June 2, 2016

WISCONSIN FIELD OFFICE TECHNICAL GUIDE
450-11-TECHNICAL GUIDE
FOTG NOTICE WI-79

SUBJECT: WISCONSIN FIELD OFFICE TECHNICAL GUIDE

Purpose. Revisions to Wisconsin Conservation Practice Standards and Specifications

Explanation of Changes.

Section IV: Conservation Practice Standards and Specifications:

Concrete (WCS 4) – Current changes include the following:

- Design of the Concrete Mix
  - Modified to bullet formatting
  - Removed reference to any minimum compressive strength in the specification.
  - Modified design slump to a maximum not to exceed 5 inches with water reducers.
  - Modified design slump language to a maximum not to exceed 8 inches with super-plasticizer.
- Mixing
  - Allowed for additional water above the design mix, but not to exceed 0.45 at any time, including the addition of water at the site.
- Placing, Consolidating, and Finishing Concrete
  - Added requirement for daily data including: The ambient temperature, relative humidity, and wind velocity when concrete is placed.
- Placement
  - Modified language of the slump of placed concrete to a maximum not to exceed 5 inches with the use of water reducers.
    - (i.e. no placement of concrete over 5 inch slump. ASTM C-94 tolerance is 5 inches and less)
  - The slump of the placed concrete shall not exceed the maximum slump of 8 inches with the use of super-plasticizer.
- Editorial Changes for Clarification

The following revisions to the Wisconsin FOTG have been posted on the Wisconsin e-FOTG website:

Remove the following outdated Standards and Specifications from any printed copies of the WI FOTG:

- Index
- Concrete (WCS 4)

Add the following Standards and Specifications to any printed copies of the WI FOTG:

- Index
- Concrete (WCS 4)

A link to the Wisconsin FOTG is located on the Wisconsin NRCS website at:
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/fotg/

JIMMY BRAMBLETT
State Conservationist

Wisconsin Construction Specifications

Number	Practice Name	Discipline	Date
1	Clearing	Engineering	5/12
2	Excavation	Engineering	5/12
3	Earthfill	Engineering	5/12
3a	Earthfill (Ditch Fills or Partial Filling)	Engineering	6/13
4	Concrete	Engineering	6/16
5	Construction Site Pollution Control	Engineering	5/12
6	Corrugated Metal Pipe Conduits	Engineering	1/12
7	Mobilization and Demoblization	Engineering	5/12
8	Drainfill	Engineering	5/12
9	Rock Riprap	Engineering	11/11
10	Fences	Engineering	3/15
11	Small Rock Aggregate (Non-Concrete)	Engineering	3/13
12	Cathodic Protection	Engineering	5/12
13	Geotextiles	Engineering	5/10
14	Timber Fabrication & Installation	Engineering	9/10
15	Plastic Pipe Conduits	Engineering	4/09
16	Stream Clearing and Snagging	Engineering	5/12
17	Wire Mesh Gabions or Mattresses	Engineering	5/12
18	Sack or Tubular Gabion	Engineering	4/09
19	Drilled Well Abandonment/Decommissioning	Engineering	5/12
20	Soil Bioengineering	Engineering	5/12
21	Structural Measures for Streambank and Shorelines	Engineering	5/12
22	Temporary Wave Barrier (Breakwaters)	Engineering	5/12
23	Aluminum or Steel Roof Gutters	Engineering	9/15
24	Construction Surveys	Engineering	5/12
25	GPS Machine Control Construction	Engineering	3/15
26	Topsoiling	Engineering	5/12
44	Corrugated Polyethylene Tubing	Engineering	5/12
50	Organic Fill for Ditch Fills or Filling	Engineering	6/13
51	Organic Fill for Embankments and Ditch Plugs	Engineering	6/13
100	Poultry Carcass Composter	Engineering	4/09
200	Grouted Rock Riprap	Engineering	5/12
201	Steel Sheet Piling	Engineering	5/12
202	Polyethylene Geomembrane Lining	Engineering	9/12
203	Geosynthetic Clay Liner	Engineering	4/11
204	Earthfill for Waste Storage Facilities	Engineering	10/12
205	Ethyl Propylene Diene Monomer (EPDM) Geomembrane Lining	Engineering	9/12
211	Vinyl Sheet Piling	Engineering	3/12
300	Clay Liner	Engineering	3/15
634	Waste Transfer Pipe	Engineering	3/15

WISCONSIN CONSTRUCTION SPECIFICATION

4. CONCRETE

1. SCOPE

The work shall consist of furnishing, forming, placing, consolidating, finishing, and curing Portland cement concrete and the furnishing and placing of steel reinforcement or other appurtenances as required on the construction drawings. All materials, test procedures, and admixtures shall meet the requirements of the latest edition of the applicable ASTM designation.

Failure to meet any requirements contained in this specification may be cause for rejection of the concrete or delay of placement.

2. DEFINITIONS

The following definitions are provided for the purpose of this specification. The words that are defined in this section are italicized the first time that they are used in the text.

Batch delivery ticket refers to the form showing the total weights of all the ingredients used to mix the contents of the rotating drum mixer (total weights of all ingredients on the load) and other job-pertinent information.

Consolidating refers to the process of reducing the volume of entrapped air in a fresh cementitious mixture, usually accomplished by inputting mechanical energy.

Construction joints are those joints where two successive placements of concrete meet, through which reinforcement is continuous and bond is required between the two pours.

Finishing refers to the process of treating surfaces of fresh or recently placed concrete or mortar to produce desired appearance and service.

Firm refers to the condition of the subgrade where it is not significantly displaced or deformed by foot traffic during construction, and is able to properly support reinforcement chairs.

Flatwork refers to concrete slabs poured on slopes flatter than 5:1 (Horizontal:Vertical).

Form release agent refers to commercially manufactured formwork release agents that prevent formwork absorption of moisture, prevent bond with concrete, and do not stain the concrete surfaces.

Formed surfaces are those that require a temporary structure or mold for the support of concrete while it is setting and gaining sufficient strength to be self-supporting, such as walls or poured-in-place tank lids.

Hand tamping refers to the operation of consolidating freshly placed concrete by hand-held implements.

Honeycomb refers to voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles.

Jitterbug refers to a grate tamper for pushing coarse aggregate slightly below the surface of a slab to facilitate finishing.

Liquid-tight concrete refers to applications using specific placement and finishing techniques, and design features to minimize the loss of liquids.

Manufacturer refers to the producer/supplier of the ready-mixed concrete.

Mesh roller refers to a finishing tool consisting of a rolling drum attached to a handle, of which the surface of the drum is made of mesh, sometimes used for rolling over the surface of fresh concrete to embed coarse aggregate

Rock pocket refers to a porous, mortar-deficient portion of hardened concrete consisting primarily of coarse aggregate and open voids; caused by leakage of mortar from the form, separation (segregation) during placement, or insufficient consolidation.

Sloped slabs refers to concrete slabs poured on slopes of 5:1 (Horizontal:Vertical) or steeper.

Technician refers to an individual trained in specific technical processes, and may include an engineer, government agency representative, private sector technical service provider, qualified independent third party quality assurance inspector, or a similar person that is primarily responsible for the project quality assurance.

Ternary mix is a mixture using three cementitious materials, such as Portland cement, fly ash, and ground granulated blast-furnace slag (slag).

Top bars are horizontal reinforcements placed such that more than 12 inches of fresh concrete is cast below the reinforcing bar (such as horizontal wall bars).

Vibration refers to mechanical energetic agitation of freshly mixed concrete during placement by mechanical devices, either pneumatic or electric, that create vibratory impulses of moderately high frequency to assist in consolidating the concrete.

- Internal vibration employs one or more vibrating elements that can be inserted into the fresh concrete at selected locations.
- Surface vibration employs a portable horizontal platform on which a vibrating element is mounted.

Water-cement ratio (w/c) is the ratio of the weight of free water (excluding that absorbed by the aggregates) to the weight of Portland cement in a concrete mix expressed as a decimal.

Water-cementitious material ratio (w/cm) is the ratio of the weight of free water (excluding that absorbed by the aggregates) to the weight of cementitious material (fly ash, Portland cement, and slag) in a concrete mix expressed as a decimal.

3. MATERIALS

The Contractor shall provide test data, independent laboratory reports, or other evidence from the concrete manufacturer showing that all materials meet the requirements of this specification. All materials proposed for use shall be approved by the Technician.

1. Portland cement shall conform to ASTM C 150 and shall be Type I, II, or III.

2. Fine aggregate shall conform to ASTM C 33 and be composed of clean, uncoated grains of material. Refer to the fine aggregate gradation table in Section 4 of this specification.

3. Coarse aggregates shall be gravel or crushed stone conforming to ASTM C 33 and be clean, hard, durable, and free from clay or coating of any character. Refer to the coarse aggregate gradation table in Section 4 of this specification.

4. Water shall be clean and free from injurious amounts of oil, salt, acid, alkali, organic matter, or other deleterious substances.

5. Air entraining agent shall conform to ASTM C 260.

6. Pozzolan (fly ash) shall conform to ASTM C 618, Class C or F. The loss of ignition shall not exceed 2 percent for Class C and 6 percent for Class F.

7. Ground granulated blast furnace (GGBF) slag shall conform to ASTM C 989.

8. Chemical admixtures shall be used in strict compliance with the manufacturer's recommendations, conform to ASTM C 494, and may be the following types:

    1. Type A - Water-reducing admixtures.
    2. Type B - Retarding admixtures.
    3. Type C - Accelerating admixtures.
    4. Type D - Water-reducing and retarding admixtures.
    5. Type E – Water-reducing and accelerating admixtures.
    6. Type F - Water-reducing, high range admixtures (superplasticizers).
    7. Type G - Water-reducing, high range, and retarding admixtures (superplasticizers).

    If Type C or E is used, the manufacturer shall provide the Technician a product data sheet verifying that the product is a non-chloride accelerator.

    Calcium chloride or admixtures containing chloride ions other than from impurities in admixture ingredients shall not be used.

9. Preformed expansion joint filler shall be commercially available products made of sponge rubber, closed cell foam, or boards containing bituminous materials. The joint filler shall have a minimum thickness of ½ inch and a width equal to the full cross sectional width of the concrete at the joint.

10. Deformed reinforcing bars shall be free from loose rust, oil, grease, paint, or other deleterious matter. Steel bars for concrete reinforcement shall meet the requirements of ASTM A 615. The steel shall be deformed Grade 40 or Grade 60 billet-steel bars as noted on the plans.

11. Deformed welded wire reinforcement (WWR) shall conform to the requirements of ASTM A 1064 and shall be furnished in flat sheets, and shall be size D4 or larger as indicated on the plans. This material may only be used for non-structural elements such as slabs on grade. Spacing of welded intersections shall not exceed 16 inches.

12. Embedded waterstops shall be made of polyvinyl chloride (PVC), thermoplastic elastomeric rubber (TPE-R), or polyethylene (PE or VLDPE). The minimum width of waterstop shall be 6 inches, or the width and material shown on an NRCS approved Wisconsin Standard Drawing. The waterstop web thickness shall be a minimum of 3/16 inches throughout the entire cross section of the waterstop. Waterstops shall be the type intended for placement entirely within the concrete cross section, or as shown on an NRCS approved Wisconsin Standard Drawing or other drawings as approved by the NRCS State Conservation Engineer. Waterstops shall have ribbed

or “dumb-bell” type anchor flanges and a hollow tubular center bulb. Split flange waterstops are prohibited.

13. Curing compound shall be a liquid membrane-forming compound suitable for spraying on the concrete surface. The curing compound shall meet the requirements of ASTM C 309, Type 2 (white pigmented).

14. Expansive waterstops shall consist of preformed strips or mastic (caulk) made of hydrophilic materials that expand when subjected to moisture and shall not contain bentonite. Use shall be limited to non-movement joints (fixed joints).

4. Design of the Concrete Mix

No less than seven (7) days prior to the start of concrete placement the Contractor is responsible for submitting documentation of the proposed design mix to the Technician. The Contractor is responsible for providing a mix with the minimum required 28-day compressive strength in the construction plan and meet the following:

- The water-cement (w/c) or the water-cementitious material (w/cm) ratio shall not exceed 0.45 for all concrete construction.
- The cementitious material required shall be 564 pounds per cubic yard of concrete.
    - The cementitious material may include a maximum of 25 percent (by weight) of fly ash or a maximum of 30 percent (by weight) of ground granulated blast-furnace (GGBF) slag. The remaining cementitious materials shall be Portland cement.
    - Mixes containing both fly ash and GGBF slag shall not exceed 30 percent in combination (*ternary mix*) and no more than 25 percent shall be fly ash. The remaining cementitious materials shall be Portland cement.
- The air content (by volume) shall be 6 percent of the volume of the concrete.
- The maximum (not to exceed) slump, with the use of water reducers, shall be 5 inches.
- The maximum (not to exceed) slump, with the use of superplasticizers, shall be 8 inches.

The fine aggregate oven dry weight shall be 30-45 percent of the total oven dry weight of the combined coarse and fine aggregates. The well-graded fine aggregate shall conform to the following ASTM C 33 or Wisconsin DOT gradation requirements shown below:

Fine Aggregate Gradation

Sieve Size	Percent Passing By Weight	
	ASTM C 33	WI DOT
⅜" (9.5 mm)	100	100
No. 4 (4.75 mm)	95-100	90-100
No. 8 (2.36 mm)	80-100	---
No. 16 (1.18 mm)	50-85	45-85
No. 30 (600 µm)	25-60	---
No. 50 (300 µm)	5-30	5-30
No. 100 (150 µm)	0-10	0-10
No. 200 (75 µm)	0-5	0-3.5

The well graded coarse aggregate shall conform to the following ASTM C 33 gradation requirements for size number 67 aggregate shown below:

Coarse Aggregate Gradation

Sieve Size	Percent Passing By Weight
1" (25.0 mm)	100
¾" (19.0 mm)	90-100
⅜" (9.5 mm)	20-55
No. 4 (4.75 mm)	0-10
No. 8 (2.36 mm)	0-5
No. 200 (µm)	0-1.5

5. MIXING

Ready-mixed concrete shall be in accordance with ASTM C 94 for ordering (OPTION C, Minimum Cement Content), batching, mixing, and transporting.

Batching Tolerances (maximum w/c or w/cm ratio shall not exceed 0.45):

1. Cementitious Material: The weight of the cementitious material shall be within plus or minus 1 percent (+/- 1%) of the required weight of the cementitious material.
2. Aggregate: The weight of the fine and coarse aggregate shall be within plus or minus 2 percent (+/- 2%) of the required weight.
3. Mixing Water: The water added to the batch, including free water on the aggregates, shall be measured by weight or volume to an accuracy of 1 percent of the required total mixing water. Added ice shall be measured by weight.
4. Admixtures: The admixtures shall be within plus or minus 3 percent (+/- 3%) of the required weight or volume for each specific admixture.

5. Air: The air content (by volume) shall be 6 ± 1.5 percent of the volume of the concrete at the location and time of placement.

Concrete shall be uniform and thoroughly mixed when delivered to the forms.

The water-cement (w/c) ratio or water-cementitious material (w/cm) shall not exceed 0.45 at any time, including the addition of water at the site.

The concrete shall be batched and mixed such that the temperature of the concrete at time of placement shall not be less than 55 degrees Fahrenheit or, at no time during its production or transportation more than 90 degrees Fahrenheit.

6. BATCH DELIVERY TICKET INFORMATION

The Contractor shall obtain from the manufacturer a batch delivery ticket for each load of concrete before unloading at the site. Any concrete load delivered without a batch delivery ticket containing all the following information shall not be allowed to be discharged in any part of the construction project covered under this specification.

The following minimum information shall be included on the batch delivery ticket.

1. Job-pertinent information

   - Name of concrete manufacturer and batch plant
   - Name of purchaser and job location
   - Date of delivery
   - Truck number
   - Amount of concrete delivered
   - Time loaded or time of first mixing of cement and aggregates

2. Ingredients used to mix the batch

   - Mixing water in the load added as free water
   - Percent moisture content, or weight of free water contained in the aggregates
   - Percent moisture content, or weight of free water absorbed by the aggregates
   - Type and amount of cementious materials
   - Type and amount of admixtures
   - Weights of fine and coarse aggregates

3. The Contractor is responsible for adding the following information

   - Volume of water added by the receiver of the concrete
   - Time the concrete arrived at the site
   - Time the concrete was completely unloaded

Upon completion of the concrete placement, copies of all batch delivery tickets shall be provided to the Technician.

7. PLACEMENT OF SUBGRADE, FORMS, REINFORCING STEEL, AND WATERSTOP

A. Subgrade

The site shall be graded to the dimensions and elevations as specified in the construction plans.

All surfaces shall be firm and damp prior to placing concrete. Concrete shall not be placed on mud, dried earth, uncompacted fill, frozen subgrade, or in standing water. The use of plastic sheeting to isolate the concrete from unsuitable foundations shall not be permitted.

B. Forms

The forms and associated bracing shall be substantial, unyielding and constructed so that the finished concrete will conform to the specified dimensions and contours. Forms shall be mortar tight. Forms shall be coated with a *form release agent* before being set into place. Form release agent shall not come in contact with the steel reinforcement, waterstop, or with hardened concrete against which fresh concrete is to be placed.

For structures which are to be liquid-tight, form ties shall be used that permit their removal to a depth of at least ½ inch.

Concrete joints shall be placed at locations and be of the type shown on the construction drawings.

C. Reinforcing Steel

Reinforcement shall be accurately placed as shown on the drawings and secured in position in a manner that will prevent its displacement during the placement of concrete.

1. Tolerances - The following tolerances will be allowed in the placement of reinforcement:
   - Where 1½ inches clear distance is shown between reinforcing steel and forms, or embedded objects, allowable clear distance is 1⅛ to 1½ inches.
   - Where 2 inches clear distance is shown between reinforcing steel and forms, allowable clear distance is 1⅝ to 2 inches.
   - Where 3 inches clear distance is shown between reinforcing steel and earth or forms, allowable clear distance is 2½ to 3 inches. Over-excavation backfilled with concrete shall not be considered as clear distance.
   - The maximum variation from the reinforcing steel spacing shown, shall be 1/12 of the spacing, without a reduction in the amount of reinforcing steel specified.
   - The ends of all reinforcing steel shall be covered with at least 1½ inches of concrete, with an allowable minimum distance of 1⅛ inches.
2. Reinforcement Support - Holding steel reinforcement in position with temporary supports is not permitted. Tack welding of bars is not permitted. Metal chairs, metal hangers, metal spacers, plastic chairs, or concrete chairs shall be used to support the reinforcement. Precast concrete chairs shall be manufactured from concrete equal in compressive strength to the concrete being placed. Reinforcement shall be supported at a minimum as follows:
   a. Deformed reinforcing bars for flatwork and sloped slabs shall be supported by a minimum of 1 support chair every 4 feet in each direction. Reinforcement shall not deflect or sag between supports. Deformed reinforcing bars shall be tied at every other rebar intersection or as approved by the Technician.

b. Deformed welded wire reinforcement (WWR) shall be supported no further than as indicated in the table below.

WWR Support

Welded Wire Reinforcement Size[(1)]	Welded Wire Spacing	Maximum Support Spacing in Each Direction[(2)], feet
D9 or larger	12 inches or more	4 to 6 feet
D5 to D8	12 inches or more	3 to 4 feet
D9 or larger	Less than 12 inches	3 to 4 feet
D4 to D8	Less than 12 inches	2 to 3 feet

Notes: (1) "D" is the standard designation for deformed wire.
(2) Support spacing shall be adequate to support all loads, including construction personnel and equipment. If excessive deflections occur, closer support spacing is required.

Flatwork reinforcement may be driven on prior to placement of supports if both of the following conditions are met:

- The subgrade is firm so that minimal displacement is made by equipment. If significant displacement occurs, the steel shall be removed, the subgrade regraded and compacted before steel and concrete placement.
- The reinforcing steel is not deformed by the equipment. If the steel is deformed, it shall be replaced before concrete placement.

Steel tying to protruding steel from a previous pour or form construction for new concrete that will be in contact with previously poured concrete shall not be started until the previously poured concrete has cured a minimum of 12 hours.

3. Reinforcement Splice Lengths and Bend diameters:

a. Deformed reinforcing bars

Bend diameter: 6 bar diameters for #3 through #8 bar sizes and 8 bar diameters for larger bars. Reinforcing bars shall not be heated to facilitate bending.

Splice Length: The minimum splice lengths in the table below are for concrete designed with a 28-day compressive strength of 3,500 psi. (NRCS standard wall designs) Other higher concrete design strengths and reinforcement grades require different splice lengths (typically shorter) in accordance with ACI 318. Deformed reinforcing bars shall not be spliced by welding. All lap splices shall be adequately tied together to firmly hold the reinforcement in position to maintain the proper splice length.

Minimum Splice Lengths [Note 1]

	Grade 40	Grade 60
#3 through #6 bars		
Top bars	27 bar diameters	41 bar diameters
all other bars	21 bar diameters	32 bar diameters
#7 and larger bars		
Top bars	34 bar diameters	51 bar diameters
all other bars	26 bar diameters	40 bar diameters

Note 1: Splice lengths shall be the greater of that indicated in the Table or 12-inches.

b. Deformed welded wire reinforcement (WWR) - Splice length shall be in accordance with the requirements of ACI 318-08 or ACI 318-11 Part 12.18. Deformed welded wire reinforcement shall not be spliced by welding. All lap splices shall be tied to firmly hold the reinforcement in position to maintain the proper splice length.

D. Embedded Waterstop

Embedded waterstops shall be located as shown on the drawings and secured in position so that displacement does not occur during concrete placement. Vertical applications (footing to wall joints and wall to wall joints) shall be secured to reinforcement using wire or "hog ring" type fasteners or factory installed grommets at the outermost rib at the spacing as recommended by the waterstop manufacturer (usually 12 inches on center). Hog rings shall be factory installed, if the manufacturer has that option available. Each waterstop shall be placed and secured with the hollow bulb aligned in the center of the planned joint.

Waterstop clearance shall be a minimum of 1½ inches from reinforcement and one half the waterstops width to the face of the concrete (3 inches for 6 inch wide waterstop).

Manufacturers' fabricated waterstop intersections shall be provided. Only straight butt joint splices are allowed for field fabrication. Splices in waterstops shall be welded as recommended by the manufacturer. The specific splicing iron and the temperature of the iron shall be in accordance with the manufactures instructions for the type of waterstop being spliced. Manufacturer-certified contractors may fabricate waterstop intersections in a controlled environment and with proper manufacturers' equipment. Prior to the time of delivery of the fabricated intersections, documentation of certification must be presented to the Technician.

Joints with embedded waterstops shall not be placed horizontally across sloped slabs.

Continuous placement of concrete through a waterstop joint is not allowed, except for control joints in formed walls where preformed joint control formers are used in conjunction with the waterstops, or in control joints as shown on an NRCS approved Wisconsin Standard Drawing or other drawings as approved by the NRCS State Conservation Engineer.

E. Expansive Waterstop

Expansive waterstop shall be placed at the locations shown on the drawings in accordance with the manufacturer's instructions. Preformed strips may require adhesive or other forms of mechanical fastening to existing concrete based on the manufacturer's instructions. Mastic (caulk) type expansive waterstops shall be placed to the bead size as recommended by the manufacturer based on the amount of concrete cover provided. The adhesive for preformed expansive waterstop and the mastic for caulk type expansive waterstop shall be allowed to cure

for the duration as indicated by the manufacturer prior to placing concrete over the waterstop. Colder temperatures will require longer curing periods prior to concrete placement. Do not allow the expansive waterstop to become wet prior to placing concrete over the waterstop.

8. PLACING, CONSOLIDATING, AND FINISHING CONCRETE

The Contractor shall notify the Technician of the proposed method of placement, consolidation, and finishing of the concrete at least seven (7) days prior to the start of concrete placement. The Contractor shall furnish the Technician a record of daily data including:

- Ambient temperature
- Relative humidity
- Wind velocity

A. General

Prior to placement of concrete, the forms and subgrade shall be free of chips, sawdust, debris, water, ice, snow, extraneous oil, mortar, or other harmful substances or coatings. Any oil on the reinforcing steel or other surfaces required to be bonded to the concrete shall be removed. Concrete shall not be placed until the subgrade, forms, waterstop, and steel reinforcement have been inspected and accepted by the Technician. Any deficiencies shall be corrected before the concrete is delivered for placement. Forms, reinforcing steel, and subgrade shall be moistened prior to placing concrete.

B. Delivery

Concrete shall be delivered to the site and discharged into the forms within 1½ hours after the introduction of the mixing water to the cement and aggregates, or when a superplasticizer is used, the manufacturer's recommended time limit for discharge after addition shall apply. The 1½ hour time may be extended if the concrete is of a slump that it can be placed, consolidated, and finished without the addition of water to the batch. Upon arrival at the job site, addition of water will be allowed to adjust the slump, provided such addition does not exceed the water-cement (w/c) ratio or water-cementitious material ratio (w/cm). Final placement of the batch shall begin immediately after mixing of the added water is completed.

Additional superplasticizer shall not be added to the concrete mix after discharge of the concrete at the job site has commenced.

C. Placement

The slump of the placed concrete shall not exceed the maximum slump of 5 inches with the use of water reducers.

The slump of the placed concrete shall not exceed the maximum slump of 8 inches with the use of superplacticizers.

Concrete shall be deposited as closely as possible to its final position. Concrete shall be worked into the corners and angles of the forms and around all reinforcement and embedded items in a manner to prevent segregation of aggregates. All placement shall be done in a manner that prevents incorporation of subgrade material into the concrete.

Methods for placing concrete on sloped slabs shall only include chutes, pumps, conveyors, wheelbarrows, or similar means of directly depositing concrete as near as possible to its final position. Placement of concrete by other methods where concrete is deposited upslope and flows to its final position downslope (commonly called "lava flow", "glacial pours", etc.) shall not be permitted.

Concrete shall not be dropped more than 6 feet vertically unless suitable equipment is used to prevent segregation. Concrete containing superplasticizer shall not be dropped more than 12 feet vertically and shall not be placed in lifts exceeding 6 feet in depth. Non-superplasticized concrete shall be placed in forms in horizontal layers not more than 24 inches deep. Each layer shall be thoroughly consolidated before the next is placed, at a rate such that previously placed concrete has not yet set when the next layer of concrete is placed upon it.

D. Consolidation

1. Formed Surfaces

All concrete walls shall be vibrated.

Immediately after the concrete is placed in the forms, it shall be consolidated by internal vibration or hand tamping as necessary to insure dense concrete. Vibration shall be applied to the freshly deposited concrete by rapidly inserting the vibrator and slowly, in an up and down motion, removing the vibrator at points uniformly spaced at not more than 1.5 times the radius of the area visibly effected by vibration. Generally, this is at 5 to 10 seconds per foot on 14-inch spacings or less. The area visibly effected by the vibrator shall overlap the adjacent, just vibrated area. The vibrator shall extend vertically into the previously placed layer of fresh concrete by at least 6 inches at all points. Concrete supplied with superplasticizer shall be placed with a minimum amount of vibrating and finishing effort. Vibration shall not be applied directly to the reinforcement steel or the forms, nor to concrete that has hardened to the degree that it does not become plastic when vibrated. Each pour shall be consolidated to insure a monolithic bond with the preceding pour.

The use of vibrators to transport concrete in the forms, slabs or conveying equipment will not be permitted.

2. Slabs

Immediately after the concrete is placed, it shall be consolidated by hand or mechanical methods as necessary to insure dense concrete.

- Surface vibrators may be used to consolidate slabs 8 inches and less in thickness.
- Slabs more than 8 inches thick shall be consolidated with internal vibration and may be augmented through use of a surface vibrator.

Surface vibrators include vibrating screeds, plate or grid vibratory tampers, or vibratory roller screeds. (Mesh rollers, jitterbugs, and grate tampers are finishing tools and not consolidation tools.)

When the concrete slab is to be consolidated using surface vibration methods, the contractor shall detail how this work is to be performed in writing to the technician for review and approval. This report must be submitted no less than 7 calendar days before placing concrete by this method. It includes equipment selection and specifications.

3. Embedded Waterstops

Internal vibration is required along the entire length of all joints that contain embedded waterstops for both formed surfaces and slabs.

E. Finishing

All screed support devices shall be removed from the concrete or driven down flush with the subgrade prior to finishing.

1. Formed Surfaces: All formed concrete surfaces shall be true and even, and shall be free of depressions, holes, projections, bulges, or other defects in the specified surface finish or alignment. All surface defects shall be repaired as stated in the "Form Removal" section of this specification.

2. Slabs: All flatwork and sloped slabs shall be worked to a uniform grade, maintaining the specified thickness. Concrete shall be worked to minimize segregation and in a manner that does not adversely affect the structural integrity, durability or function of the structure. Surfaces shall be free from rock pockets, or honeycomb areas or other harmful irregularities or defects.

   Water shall not be sprinkled or added to the surface of the concrete to facilitate finishing. An additional finish shall be applied if specified in the construction plans.

   The proposed finished texture (broom, float, mesh roller, trowel, non-slip, etc.) of the concrete surface shall be approved by the Technician.

   Evaporation reducer may be used during the finishing operation if approved by the Technician. Curing of the concrete is still required as per Section 11, Curing.

   If a protective concrete coating is specified on the drawings, the coating manufacturer's recommendations for curing and surface preparation shall be followed.

F. Construction Joints

If the concrete sets during placement to the degree that it will not flow and merge with the succeeding pour when tamped or vibrated, the Contractor shall discontinue placing concrete and install a formed construction joint. The Contractor shall be prepared to install unplanned *construction joints* in the event that there is an interruption of the pour, equipment breakdown, or other problem which makes it necessary to stop placement of concrete at locations other than those previously planned. The reinforcement shall pass through the joint, unless otherwise indicated on the construction plan. Prior to the succeeding pour, the joint surface shall be cleaned to remove all unsatisfactory concrete, laitance, coatings, stains, or debris by one of the following methods:

1. The joint surface shall be cleaned to expose the fine aggregate and sound surface mortar, but not so deep as to undercut the edges of coarse aggregate. Cleaning shall be by wire brush, sandblasting, or high pressure air-water cutting after the concrete has gained sufficient strength to prevent displacement of the coarse aggregate. The joint surface shall be washed to remove all loose material after cutting.

2. According to methods specified by the person approving the construction plans.

The surfaces of all construction joints shall be wetted and standing water removed immediately prior to placement of the new concrete. The new concrete shall be placed directly on the cleaned and washed surface. New concrete shall not be placed until the hardened concrete has cured at least 12 hours. The newly placed concrete shall be consolidated to achieve a good bond with the previously hardened concrete.

9. Form Removal and Concrete Repair

A. Form Removal

Forms shall be removed without damage to the concrete. Supports shall be removed in a manner that permits the concrete to take the stresses due to its own weight uniformly and gradually. The minimum period from completion of the concrete placement to the removal of the forms shall be based on either strength tests or cumulative times.

1. Strength Tests: The strength of the in-place concrete is determined by testing concrete cylinders specifically cast for this purpose and cured adjacent to the member in accordance with the ASTM C 31 methods for determining removal time. Unless otherwise specified, forms supporting the weight of the concrete member may be removed after the concrete strength is 70 percent of that specified for the 28-day compressive strength.

2. Cumulative Time: The total accumulated time, not necessarily continuous, that the air adjacent to the concrete is above 50 degrees Fahrenheit will be determined by the Contractor and accepted by the Technician. The forms may be removed after the total accumulated time shown in the following table:

Form Removal

Forms		Time
Sides of slabs or beams without waterstop		12 hours
Sides of slabs or beams with waterstop		16 hours
Undersides of slabs or beams	Clear Span < 10 feet	4 days
	10-20 feet	7 days
	>20 feet	14 days
Sides of walls or columns	Height of forms < 20 feet	24 hours
	>20 feet	72 hours

For structures which are not required to be liquid-tight, form ties shall be removed flush with or below the concrete surface. For structures which are to be liquid-tight, form ties shall be removed to a minimum depth of ½ inch. All cavities or depressions resulting from form tie removal shall be patched in accordance with Part C of this Section.

Forms shall be removed and the concrete inspected by the Technician before walls are backfilled. Concrete loading shall be in accordance with Section 13, Loading New Reinforced Concrete Structures.

B. Repair of Surface Defects (other than tie holes)

Immediately after removal of the forms, concrete which is honeycombed, damaged or otherwise defective as identified by the Technician shall be repaired or replaced by the Contractor. All repairs of surface defects shall be completed prior to the application of curing compound. Repair of surface defects such as honeycombed or otherwise defective concrete shall be made using

bonding grout and site mixed Portland cement mortar or other products specifically intended to repair surface defects that are applied in accordance with the manufacturer's recommendations.

1. Bonding grout and site mixed Portland cement mortar:

    a. Outline the honeycombed or otherwise defective concrete with a ½ to ¾ inch deep saw cut and remove such concrete down to sound concrete. When chipping is necessary, leave chipped edges perpendicular to the surface or slightly undercut. Do not feather edges.

    b. Dampen the area to be patched plus another 6 inches around the patch area perimeter.

    c. Prepare bonding grout by mixing approximately one part Portland cement and one part fine sand with water to the consistency of thick cream.

    d. Thoroughly brush the bonding grout into the surface. When the bond coat begins to lose water sheen, apply repair mortar. Repair mortar is made by mixing 1 part Portland cement to 2½ parts fine sand (approximately finer than the No. 16 sieve size) by damp loose volume. The mortar shall be at a stiff consistency with no more mixing water than is necessary for handling and placing. Mix the repair mortar and manipulate the mortar frequently with a trowel without adding water.

    e. Thoroughly consolidate the mortar into place and strike off, leaving the patch slightly higher than the surrounding surface to compensate for shrinkage. Leave the patch undisturbed for 1 hour before finishing. The repair shall be cured as specified Section 10, Curing.

2. Repair materials other than site mixed Portland cement:

    a. Portland cement mortar modified with a latex bonding agent conforming to ASTM C 1059, Type II.

    b. Epoxy mortars and epoxy compounds that are moisture-insensitive during application and after curing and that embody an epoxy binder conforming to ASTM C 881. The type, grade, and class shall be appropriate for the application as specified in ASTM C 881.

    c. Nonshrink Portland cement grout conforming to ASTM C 1107.

    d. Packaged dry concrete repair materials conforming to ASTM C 928.

    e. Other products specifically intended to repair surface defects that are applied and cured in accordance with the manufacturer's recommendations.

C. Repair of Form Tie Holes

Liquid-Tight Concrete Structures – Repair tie holes immediately after formwork removal and prior to the application of curing compound. All cavities or depressions resulting from form tie removal shall be patched with commercially available patching products or site mixed Portland cement repair mortar.

1. Site-mixed Portland cement repair mortar

    Repair mortar is made by mixing 1-part cement to 2.5-parts fine sand (approximately finer than the No. 16 sieve size) by damp loose volume. Mortar shall be at a stiff consistency with

no more mixing water than is necessary for handling and placing. Mix the repair mortar and manipulate the mortar frequently with a trowel without adding water. Clean and dampen tie holes before applying the mortar. Cure in accordance with Section 10, Curing.

2. Repair materials other than site mixed Portland cement:

   a. All those materials listed in Section 9.B.2.a-d.

   b. Other products specifically intended to fill form tie holes for liquid-tight applications that are applied and cured in accordance with the manufacturer's recommendations.

10. CURING

Concrete shall be cured for a period of at least 7 consecutive days (curing period) after it is placed, except as stated in Section 12. Exposed concrete surfaces shall be kept continually wet during the entire curing period or until curing compound is applied.

Curing compound shall be applied at the rate and with the proper equipment recommended by the manufacturer. It shall form a uniform, continuous, adherent film that shall not check, crack, or peel and shall be free from pinholes or other imperfections.

Curing compound shall not be used at construction joints or other areas that are to be bonded to additional concrete. Surfaces subjected to heavy rainfall or running water within 3 hours after the application of curing compound, or surfaces damaged by subsequent construction operations during the curing period, shall be recoated in the same manner as the original application.

11. CONCRETE PLACEMENT IN HOT WEATHER

Hot weather conditions exist at the time of proposed placement when:

1. The rate of evaporation greater than 0.10 lb. /sq. ft. /hr. OR

2. Two or more of the following factors are exceeded:

   a. Ambient temperature is greater than 80 degrees Fahrenheit
   b. Relative humidity is less than 60 percent
   c. Wind velocity (average) is greater than 10 mph

Concrete surfaces shall not be allowed to dry after placement and during the curing period.

Measures to reduce surface moisture loss and rate of cement hydration must be taken to immediately protect and cure the concrete due to rapid drying conditions.

- Plan placement to early morning, late afternoon or evening.
- Use a set-retarding admixture meeting the requirements in Section 3 of WCS-4 when the time between the introduction of the mixing water to the cement and aggregates and discharge exceeds 45 minutes. The 45 minute time may be extended if the concrete is of a slump that it can be placed, consolidated, and finished without the addition of water to the batch.
- Use a fog spray to raise the relative humidity of the ambient air.
- Moist cure the concrete surface as soon as the surfaces are finished and continue for at least 24 hours.

- Use a monomolecular film, or evaporation retarder in accordance with the manufacturers printed instructions.

Concrete placement shall be suspended when:

1. The rate of evaporation is greater than 0.25 lb./sq. ft./hr. OR

2. When all of the following factors, as measured at the time of concrete placement are exceeded:

   a. The ambient temperature is greater than 80 degrees Fahrenheit,
   b. Relative humidity is less than 40 percent, and
   c. Wind velocity (average) is greater than 15 mph

   $$E = (Tc^{2.5} - R * Ta^{2.5})(1+0.4V) \times 10^{-6}$$

   where:

   E = evaporation rate, lb. /sq. ft. /hr.
   Tc = concrete surface temperature, °F
   Ta = air temperature, °F
   R = percent relative humidity /100 (decimal form 20% = 0.20)
   V = wind velocity, mph

   Wind speeds at reporting station are taken above the ground surface, so V = average reported wind speeds x 0.66).

12. CONCRETING IN COLD WEATHER

The following provisions shall apply when the minimum air temperature at the local job site is less than 35 degrees Fahrenheit (the forecasted temperature, which shall be verified with a maximum/minimum thermometer at the start of the morning job shift).

A. No concrete shall be placed without the required thermometers at the job site.

B. The Contractor shall furnish the Technician a record of daily temperature data including:

- Outside air maximum and minimum temperatures at the local job site, and
- Temperatures, of the air adjacent to the surface of the concrete, at several points along the concrete surface for all concrete curing periods.

C. When the cement is initially added to the mix, the temperature of the mixing water shall not exceed 100 degrees Fahrenheit nor shall the temperature of the aggregate exceed 100 degrees Fahrenheit.

D. The temperature of the concrete at the time of placement shall be not less than 55 degrees Fahrenheit or at no time during its production or transport more than 90 degrees Fahrenheit.

E. Placed concrete may be protected by covering, housing, insulating or heating concrete structures.

F. The minimum air temperature adjacent to the surface of the concrete shall be maintained above 40 degrees Fahrenheit for a period of at least 7 accumulated days. These 7 days must occur

during the first 10 days after the concrete is placed. At no time, during the first 10 days after concrete is placed, shall the minimum air temperature adjacent to the surface of the concrete be less than 32 degrees Fahrenheit unless Type III cement or an approved accelerating admixuture is used (see Item G below).

G. The curing period may be reduced from 7 cumulative days to 3 consecutive days when Type III cement or an approved accelerating admixture is used. The accelerating admixture shall be used at the proportions recommended by the manufacturer. The minimum air temperature adjacent to the surface of the concrete shall be maintained above 40 degrees Fahrenheit for the 3 day curing period.

H. Combustion heaters shall have exhaust flue gases vented out of the concrete protection enclosure. The heat from heaters and ducts shall be directed in such a manner as to not overheat or dry the concrete in localized areas or to dry the exposed concrete surface.

At the end of the curing period, the concrete shall be allowed to cool gradually. The maximum temperature decrease at the concrete surface in a 24-hour period shall not exceed 40 degrees.

13. Loading New Reinforced Concrete Structures

Backfill material shall be the type indicated on the drawings and shall be free of large stones or debris.

Compaction within 3 feet of the new structure wall will be by means of small manually directed tamping or vibrating equipment.

The age of concrete shall be at least 7 days before any load (including backfill) is applied other than the weight of the wall, forms, or scaffolds for succeeding lifts or light equipment. The 7-days may be reduced to 3 days when Type III cement or an approved accelerating admixture is used. Loads may also be applied to new concrete less than 7 days after placement when 75 percent of the design strength has been attained through compressive strength testing on cylinders that have been cured on-site under field conditions.

14. Inspection and Testing

The inspection and testing details of this section shall apply when specific concrete tests are required in the construction drawings or quality assurance plan. This testing does not relieve the Contractor of the responsibility to perform the work according to this specification. The Technician shall have free access to the work **site and batching** to obtain samples.

When testing is conducted, the following methods shall be used:

Type of Test	Test Method (ASTM Designation)
Sampling	C 172
Slump	C 143
Air Content	C 231 or C 173
Making and Curing Specimens in the Field	C 31
Obtaining and Testing Drilled Cores	C 42
Compressive Strength	C 39
Density (Unit Weight)	C 138
Temperature	C 1064

The contractor is responsible for determining who is responsible for testing, and providing results to all parties.

Compressive strength of the concrete shall be considered satisfactory if test results equal or exceed the 28-day design strength. For each ASTM C 39 strength test, three test specimens shall be made. The test result shall be the average of the compressive strength tests of any two of the three test specimens. If one test specimen shows evidence of improper sampling, molding, or testing, it shall be discarded and the remaining specimens tested. The strengths of the remaining two specimens shall be averaged, and the result shall then be considered the compressive strength of the concrete. If more than one specimen shows such defects, the test is not valid and the remaining specimen shall be discarded.

If test results are invalid due to specimen defects, or the in-place concrete that is in question was not sampled, the in-place concrete may be sampled by coring in accordance with ASTM C 42. For core tests, at least three representative cores shall be taken from each area of the concrete in question. If one or more of the cores shows signs of being damaged before testing, it shall be replaced by a new one.