 5. ASTM C 260 Specification for Air-Entraining Admixtures for Concrete
 - 6. ASTM C 618 Specification for Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral in Portland Cement Concrete

- D. American Welding Society (AWS):
 - 1. AWS D1.1 Structural Welding Code-Steel, Twelfth Edition
 - 2. AWS D1.4 Structural Welding Code-Reinforcing Steel

- E. U.S. Army Corps of Engineers (USCOE):
 - USCOE CRD-C572 Corps of Engineers Specifications for Polyvinylchloride Waterstop

- F. Concrete Plant Manufacturer's Bureau:
 - 1. Concrete Plant Standards of the Concrete Plant Manufacturer's Bureau
 - 2. Concrete Plant Mixer Standards of the Plant Mixer Manufacturers Division

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- G. National Ready Mixed Concrete Association (NRMCA):
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| NRMCA | Certification of Ready Mixed Concrete Production Facilities Certification Program |
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- H. Truck Mixer Manufacturer's Bureau:
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| Truck Mixer and Agitator Standards | Truck Mixer and Agitator Standards of the Truck Mixer Manufacturers' Bureau |
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1.04 SUBMITTALS:

CONTRACTOR shall provide the following submittals to allow for evaluation by **MANAGER** and **ENGINEER OF RECORD**:

- A. Prequalification test data and MANUFACTURER's literature on proposed cement and air entrainment admixture for proposed concrete mixes.
- B. Dates of most recent calibration of weighing and measuring equipment.
- C. Proposed concrete mix design proportions with supporting test data, including slump on which design is based, quantity of cement, total gallons of water per cubic yard, ratio of fine to total aggregates, and time of initial set.
- D. Listing of sources and full technical identification of proposed cement, aggregates, air entrainment admixture, and water, including brand, type, and composition of cement, specific gravity and gradation of each aggregate and weight (surface dry) of each aggregate per cubic yard.
- E. Description of proposed batching, mixing, and delivering operations.
- F. Uniformity tests results for truck mixers.
- G. A current certificate from the National Ready Mix Concrete Association (NRMCA) which certifies that concrete batching equipment and facilities conform to the NRMCA Certification Program requirements.
- H. A certificate stating that the concrete batching equipment and facilities bear a rating plate issued by the Truck Mixer Manufacturer's Bureau.
- I. Submit material lists of items to be provided under this Section.
- J. Submit MANUFACTURER's specifications, instructions, and other product data needed to prove compliance with the specified requirements.
- K. Submit placing drawings and shop drawings of other items provided under this section showing material designations, shop and field welds and protective coating.
- L. Submit, if applicable, drawings showing alternative location of construction joints.
- M. Submit construction plan.
- N. Submit air and concrete curing temperature records as required in paragraph 3.13, herein.
- O. Submit certified mill test reports furnished by the electrode MANUFACTURER with results of all required tests showing conformance with AWS filler metal specifications and typical for each lot or heat of the filler metal material furnished herein.

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1.05 QUALITY ASSURANCE REQUIREMENTS:

A. Hold Points:

The following are the mandatory hold points for which prior notification is required:

1. Receipt by the **MANAGER** or **ENGINEER OF RECORD** of the equipment certifications as required in this Section and paragraph 1.02, above.
2. Approval by the **MANAGER** or **ENGINEER OF RECORD** of the concrete materials and mix proportions.
3. Notification by the **CONTRACTOR** to **MANAGER** or **ENGINEER OF RECORD** of the **CONTRACTOR's** intention to place concrete forty-eight (48) hours prior to schedule placement.
 - a. Upon notification, the **MANAGER** or **ENGINEER OF RECORD** will furnish a Concrete Placement Card (Attachment 1 at end of this Section) to the **CONTRACTOR**. The Placement Card will reference the particular structure and the specific limits of the placement, and the concrete strength to be used.
 - b. Prior to placement, the **CONTRACTOR** shall return the Placement Card to the **MANAGER** or **ENGINEER OF RECORD** with **CONTRACTOR** signatures verifying that all the preparatory items shown on the Placement Card are complete and ready for inspection. Cleanup is an essential item.
 - c. The **MANAGER** or **ENGINEER OF RECORD** will inspect the following items and initial each applicable item when found acceptable:
 - 1) Forms
 - 2) Reinforcing
 - 3) Drain Pipe, if any
 - 4) Miscellaneous
 - 5) EngineeringThe **MANAGER** or **ENGINEER OF RECORD** will then sign "Released for Placement".
 - d. The **MANAGER** or **ENGINEER OF RECORD** will inspect and initial the Quality Control item when found acceptable, and sign "Released for Placement". The Placement Card constitutes a release for the **CONTRACTOR** to proceed with the placement when completely signed off.
 - e. The **CONTRACTOR** shall return the top half of the Placement Card along with copies of all concrete truck tickets associated with the placement to the **MANAGER** or **ENGINEER OF RECORD**. The **MANAGER** or **ENGINEER OF RECORD** will keep copies of these items and file the originals offsite.
4. The **MANAGER** or **ENGINEER OF RECORD** reserves the right to establish other hold points.

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B. Construction Tolerances:

1. Variation in alignment, grade, and dimensions of the structures from the established alignment, grade, and dimensions shown on the DRAWINGS shall conform to ACI 301, Section 1.7.2.
2. Level and grade tolerance measurements shall be made as soon as possible after finishing. When forms or shoring are used, the measurements shall be made prior to removal.

C. Surface Requirements:

1. The surface requirements for the class of finish required by paragraph 3.15, herein for unformed surfaces, shall be as hereinafter specified.
2. Allowable irregularities are designated “abrupt” or “gradual” for purposes of providing for surface variations.
3. Offsets resulting from displaced, misplaced, or mismatched forms, or sheathing, or by loose knots in sheathing, or other similar form defects, shall be considered “abrupt” irregularities.
4. Irregularities resulting from warping, unplaneness, or similar uniform variations from planeness or true curvature, shall be considered “gradual” irregularities. “Gradual” irregularities will be checked for compliance within the prescribed limits with a five (5) foot template, consisting of a straightedge for plane surfaces and a shaped template for curved or warped surfaces.
5. In measuring irregularities, the straightedge or template may be placed anywhere on the surface in any direction, with the testing edge held parallel to the intended surface.

**TABLE 03300-1
CONCRETE IRREGULARITIES**

Class of Finish	Irregularities	
	Abrupt, inches	Gradual, inches
All concrete	1/4	1/2

6. Appearance: Permanently exposed surfaces shall be cleaned, if stained or otherwise discolored, by a method that does not harm the concrete and that is approved by the **MANAGER** or **ENGINEER OF RECORD**.

1.06 TESTING CONCRETE AND CONCRETE MATERIALS:

- A. All concrete testing (both field and laboratory testing) will be the responsibility of **CONTRACTOR**. **CONTRACTOR** shall be responsible for cooperating with CQA Monitor during all testing activities. **CONTRACTOR** shall provide equipment and labor to assist CQA Monitor in sampling, if requested, and shall also provide access to all areas requiring testing activities.
- B. Concrete, reinforcement, and embedded items shall be tested by an Independent Testing Laboratory arranged for by the **CONTRACTOR** and acceptable to the **MANAGER** or **ENGINEER OF RECORD**.

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- C. The activities of the Independent Testing Laboratory shall in no way relieve the **CONTRACTOR** of the responsibility to furnish materials and perform the Work in full compliance with these SPECIFICATIONS. The Independent Testing Laboratory shall perform those tests as required to document compliance with the SPECIFICATION requirements.
- D. Should materials, or final products or Work be determined as unsuitable or not in conformity with the requirements of these SPECIFICATIONS, they shall be rejected at the discretion of the **MANAGER** or **ENGINEER OF RECORD**. The removal and disposal of rejected materials is the responsibility of the **CONTRACTOR**.
- E. Testing of concrete materials and of concrete by the **CONTRACTOR** shall conform to ACI 301, Section 1.6.
- F. Any Work found unsatisfactory or any Work disturbed by subsequent operations before acceptance is granted shall be corrected by **CONTRACTOR** at the **CONTRACTOR's** expense.
- G. Test results for concrete shall be evaluated in accordance with ACI 301, Section 1.6.

PART 2: PRODUCTS

2.01 MATERIALS:

- A. All materials furnished in accordance with this section shall conform to the requirements indicated below.
- B. Materials that are subject to additional requirements such as design, workmanship, fabrication, welding, surface preparation, painting, erection, or others, shall conform to the applicable terms of this section.
- C. All materials shall be prepared for shipment and shipped using the **MANUFACTURER's** standard packaging.

2.02 DELIVERY, STORAGE, AND HANDLING OF MATERIALS:

Delivery, storage, and handling of materials shall be in accordance with ACI 301, Section 5.1.3.

2.03 CEMENT:

- A. All cement shall conform to ASTM C 150, Type II, moderate sulfate resistant. Air-entraining cement shall not be used.
- B. Certified mill test reports for the cement used on this project shall be retained for the duration of the concrete work.
- C. The mill test reports for cement shall show, in addition to physical and chemical properties, the date delivered to the ready-mix plant, the date of manufacture and lot number, and controlling ASTM specification and type.
- D. Cement that has become caked, partially set, deteriorated, damaged or contaminated shall not be used. The temperature of the cement as delivered to the ready-mix plant shall not exceed one hundred fifty degrees Fahrenheit (150°F).

2.04 AIR-ENTRAINING CHEMICAL ADMIXTURE:

- A. An air-entraining agent shall be used in the concrete mix to entrain the specified percentage of air, by volume, in the concrete. This agent shall conform to the requirements of ASTM C 260. Air entraining agents shall be one of the following: Darex or Daravair by W.R. Grace; MBVR or

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MB-AE10 by Master Builders: Protex Air Entraining Solution by Protex Industries, Inc.; or **MANAGER** or **ENGINEER OF RECORD** approved equal. In the batching process, the air entraining solution shall be added to the batching water.

- B. No other chemical admixtures will be allowed to be used in the concrete mix without prior approval of **MANAGER** or **ENGINEER OF RECORD**.

2.05 FLY ASH:

The concrete mix shall make use of fly ash in the mix design. Fly ash shall constitute twenty (20) percent, by weight, of the total cementitious materials. Fly ash shall be ASTM C 615, Class F.

2.06 AGGREGATES:

Fine and coarse aggregates shall conform to ASTM C 33. Aggregate shall come from a **MANAGER** or **ENGINEER OF RECORD** approved source.

2.07 WATER:

Mixing water for all concrete work and water for curing concrete shall be clean and clear and free from injurious amounts of oil, acids, alkalis, organic matter, or other deleterious substances, and shall conform to the requirements of ASTM C 94.

2.08 PVC WATERSTOP:

- A. PVC waterstop material shall comply with USCOE CRD-C572 for polyvinyl chloride and shall be of the dimensions and profile shown on the DRAWINGS.
- B. Waterstop installed in joints shall be capable of resisting a water head of one hundred (100) feet and perform between -20°F and +150°F temperatures.
- C. All splices in waterstop shall incorporate the fittings and adhesives and be made using tools or equipment recommended by the MANUFACTURER.
- D. PVC waterstop and accessories shall be equal to waterstop manufactured by the following:
 - 1. W.R. Meadows, Elgin, IL
 - 2. Progress Unlimited, Inc., New York, NY
 - 3. Williams Products, Inc., Troy, MI

2.09 FORM MATERIALS:

- A. Formwork shall generally be steel or plywood, unless otherwise required herein or on the DRAWINGS.
- B. Formed surfaces shall be a rough-form finish as specified in paragraph 3.06, below.
- C. Formwork materials, sizes and thickness of members, accessories, hardware, supports, and attachments shall satisfy requirements of ACI 347 and the MANUFACTURER's printed recommendations.

2.10 FORM RELEASE AGENTS:

General purpose form release agents shall be nonstaining products such as Formshield as manufactured by A. C. Horn Inc., Duogard by W. R. Meadows, Inc., Nox-crete by The Nox-crete Company, Magic Kote by Symons Manufacturing Company, or equal, as approved by the **MANAGER** or **ENGINEER OF RECORD**.

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2.11 FORM TIES

- A. Ties and other similar form accessories to be partially or wholly embedded in the concrete shall be of a commercially manufactured type.
- B. After the ends or end fasteners have been removed, the embedded portion of metal ties shall terminate not less than two (2) inches from any concrete surface either exposed to view or exposed to water.
- C. Form ties shall be constructed so that the ends or end fasteners can be removed without spalling the concrete.

2.12 WELD FILLER METALS:

- A. All weld filler metals shall conform to AWS D1.1, Section 4, or AWS D1.4, Section 5.
- B. Electrode containers shall be hermetically sealed and shall be marked to fully identify contents.

2.13 BOND BREAKER:

- A. Joint and dowel surfaces requiring a bond breaker shall be coated with curing compound or with bituminous paint.
- B. Waterstop shall be protected during application of bond breaking material to prevent it from being coated.

2.14 BURLAP CLOTH FOR MOIST CURING OF CONCRETE

Burlap cloth used for moist curing of concrete shall conform to AASHTO M 182.

2.15 TECHNICAL REQUIREMENTS:

- A. Concrete mix design shall be designed by an independent testing laboratory based on the following requirements.
- B. Proportioning: The concrete supplied shall have the properties listed in Table 03300-2.

**TABLE 03300-2
CONCRETE PROPERTIES**

Mix Parameter:	All reinforced structural concrete
Slump:	4 inches \pm 1-inch (In accordance with ACI 301, Section 4.2.2.2)
Maximum Coarse Aggregate Size:	1-1/2 in.
Coarse Aggregate Gradation:	ASTM C 33, Size No. 467
Required Percent Range Air Entrainment:	5 percent \pm 1 percent
Design Strength (28 Days):	5,000 psi
Maximum Water/Cement Ratio	0.45

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- C. The **CONTRACTOR** shall use established and tested concrete mix proportions based on the provisions of ACI 301, Section 4.2.3, to obtain mixes that satisfy the above requirements.
- D. The **CONTRACTOR** shall not deliberately overdesign the concrete mix 28-day compressive strength without written approval of the **MANAGER** or **ENGINEER OF RECORD**.
- E. Actual mixes used shall be based on the results of test mix data submitted by the **CONTRACTOR** for evaluation by the **MANAGER** or **ENGINEER OF RECORD**.
- F. In no case shall concrete achieve a compressive strength at 28 days greater than 750 psi above the minimum specified compressive strength.

2.16 SLUMP REQUIREMENTS:

- A. The slump for each concrete delivery shall meet the specified slump. When required, initial slump adjustment shall be in conformance with ASTM C 94, paragraph 11.7.
- B. Once discharge of concrete to placement has started, no further adjustment of water content will be permitted.
- C. Concrete that fails to meet the specified slump within the tolerances permitted in ASTM C 94, Paragraph 6.1 and 6.2, shall be rejected.

2.17 REJECTION OF CONCRETE:

- A. Any concrete that does not meet the mix requirements as specified above shall be rejected.
- B. Any concrete that has not been discharged from the delivery vehicle within ninety (90) minutes after batching shall be rejected except that during periods of hot weather as defined by ACI 305, the time limit shall be forty-five (45) minutes or commencement of initial set, whichever occurs first.
- C. The Independent Testing Laboratory shall immediately notify the **MANAGER** or **ENGINEER OF RECORD** when any concrete is rejected.

PART 3: EXECUTION

3.01 BATCHING, MIXING, AND DELIVERY:

- A. Basic Requirements:
 - 1. Concrete materials shall be batched, mixed, and transported in accordance with ASTM C 94.
 - 2. The temperature of cement shall not exceed 150°F at the time of batching.
 - 3. Starter grout mixtures shall be uniform and controlled to the same temperature and time requirements as specified for concrete mixes.
 - 4. Where truck mixers are used to transport concrete, a suitable portion of the allowable water may be withheld until the truck reaches the point of discharge. Also, slump adjustments shall be made at the placement site not exceeding the slump range specified herein, in accordance with ACI 301, Section 4.3.2.1.
 - 5. Three batching tickets shall be provided for the ready-mixed concrete and shall accompany each delivery truck to the point of discharge. Each record ticket shall have the name of the **CONTRACTOR** and supplier/subcontractor, the job location, and the mix designation.

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6. The **MANAGER** or **ENGINEER OF RECORD** shall specifically approve the method of batching, mixing and delivering the concrete to the point of discharge.

B. Batching:

Batching shall conform to the Concrete Plant Manufacturers Bureau standards and shall meet the following additional requirements:

1. Hot weather conditions may require partial or total replacement of mixing water with ice. Ice shall be weighed to within one (1) percent by weight.
2. Adequate equipment shall be provided at the batching plant for heating concrete materials and protecting the concrete in transit during freezing or near freezing weather. The heating equipment shall have sufficient capacity so that the concrete produced meets the temperature limitations given in ACI 301, Section 4.2.2.8.
3. Batch admixtures in accordance with the MANUFACTURER's instructions and the provisions of ASTM C 94.

C. Mixing:

1. Truck mixers shall comply with the requirements of the Truck Mixer and Agitator Standards.
2. The suitability of these units as mixers shall be demonstrated by making a mixer uniformity test in accordance with ASTM C 94 for each mixer of different design and blade conditions initially and thereafter whenever requested by the **MANAGER** or **ENGINEER OF RECORD**.
3. Each truck shall have a revolution counter and an automatic water-measuring device in good working order.

D. Delivery:

1. Freshly mixed concrete and starter grout shall be delivered to the point of placement in accordance with ASTM C 94 and in a thoroughly mixed, homogeneous condition, with uniform consistency from batch to batch.
2. Discharge of concrete from trucks shall be completed within ninety (90) minutes, or before the truck drum has revolved 300 revolutions, after the introduction of mixing water to the cement and aggregates.
3. Rejected concrete shall be removed from the site.
4. Evidence of premature setting, or of unusual heating-up of the concrete in the truck shall be cause for rejection of the load.
5. Concrete delivery trucks shall not have aluminum chutes. All chutes shall be round-bottomed.
6. Wash water for cleaning concrete delivery trucks shall be collected in approved sediment pit. The **CONTRACTOR** shall periodically remove and dispose of collected waste concrete offsite.

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3.02 COLD WEATHER REQUIREMENTS:

- A. Cold weather requirements for concreting shall conform to ACI 301, Section 5.3.2.1b. No frozen materials or materials containing ice shall be used.
- B. Concrete materials shall be heated sufficiently to compensate for heat loss and allow placement of the batch within ninety (90) minutes after mixing, at or above the placing temperatures listed in ACI 301, Section 4.2.2.8.

3.03 HOT WEATHER REQUIREMENTS:

- A. Hot weather requirements for concreting shall conform to ACI 301, Section 5.3.2.1c. All concrete shall be delivered to the forms at all times at the coolest temperature that is practicable under the existing conditions.
- B. Concrete will not be acceptable if it has a temperature in excess of 90°F at time of placement.

3.04 COMMUNICATION SYSTEM:

A radio communication system shall be provided and maintained between the ready-mix plant and each delivery vehicle.

3.05 FOUNDATION PREPARATION:

- A. No concrete shall be placed until all formwork, installation of items to be embedded, and preparation of subgrade and other surfaces involved in the placement have been approved by the **MANAGER** or **ENGINEER OF RECORD**.
- B. All surfaces of forms and embedded materials shall be free from curing compound, dried mortar from previous placements, and other foreign substances before the adjacent or surrounding concrete placement is begun.
- C. Prior to beginning concrete placement, the **CONTRACTOR** shall make ready a sufficient number of properly operating vibrators and operators, and shall have readily available additional vibrators to replace defective ones during the progress of the placement.
- D. All surfaces upon or against which concrete is to be placed shall be free from frost, ice, water, mud, and debris. All ponded water shall be removed from the subgrade and excavations prior to and during concrete placing operations.
- E. Earth foundations shall be damp when concrete is placed against them. Surfaces shall be thoroughly moist but not muddy to a depth of six (6) inches, or to impermeable material, whichever is less.

3.06 FORMWORK:

- A. General:

Formwork shall conform to the requirements of ACI 301, Section 2, and ACI 347 except as herein specified. All formwork shall be removed.
- B. Form Tolerances:

Formwork shall be constructed so as to ensure that the finished concrete surfaces will conform to the tolerances and finish requirements of Section 5.3 of ACI 301, for rough-form finish.

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C. Preparation of Form Surfaces:

The contact face of forms, except where otherwise specified, shall be coated with a nonstaining form release agent or mineral oil or other material suitable for this application.

3.07 TOOLED EDGES:

All concrete edges shall be tooled to a one-quarter (1/4) inch radius.

3.08 REMOVAL OF FORMS

- A. Removal of forms shall conform to ACI 301, Sections 2.3.2 and 2.3.4.
- B. No shoring, bracing, supports or other formwork shall be loosened or removed until the concrete supported thereby has acquired sufficient strength to support safely their own weight and any other probable loads.

3.09 PLACING REINFORCEMENT AND DOWELS

- A. Reinforcement and approved detailed placing drawings of reinforcing steel and dowels shall be furnished under Section 03220.0. Reinforcing steel shall be placed in conformance with ACI 301, Section 3, and ACI 318, Section 7.5, unless otherwise noted herein or shown on the **DRAWINGS**. Tolerances for cover given in ACI 301 and ACI 312 shall be applied to the minimum concrete protective covers given in those standards or herein. All accessories for positioning and maintaining reinforcement in its required location shall be furnished and installed.
- B. Locations and lengths of laps, splices, and embedments shall be as indicated on the **DRAWINGS**. Otherwise, the requirements of ACI 312, chapter 12 for tension splices and embedments shall govern.
- C. Whenever the projection of the bar is less than that required by the **DRAWINGS** for lap splicing the matter shall be referred to the **MANAGER** or **ENGINEER OF RECORD** for resolution.
- D. Welding of reinforcing steel shall be performed only when specific written approval has been obtained from the **MANAGER** or **ENGINEER OF RECORD**. Tack welding of embedded items to reinforcing steel will not be permitted. When reinforcing steel is to be welded, a welding procedure suitable for the chemical composition and intended use or service shall be used in accordance with AWS D1.4.
- E. Field fabrication of reinforcing steel shall meet the requirements of Section 03220.0, and shall require the approval of the **MANAGER** or **ENGINEER OF RECORD**. All field fabrication operations are subject to review and approval by the **MANAGER** or **ENGINEER OF RECORD**.
- F. Field bending of reinforcing steel shall be avoided wherever possible and shall require the prior approval of the **MANAGER** or **ENGINEER OF RECORD**. Bending or straightening of reinforcing steel partially embedded in set concrete shall be permitted only if the following provisions are met:
 - 1. Reinforcing steel shall be bent as gently and in as gradual an arc as possible. Bending practices shall conform to ACI 315.
 - 2. Bar sizes to No. 8 may be bent cold only once at any location and then straightened, or straightened once to remove an inadvertent bend so long as the temperature of the bar in the area of the bend is greater than 60 °F. No bend shall exceed 105 degrees. Subsequent straightening or bending shall be preheated as specified below.

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3. All sections of reinforcing steel containing any breaks, cracks, or splitting shall be removed. Portions of reinforcing steel removed shall be replaced by either welding or mechanical splicing in accordance with the requirements specified herein.
4. Bars of all sizes bent less than 10 degrees embedded in hardened concrete may be straightened at ambient temperatures.

3.10 CONSTRUCTION JOINTS:

- A. Construction joints shall be constructed at the locations and in accordance with the details shown on the DRAWINGS.
- B. The joints shall be constructed so that there will be no bond between the concrete surfaces forming the joint. Reinforcement shall not be continuous across the joint.
- C. The joints shall be made by forming the concrete on one side of the joint and curing the first placed concrete in the joint a minimum of seven (7) days prior to placing adjacent concrete.
- D. The surface of the concrete first placed at a construction joint shall be coated with bond breaker material.
- E. The dowel bars to be placed in construction joints shall be cleaned and the trailing end of the dowel shall be uniformly coated with a bond breaker or a film of clean oil or grease. The bars shall be spaced as shown on the DRAWINGS and placed across the joints so that the end of the bar without the expansion cap is embedded in the first placement. The end of the bar with the expansion cap installed shall be embedded in the second placement. The dowels shall be positioned parallel to each other and to the surfaces of the concrete slab. Special care shall be taken to maintain the dowels accurately in position during concrete placement operations.
- F. Edges of construction joints shall be tooled to a radius of one-eighth (1/8) inch and to a depth of one-quarter (1/4) inch as shown on the DRAWINGS.

3.11 CONCRETE PLACING:

- A. General: Concrete placing shall conform to the requirements of ACI 301, 304, 305R, 306R, and 318. All concrete placing equipment and methods shall be satisfactory to the **MANAGER** or **ENGINEER OF RECORD**. All concrete shall be placed in the dry. Concrete shall not be placed under water without a written procedure approved by the **MANAGER** or **ENGINEER OF RECORD**. All edges of concrete shall be tooled as specified.
- B. **CONTRACTOR** shall notify **MANAGER** or **ENGINEER OF RECORD** at least forty-eight (48) hours before each concrete placement.
- C. Placing:
 1. The retempering of concrete by the addition of water, cement, or aggregate is not permitted. However, initial slump adjustment at the point of delivery, when required, shall be made in accordance with ASTM C 94, Paragraph 11.7. Once discharge of concrete has started for final placement, no further adjustment of water content is permitted.
 2. At the time of placing, the plastic concrete temperature shall meet the requirements of ACI 301, Section 4.2.2.8.
 3. Placing of concrete may be done by means of buckets, belt conveyor, chutes, drop pipes or pumping, and shall be done in a manner that will prevent the segregation or loss of materials.

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4. There shall be no vertical free fall greater than five (5) feet for any concrete, and the drop shall be reduced if segregation occurs.
5. Lateral movement of concrete by means of vibrators shall not be permitted except for local consolidation of the mass or melting down of small mounds where deposited. The placement shall be carried on at such a rate that all concrete surfaces not yet to grade shall not have reached their initial set before additional concrete is placed thereon.

D. Cold Weather Requirements:

1. All concrete materials and all reinforcement and forms with which the concrete is to come in contact shall be free from frost, snow, and ice. Contact surfaces shall not be less than 40 °F. Cold weather concreting shall comply with the requirements of ACI 301, Section 5.3.2, and ACI 306R.
2. Salt or other chemicals shall not be used for the prevention of freezing.
3. Construction procedures and loadings during cold weather construction shall not produce stresses or loadings that exceed the requirements of ACI 318 for the actual strength of concrete being loaded.

E. Hot Weather Requirements:

1. Hot weather requirements for concreting shall conform to ACI 301, Section 5.3.2, and ACI 305R. All concrete shall be delivered to the forms at all times at the coolest temperature that is practicable under existing conditions, but consistent with the temperature requirements specified. Concrete shall not be placed when hot weather conditions would prevent proper placement and consolidation.
2. Obtaining the acceptable temperature at the time of placement may require adding ice and/or chilled water to the mix. The coarse aggregate may be sprayed with water of the same quality required for mixing when ambient temperatures exceed 80 °F. Such measures shall be taken at the batch plant to furnish concrete at acceptable temperatures. The moisture content of the aggregates shall be taken into account when determining the amount of mixing water required for the concrete mix.

F. Consolidation of Concrete:

1. Concrete shall be thoroughly worked around reinforcement and embedded fixtures and into the corners of the forms. ACI 309 shall be used as a guide to develop suitable consolidation techniques.
2. Concrete shall be placed with the aid of mechanical vibrating equipment, supplemented by hand spading, rodding, or tamping. In no case shall vibrators be used to transport concrete inside the forms. Vibrating equipment shall be of the internal type and shall at all times be adequate in number of units and power of each unit to properly consolidate all concrete. Form or surface vibrators shall not be used.
3. To obtain a good bond between the new and old section of the wall or slab at the vertical construction joint, the concrete shall be thoroughly vibrated immediately adjacent to the existing wall or slab.
4. Concrete consolidation shall be judged satisfactory when the large aggregate is well embedded, the batch has generally leveled off, there is visible blending of the batch perimeter with concrete previously placed, a thin film of glistening mortar lies on the surface, air bubbles rising to the surface have practically been eliminated, and cement

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paste shows at the junction of the concrete and the form. In placing concrete, coarse aggregate that protrudes from the surface of the layer shall be depressed into the mass during the initial consolidating or vibrating operations.

3.12 ROUTINE TESTS OF CONCRETE

- A. Routine testing of concrete materials and of concrete by the Independent Testing Laboratory arranged for by the **CONTRACTOR** shall conform to the requirements of paragraph 1.06, above.
- B. Concrete material for preparing test specimens will be taken at the point of discharge for placement of the concrete after final adjustment of slump.

3.13 CURING AND PROTECTION:

- A. The provisions of this Section shall apply for all structural concrete. Curing and protection of freshly deposited concrete shall conform to the requirements described herein. For other conditions not covered herein, requirements shall conform to ACI 301, Section 5.3.6. These requirements include the control of moisture loss from concrete and control of concrete temperature.
- B. Concrete shall be moist-cured for seven (7) days by covering with saturated nonstaining burlap mats. Moist-cured concrete shall be maintained continuously, not periodically, wet for the entire curing period. If water or curing materials stain or discolor concrete surfaces that are to be permanently exposed, they shall be cleaned as required by the **MANAGER** or **ENGINEER OF RECORD**.
- C. Temperature of the concrete shall be maintained in accordance with Section 5.3.6 of ACI 301.
- D. Moist-curing requires the presence of a visibly wet concrete surface together with the presence of some free water continually throughout the curing period as stipulated in ACI 301.
- E. Covers shall be lapped, weighted, or sealed at the edges, and maintained in good condition to prevent any drying of the surface.
- F. Wood forms shall be prevented from drying out whenever the ambient air temperature exceeds 50 °F.
- G. Records shall be kept of the air temperature, the temperature within any heated or protective enclosure, and of the concrete temperature during the seven-day curing period. Records shall satisfy the intent of chapter 8 of ACI 306R.

3.14 WATERSTOP INSTALLATION

- A. Waterstop shall be as specified herein and placed in joints in accordance with the details shown on the **DRAWINGS**. Field splices, where required, shall be made in accordance with the **MANUFACTURER**'s recommended procedure. Splices shall incorporate recommended fittings, adhesives, and tools.
- B. Waterstop shall be free of grease, oil, dirt, or any other foreign material that might prevent bond.
- C. All material shall be stored in as cool a place as practicable and, in no case, shall the waterstop be stored in the open or exposed to the direct rays of the sun. All material shall be stored so as to permit free circulation of air about it.
- D. Supports shall be provided, and suitable precautions shall be taken to protect the waterstop during the progress of the Work. Nailing of waterstop will not be permitted. Edges of waterstop shall not be cut to surround reinforcement.

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3.15 FINISHING

A. Unformed Surfaces:

1. General:

- a. The ambient temperature of spaces adjacent to surfaces being finished shall be not less than 40 °F.
- b. All unformed surfaces shall have a screeded finish followed by a trowel finish, and shall be true to the elevation shown on the DRAWINGS. Finishing operations shall consist of sufficient leveling and screeding to produce even uniform surfaces.
- c. Surfaces of the concrete shall be sloped for drainage unless otherwise shown on the DRAWINGS or as directed.
- d. Joints shall be carefully made with a jointing or edging tool.
- e. The finished surfaces shall be protected from stains or abrasions.

2. Float Finish:

- a. Surfaces shall be screeded and darried or bullfloated to bring the surface to the required finish level with no coarse aggregate visible. No water, cement, or mortar shall be added to the surface during the finishing operation.
- b. The concrete, while still green but sufficiently hardened to bear a man's weight without deep imprint, shall be floated to a true and even plane.
- c. Floating may be performed by use of suitable hand floats or power-driven equipment. Hand floats shall be made of magnesium or aluminum. Floating is also used as the second stage of a trowel finish.
- d. Tolerance for a floated finish shall be true plane within five-sixteenths (5/16) inch in ten (10) feet as determined by a 10-foot straightedge placed anywhere on the slab in any direction, unless specified otherwise.

3. Trowel Finish:

- a. Unformed surfaces exposed to view shall receive a trowel finish.
- b. After bleed water has disappeared and when the floated surface has hardened sufficiently to prevent an excess of fine material from being drawn to the surface, steel troweling shall be started.
- c. Steel troweling shall be performed with firm pressure so as to flatten the sandy texture of the floated surface and produce a dense uniform surface, free from blemishes and trowel marks.

4. Protection:

- a. The finished surfaces shall be protected from stains or abrasions.
- b. Surfaces and edges shall be protected from damage.

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B. Formed Surfaces:

1. Formed surfaces shall be left with the texture imparted by the forms except that defective surfaces shall be repaired as described in the following.
2. After removal of forms, all ridges or lips shall be removed and undesirable local bulging on the surfaces to be permanently exposed shall be remedied. Epoxy bonding agent shall be in accordance with ACI 503.2. Latex bonding agent meeting the requirements of ASTM C 1059 may be used instead of epoxy resin if concrete to be patched was placed less than twenty-four (24) hours previously. Repair of surfaces damaged during excavation or as a result of excavation shall conform to the requirements of this section.
3. Repair of Formed Surfaces: After removal of forms, defective areas of concrete as defined below, shall be reamed or chipped to sound concrete and filled with dry pack mortar. If chipping is required, make edges perpendicular or undercut to surface with a minimum of one-half (1/2) inch in depth. Do not feather edges. Obtain **MANAGER** or **ENGINEER OF RECORD** approval of chipping work. Defective and unsound areas larger than forty-five (45) square inches and deeper than two (2) inches shall be removed by saw cuts in a rectangular pattern and repaired with concrete replacement as required in paragraph 3.15D below. The prepared area shall be brush-coated with an approved epoxy resin or with a neat cement grout after dampening and then filled with mortar or concrete. Patch defective areas to match appearance of adjacent concrete surfaces after cracks are filled.
4. Defective areas are defined as surface defects that include honeycomb, rock pockets, indentations, cracks larger than one-eighth (1/8) inch wide, cracks that leak in water-holding basins, spalls, chips, embedded debris, lift lines, sand lines, bleed lines, leakage from form joints, fins and other projections, form popouts, texture irregularities, stains that cannot be removed by cleaning, and voids.

C. Tie Holes:

1. Fill all tie holes with dry pack non-shrink grout in accordance with the details shown on the DRAWINGS. Surfaces of the holes shall be thoroughly cleaned and presoaked prior to application of the mortar bond coat.
2. Dry pack grout shall be Five Star Non-Shrink Cement-Based Grout manufactured by Five Star Products, Inc., Fairfield, CT, 06825, or equal, and mixed to a consistency such that the mortar will stick together when molded by hand and not exude water when squeezed.
3. A mortar bond coat shall be applied to the concrete hole surface prior to placing dry pack. The mortar bond coat shall consist of one (1) part portland cement to one (1) part sand mixed with water to give a fluid paste consistency. The mortar bond coat shall be thoroughly brushed onto the hole surfaces.
4. The dry-pack grout shall be immediately packed into place in three-eighth (3/8) inch compacted layers before the bond coat has dried or cured.
5. Compacting, finishing, and curing of the grout shall be as specified in Paragraph 3.15D below.

D. Material and Procedure for Concrete Repairs:

1. The cement used in the dry-pack mortar or replacement concrete shall be a blend of the cement utilized for production of project concrete and white Portland cement properly proportioned so that the final color of the mortar or concrete will match adjacent concrete. Trial batches shall be utilized to determine the proportions required to match colors.

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2. Dry-pack mortar shall consist of one (1) part cement to two and a half (2-1/2) parts fine aggregate. The fine aggregate shall be that utilized for production of project concrete. The mortar shall be remixed without addition of water until it obtains the stiffest consistency that will permit placing.
3. Mortar shall be thoroughly compacted into the prepared void by tamping, rodding, ramming, etc., and struck off flush with adjacent concrete. Replacement concrete shall be produced utilizing project materials to meet requirements of the concrete it is replacing, and shall be proportioned by the **CONTRACTOR** and approved by the **MANAGER** or **ENGINEER OF RECORD**. It shall be drier than the usual mixtures and shall be thoroughly compacted into the prepared void by tamping, rodding, ramming, etc., and shall be struck off and finished to adjacent concrete. Forms shall be utilized as required or as directed.
4. Metal tools shall not be used to finish permanent view surfaces. The repaired areas shall be cured for seven (7) days. The temperature of the in-situ concrete, adjacent air and replacement mortar or concrete shall be above 40°F during placement, finishing and curing. Packaged materials meeting the requirements of ASTM C 928 may be used in lieu of dry-pack mortar when approved.
5. Unless painting of surfaces is required, uniform color of the concrete shall be maintained by use of only one mixture without changes in materials or proportions for any structure or portion of structure that is exposed to view or on which a special finish is required.
6. The form panels used to produce the finish shall be orderly in arrangement, with joints between panels planned in approved relation to openings, building corners, and other architectural features. Forms shall not be reused if there is any evidence of surface wear or defects that would impair the quality of the surface.

*** END OF SECTION ***

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SECTION 03371.0 SHOTCRETE

PART 1: GENERAL

1.01 RELATED SECTIONS:

Refer to the following Section for related Work:

Section 03220.0 – Reinforcing Steel
Section 03300.0 - Cast-in-Place Concrete

1.02 SECTION INCLUDES:

Furnishing all materials and performing all Work necessary for the installation of shotcrete at the location shown on the DRAWINGS.

1.03 REFERENCES:

- A. American Concrete Institute (ACI)
 - ACI 506.2 Shotcrete

- B. ASTM International (ASTM)
 - 1. ASTM A 185 Steel Welded Wire Reinforcement, Plain, for Concrete
 - 2. ASTM A 497 Steel Welded Wire Reinforcement, Deformed, for Concrete
 - 3. ASTM A 615 Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
 - 4. ASTM A 996 Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement
 - 5. ASTM C 31 Making and Curing Concrete Test Specimens in the Field
 - 6. ASTM C 33 Concrete Aggregates
 - 7. ASTM C 39 Compressive Strength of Cylindrical Concrete Specimens
 - 8. ASTM C 143 Slump of Hydraulic-Cement Concrete
 - 9. ASTM C 33 Concrete Aggregates
 - 10. ASTM C 150 Portland Cement
 - 11. ASTM C 231 Air Content of Freshly Mixed Concrete by the Pressure Method
 - 12. ASTM C 260 Air-Entraining Admixtures for Concrete
 - 13. ASTM C 309 Liquid Membrane-Forming Compounds for Curing Concrete
 - 14. ASTM C 494 Chemical Admixtures for Concrete
 - 15. ASTM C 618 Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete

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1.04 SUBMITTALS:

CONTRACTOR shall provide the following submittals sufficient to allow evaluation by **MANAGER** and **ENGINEER OF RECORD**.

- A. Mix Design: Shotcrete mix design.
- B. MANUFACTURER's Data: Product data for each cement, pozzolan, admixture, and curing compound.
- C. Certifications: MANUFACTURER's certification that cement and pozzolan meet specified requirements. Include one set of mill test results with each certification.
- D. Instructions: MANUFACTURER's application instructions for curing compounds.

1.05 QUALITY ASSURANCE:

- A. All shotcrete testing (both field and laboratory testing) will be the responsibility of **CONTRACTOR**. **CONTRACTOR** shall be responsible for cooperating with CQA Monitor during all testing activities. **CONTRACTOR** shall provide equipment and labor to assist CQA Monitor in sampling, if requested, and shall also provide access to all areas requiring testing activities.
- B. Any Work found unsatisfactory or any Work disturbed by subsequent operations before acceptance is granted shall be corrected by **CONTRACTOR**.
- C. Perform work in accordance with ACI 502.6.

PART 2: PRODUCTS

2.01 SHOTCRETE MATERIALS:

- A. Portland Cement: As specified for concrete in Section 03300.0.
- B. Water: Clean potable water free of detrimental quantities of silt, organic matter, salts, and other impurities.
- C. Fine Aggregate: ASTM C 33.
- D. Coarse Aggregate: ASTM C 33, Size No. 8.

2.02 ADMIXTURES:

- A. Pozzolan: ASTM C 618, Class F.
- B. Air Entraining: ASTM C 260. Use a neutralized vinsol resin formulation when air-entraining admixture is used in conjunction with ASTM C 494, Type F or G chemical admixtures.
- C. Chemical: ASTM C 494, Types A, D, F, or G may be added to shotcrete. Do not use chemical admixtures which introduce more than one-tenth (0.1) percent chloride, by weight of cementitious materials.

2.03 REINFORCEMENTS:

- A. Dowels: ASTM A 615, Grade 60, or ASTM A 996, Type A, Grade 60. Deformed steel bar.

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- B. Reinforcing Fabric: ASTM A 185 or ASTM A 497, electrically-welded wire fabric, size as shown on the DRAWINGS.

2.04 CURING MATERIALS:

Curing Compound: ASTM C 309.

2.05 SHOTCRETE MIX:

- A. Design and adjust shotcrete mix.
- B. Pozzolan may be substituted for twenty (20) percent plus or minus five (5) percent of design cementitious materials content.
- C. Slump: four (4) to five (5) inches at placement when tested in accordance with ASTM C 143.
- D. Compressive Strength: four thousand (4,000) pounds per square inch (psi), minimum, at twenty-eight (28) days when tested in accordance with ASTM C 31 and ASTM C 39 using six (6) by twelve (12) inch cast cylinders.
- E. Air Entrainment: four (4) to six (6) percent of air, by volume of concrete, as discharged from mixer when tested in accordance with ASTM C 231.
- F. Do not add set-accelerating admixtures or calcium chloride to shotcrete.

2.06 MIXING:

Mix by wet or dry process in accordance with ACI 502.6.

2.07 SHOTCRETE TEMPERATURE:

The shotcrete temperature shall be between 50 and 90 degrees Fahrenheit (°F) during application.

PART 3: EXECUTION

3.01 PREPARATION:

- A. Remove standing water, mud, and debris from surfaces to be covered by shotcrete.
- B. Roughen concrete surfaces to an amplitude of one-quarter (1/4) -inch.
- C. Prepare earth subgrade free from frost or ice.
- D. Thoroughly moisten absorptive surfaces to be covered with shotcrete so that moisture will not be drawn from fresh shotcrete.

3.02 APPLICATION:

- A. Place reinforcement in accordance with ACI 506.2.
- B. Use mixing and delivery equipment capable of thoroughly mixing aggregate, cement, and water in sufficient quantity to maintain continuous and uniform placement.
- C. Do not apply shotcrete more than forty-five (45) minutes after adding cement to mix.
- D. Do not place shotcrete on surfaces that are frozen or spongy.

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- E. Achieve maximum compaction with minimum rebound.
- F. Build-up to required thickness in multiple passes to achieve layering. Encase reinforcement with first pass.
- G. Allow each layer to take initial set before applying succeeding layers.
- H. Do not permit applied shotcrete to sag, slough, or displace.
- I. After initial set of final layer, remove excess material outside of alignment lines.
- J. Finish surface of final layer with natural gun finish.
- K. Remove rebound material which does not fall clear of work. Remove rebound at construction and expansion joints. Discard salvaged rebound.
- L. Maintain shotcrete with minimal moisture loss at relatively constant temperature for period necessary for hydration of cement and hardening of shotcrete.
- M. Immediately after placement, protect shotcrete from premature drying, excessively hot or cold temperatures, and mechanical injury.
- N. Cure by application of clear water-emulsified curing compound. Mix and apply curing compound in accordance with MANUFACTURER's instructions.
- O. Sound test applied material with hammer for voids. Remove void areas and replace with new shotcrete ensuring full bond with adjacent work.

*** END OF SECTION ***