

SECTION 03 10 00

CONCRETE FORMWORK AND ACCESSORIES

PART 1 GENERAL

1.1 SUMMARY

- A. Comply with Division 1, General Requirements.
- B. This Section forms part of Section 03 30 00, Cast-in-Place Concrete.

1.2 REFERENCES

- A. Comply with the latest edition of the following statutes codes and standards and all amendments thereto.
 - 1. Canadian Standards Association (CSA):
 - a. A23.1, Concrete Materials and Methods of Concrete Construction.
 - b. S269.1, Falsework for Construction Purposes.
 - c. S269.2-M, Access Scaffolding for Construction Purposes.
 - d. S269.3-M, Concrete Formwork
 - 2. American Concrete Institute (ACI):
 - a. 347, Guide to Formwork for Concrete.
 - 3. National Lumber Grades Authority (NLGA):
 - a. Standard Grading Rules for Canadian Lumber.

1.3 DESIGN REQUIREMENTS

- A. Design formwork in accordance with CSA S269.1, S269.2-M, and S269.3-M and CSA A 23.1-09 Clause 6.5 Formwork to provide specified finishes.
- B. Design formwork and falsework to carry dead loads and construction live loads.
- C. When high range water reducer (superplasticizer) is used in concrete mix, design forms for full hydrostatic pressure.
- D. Make joints in forms watertight.
- E. Design formwork to meet variations from a reference system specified in CSA A23.1-09 Clause 6.4 Construction Tolerances for Cast-in-Place Concrete.

1.4 SUBMITTALS

- A. Shop Drawings:
 - 1. Submit formwork and falsework drawings bearing seal and signature of a professional engineer licensed in the Province of Manitoba for record purpose.
 - 2. Formwork and falsework shop drawings will not be reviewed for structural adequacy.

3. Be fully responsible for the design, construction, and maintenance of formwork and falsework.
 - a. Show design criteria as specified in CSA A23.1-09 Clause 6.5.2.1.
 4. Indicate:
 - a. For suspended slabs
 - 1) Shoring left in place until concrete has reached specified strength.
 - 2) Re-shoring below slabs or beams supporting shoring above.
 - a) Lateral bracing system.
 - b. For walls and columns on top of slabs and beams
 - 1) Shoring left in place until concrete in walls and columns above has reached specified strength.
 - 2) Lateral bracing system.
 5. Layout of panel joints, form liners, and tie hole pattern. Method of sealing form tie hole. Coordinate with details where shown.
 6. Two unstamped copies of the shop drawings will be returned with Contract Administrator's comments.
- B. Product Data Sheets:
1. Submit manufacturer's product data sheets including materials, allowable loading, installation, application, and maintenance instructions for:
 - a. Proprietary scaffolding.
 - b. Shoring beams.
 - c. Lumber for formwork and falsework.
 - d. Plywood for formwork and falsework.
 - e. Formwork for curved surfaces.
 - f. Tubular column forms.
 - g. Void forms (tubes).
 - h. Void forms (bio-degradable).
 - i. Form release agent.
 - j. Form ties.
 - k. Controlled permeability form liner.
- C. Samples: One each as follows:
1. Form ties.
 2. Form liners.
- D. Informational Submittals:
1. Statement of qualification for formwork designer.
 2. Contractor's Certificate of Proper Installation.

1.5 QUALIFICATIONS

- A. Formwork, Falsework, and Shoring Designer: An engineer licensed in the province of Manitoba.

1.6 Quality Assurance

- A. Mockup Panels:
1. Comply with the requirements of Section 03 39 00, Concrete Curing and Finishes
 2. Construct one panel for each form liner type specified.
 3. Construct mockup panels to demonstrate wall finish.
 - a. Minimum dimensions 2400 mm by 2400 mm.
 - b. Demonstrate sandblasting to show how uniform appearance will be achieved regardless of age of concrete.
 4. Construct panels with specified materials, forming systems, reinforcing details, and leakage prevention techniques.
 5. Show architectural details, joints, form ties, form liners, and reinforcing bar spacers to produce finished surface required.
 6. Test form release agent on one mockup panel to ensure no adverse effects are caused on form or form liner materials.
 7. Cast panels from minimum of 3-cubic metre truck mixer load.
 8. Approved panels establish standard of quality by which concrete work will be judged.
 9. Replace panels if not representative of Work as specified.
 10. Panels may be incorporated into Work if approved by Engineer.
 11. Construct additional 2400 mm by 2400 mm panel or use Engineer-selected portion of as-cast wall surface hidden from view to develop and test patching techniques and mixes.
- B. Construct additional panels and use to demonstrate repair material and application procedures and obtain approval prior to using material to repair project structures.

PART 2 PRODUCTS

2.1 FORM MATERIALS

- A. General:
1. Materials:
 - a. Lumber for Formwork and Falsework: Grade-marked sawn lumber graded in accordance with NLGA.
 - b. Plywood for Formwork: High density overlay (plastic overlay) grade plywood. Plywood may be of lower finish grade when use in conjunction with form liner.
 - c. Fibreglass or steel forms in undamaged condition, of sufficient strength and surface smoothness to produce specified finish.
 2. Circular Structures:
 - a. Conform forms to circular shape of structure.
 - b. Straight panels may be substituted for circular forms provided panels do not exceed 600 mm in horizontal width and angular deflection is no greater than 3-1/2 degrees per joint.

3. Void Forms:
 - a. Bio-degradable: Suitable to support construction load with a controlled built-in strength loss.
 - b. Manufacturer: Void Form International Ltd.

- B. Form Liners:
 1. Controlled Permeability Form Liner:
 - a. Controlled pore size, maximum 0.08 mm to permit drainage of excess water; water permeability at 200 mm water head of 20 L per square metre per second.
 - b. Liner must be noncompressible under wet concrete pressure.
 - c. Manufacturer and Product:
 - 1) Dupont; Zemdram MD (re-use up to 2 times).
 - 2) Fibertex; Formtex (do not re-use).

 - C. Sandblasted Surface Forms: Medium density overlay plywood surfaces.

 - D. Painted Surface Forms: High density overlay plywood surfaces.

 - E. Form Release Agent:
 1. Use form release agent on all cast in place concrete except where form liners is used.
 2. Material: Release agent that does not bond with, leave residue on, stain, or adversely affect concrete surfaces, and does not impair subsequent treatments of concrete surfaces when applied to forms
 3. Freezing point: Minus 15 degrees C or lower.
 4. Manufacturers and Products:
 - a. BASF; MasterFinish RL 211.
 - b. Cresset Chemical Company; Crete-Lease 20-VOC.
 - c. W.R. Meadows of Canada Ltd.; Sealtight Duogard.
 - d. Euclid Admixture Canada, Inc.; Eucoslip VOX.

 - F. Rustication Grooves and Beveled Edge Corner Strips: Nonabsorbent material, compatible with form surface, fully sealed on all sides preventing loss of paste or water between the two surfaces.

 - G. Form Ties:
 1. Material: Steel.
 2. Spreader Inserts:
 - a. Conical or spherical type.
 - b. Design to maintain positive contact with forming material.
 - c. Furnish units that will leave no metal closer than 25 mm to concrete surface when forms, inserts, and tie ends are removed.
 3. Wire ties not permitted.
 4. Flat bar ties for panel forms; furnish plastic or rubber inserts with minimum 25 mm depth and sufficient dimensions to permit patching of tie hole.

5. Water Stop Ties: For water-holding structures, below grade structures, pipe galleries, and accessible spaces below finish grade, furnish one of the following:
 - a. Integral steel water stop 2.6 mm thick and 16 mm in diameter tightly and continuously welded to tie.
 - b. Neoprene water stop 5 mm thick and 24 mm diameter whose center hole is 1/2-diameter of tie, or molded plastic water stop of comparable size.
 - c. Orient water stop perpendicular to tie and symmetrical about center of tie.
 - d. Design ties to prevent rotation or disturbance of center portion of tie during removal of ends and to prevent water leaking along tie.
 - e. Through bolt ties are not permitted for water-holding structures.
 6. Through-Bolts: Tapered minimum 25 mm diameter at smallest end.
 - a. Not permitted for water-holding structures, below grade structures, pipe galleries, and accessible spaces below finish grade.
 7. Elastic Vinyl Plug:
 - a. Use in conjunction with through-bolt type form ties.
 - b. Design and size of plug to allow insertion with tool to enable plug to elongate and return to original length, and diameter upon removal forming watertight seal.
 - c. Manufacturer and Product: Dayton/Richmond Co., A58 Sure Plug.
- H. Stay-Form: Form at joints with waterstop as manufactured by AMICO Type No. 66-26 GA minimum.

PART 3 EXECUTION

3.1 FORM SURFACE PREPARATION

- A. Remove water, snow, ice, laitance, curing compound, loose soil, and other debris and thoroughly clean form surfaces that will be in contact with concrete or that have been in contact with previously cast concrete, dirt, and other surface contaminants prior to coating surface.
- B. Exposed Wood Forms in Contact with Concrete: Apply form release agent as recommended by the manufacturer.
- C. Steel Forms: Apply form release agent to steel forms as soon as they are cleaned to prevent discoloration of concrete from rust.
- D. Form Liners: Provide liners with full sheets and place seams at horizontal and vertical grooves. Prepare as recommended by manufacturer.
 1. Use anchorage systems recommended by manufacturer to anchor liner to formwork.
 2. Do not use form release agent on formwork.

3.2 ERECTION

A. General:

1. Unless specified otherwise, follow applicable recommendations of CSA S269.1, S269.2-M and S269.3-M.
2. Align form joints and make watertight. Keep number of joints to a minimum.
3. Laterally brace formwork and falsework and prevent displacement during concrete placement.
4. Form chases, openings, projections, recesses, expansion joints and construction joints.
5. Form around pipes, mechanical, and electrical equipment which penetrate the concrete structure.
6. Incorporate frames, castings, pipes, sleeves, and similar items into formwork.
7. Do not re-use damaged formwork which may not provide a uniform consistent finish.
8. Do not re-use controlled permeability form liner when water drainage from the liner has reduced to 75 percent of its first use drainage performance.

B. Beveled Edges (Chamfer):

1. Form 20 mm bevels at concrete edges, unless otherwise shown.
2. Where beveled edges on existing adjacent structures are other than 20 mm, obtain Contract Administrator's approval of size prior to placement of beveled edge.

C. Wall Forms:

1. Locate form ties and joints in an uninterrupted uniform pattern.
2. Inspect form surfaces prior to installation to assure conformance with specified tolerances.
3. Do not use through-the-wall removable form ties for walls of liquid holding structures and exterior walls below grade.
4. Where excavation shoring system is used as formwork, fasten form tie to shoring in a suitable manner to withstand applied loads.

D. Formwork with Form Liners:

1. Construct forms to structurally withstand deflection, movement, leakage, high hydraulic pressures resulting from rapid filling and heavy-high frequency vibration.
2. Lay out form joints and ties in uniform pattern, unless otherwise shown.
3. Use plywood forms when using form liners. Plywood may be of lower finish grade when used in conjunction with form liners.
4. Controlled permeability form liner applications:
 - a. Coordinate with Section 03 39 00, Concrete Curing and Finishes.
 - b. For liquid holding structures provide liner on both faces except at tunnels and galleries apply liner on wet side only. Provide liners in full sheets. Place seams at regular horizontal and vertical pattern. Prepare as recommended by the manufacturer.

- c. Use anchorage systems recommended by the manufacturer to anchor liner to formwork. Close anchorage of liner is recommended to prevent wrinkling of the liner.
 - d. Do not use form release agent on formwork.
- E. Form Tolerances: Comply to tolerances of CSA A23.1.
- F. Fasteners: Use only galvanized nails and fasteners when such fasteners will be left in place in the permanent structure.
- G. Void Forms: Brace void forms to prevent distortion and floatation.
- H. Shoring under walls or columns:
- 1. When constructing concrete walls or columns on top of slabs or beams, provide shoring under these slabs or beams to carry the total construction load.
 - 2. Leave shoring in place until the compressive strength of the concrete in the wall above has reached 75 percent of its specified 28-day compressive strength.
- I. Lateral Supports: Where required, brace walls until permanent lateral supports are in place.
- J. Formwork at Construction and Expansion Joints: Provide formwork incorporating water stop in joint. Use “Stay-Form” for joints with waterstop. Install Stay-Form as per manufacturer’s installation instructions and as shown on drawing details.

3.3 FORM REMOVAL

- A. Remove wall and column formwork as soon as possible after concrete has attained adequate strength to support its own weight and superimposed loads, without cracking or deflecting excessively in order to facilitate effective finishing, but not earlier than 30 hours after concrete placement if:
- 1. Concrete is sufficiently hard so as not to sustain damage by form removal operations, and
 - 2. Curing and protection operations are maintained.
- B. Elevated Structural Slabs, and Beams: Remove formwork after concrete has reached 75 percent of its specified 28-day compressive strength as determined by field cure test cylinders.
- C. Remove nails, fasteners, tie wire and similar items at the surface.

3.4 MANUFACTURER’S SERVICES

- A. Form liner manufacturer’s representative to provide installation assistance at site, and inspection. Contractor to provide inspection report certifying acceptable liner installation in accordance with the manufacturers’ specifications.

END OF SECTION

SECTION 03 15 00

CONCRETE JOINTS AND ACCESSORIES

PART 1 GENERAL

1.1 SUMMARY

- A. This Section forms part of Section 03 30 00, Cast-in-Place Concrete.
- B. Section Includes:
 - 1. Cast-in-place concrete accessories including:
 - a. Expansion and construction joints for the Work including:
 - 1) Joints in cast-in-place concrete with a dimensioned separation between the two separate sections of concrete and with or without a waterstop.
 - 2) Joints in cast-in-place concrete with no separation between the two separate sections of concrete and with or without a waterstop.
 - b. Protection of waterstop for future expansion at joints.
- C. Products Installed But Not Supplied Under the Work of This Section:
 - 1. Location and installation affect the work of this Section. List is not guaranteed as being complete.
 - a. Anchor bolts.
 - b. Electrical conduits.
 - c. Frames for covers and openings.
 - d. Equipment castings and pipe fittings.
 - e. Embedded plates with anchors.

1.2 DEFINITIONS

- A. Expansion Joint: Dimensional separation between two separate sections of concrete with or without PVC waterstop to permit movement. Expansion joint may contain shear transfer reinforcing bars across the joint where shown. Space between the sections is filled with specified joint filler and finished with sealant.
- B. Construction Joint: Joint in cast in place concrete with no separation between the two separate sections of concrete with or without PVC waterstop. Construction joint in hydraulic structures and below grade structures shall contain PVC waterstop. Construction joint in hydraulic structures and below grade structures against existing structure without PVC waterstops shall contain injection waterstop system.
- C. Control Joint: Similar to construction joint with PVC waterstop with nominal reinforcing bars across the joint where shown.

1.3 REFERENCES

- A. Comply with the latest edition of the following statutes codes and standards and all amendments thereto.
1. Canadian Standards Association (CSA):
 - a. A23.1-09, Concrete Materials and Methods of Concrete Construction.
 - b. A123.3, Asphalt Saturated Organic Roofing Felt
 - c. G30.18-M, Carbon Steel Bars for Concrete Reinforcement.
 - d. G40.20/21, General Requirements For Rolled or Welded Structural Quality Steel / Structural Quality Steel.
 - e. S6, Canadian Highway Bridge Design Code.
 2. American Society for Testing and Materials International (ASTM):
 - a. ASTM A123, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
 - b. A780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
 - c. C920, Standard Specification for Elastomeric Joint Sealants.
 - d. D994, Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type).
 - e. D1751, Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).
 - f. D1752, Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction.

1.4 SUBMITTALS

- A. Shop Drawings:
1. Master Plan(s) of Concrete Placements:
 - a. Before submitting shop drawings of formwork, falsework, and reinforcing bars, submit master plan(s) showing separate concrete placements and locations of construction joints, including proposed construction joints in addition to those indicated on the Drawings.
 2. Joints: Expansion, and Construction
 - a. Submit detailed shop drawings of each joints type. Submit an elevation or section taken through the plane of the joint showing the walls and slabs at the joint.
 3. PVC Waterstops, Injection Waterstop Systems:
 - a. Details of waterstop system, sizes, types, splices, method of securing and supporting waterstop to maintain proper orientation and location during concrete placement.
 - b. For PVC Waterstops:
 - 1) Identify all splices for waterstop
 - 2) Identify all field and shop splices
 - 3) Provide details of securing waterstop to reinforcing bar with carrier bars

- c. For Injection Waterstop System:
 - 1) Indicate the length of hose, attachment mechanism and overlaps
 - 2) Indicate typical attachment details and spacing of attachment
 4. Construction Joints: Layout and location for each type.
 5. Details of joint fillers, sealant, adhesives, and other appurtenances.
 6. Inserts
 - a. Detail location, size, and type of concrete inserts.
 - b. Indicate coatings, galvanizing, or surface treatments.
- B. Samples:
1. PVC water stop splice, joint, and fabricated cross of each size, shape, and fitting of water stop(s).
 2. Injection waterstop system.
 3. Joint fillers.
- C. Product Data Sheets
1. Submit three copies of manufacturer's product data sheets including installation, application, and maintenance instructions for:
 - a. PVC waterstops.
 - b. Injection waterstop system.
 - c. Foamed PVC joint filler.
 - d. Preformed joint filler.
 - e. Asphalt-impregnated fibre board.
 - f. Control joint former.
 - g. Control joint sealant.
 - h. Adhesive for expansion joint filler.
 - i. Concrete inserts.
 - j. Polyethylene sheet.

1.5 QUALITY ASSURANCE

- A. Waterstop Manufacturer Qualifications: Demonstrate 5 years, minimum, continuous successful experience in production of water stops and waterstop systems.
- B. Engage manufacturer's representative for on site supervision during and after installation. Verify that specified products are correctly installed and comply with manufacturer's printed instructions.
1. For the following products, manufacturer's representative shall provide certification that the products are suitable for the application and are installed in accordance with the manufacturer's warranted recommendations.
 - a. Injection waterstop system.
- C. Submit certification of compliance for hot-dip galvanizing in accordance with CAN/CSA-G164-M.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Acceptance at Site: Verify that delivered materials are in accordance with Specifications and manufacturer's product data sheets prior to unloading and storing onsite.

- B. Storage: Store materials under tarps to protect from oil, dirt, and sunlight.

1.7 WARRANTY

- A. Provide 5 year performance warranty for
 - 1. Injection waterstop system

PART 2 PRODUCTS

2.1 PLASTIC WATERSTOP

- A. Extruded from elastomeric plastic compound of prime virgin polyvinyl chloride (PVC) resin free of scrapped material, reclaimed material, or pigment.
- B. Factory-made vertical and horizontal crosses, tees, and ells, to form a continuous unbroken seal.
- C. Specific Gravity: Approximately 1.37.
- D. Shore Durometer Type A Hardness: Approximately 80.
- E. Type: Center bulb with parallel ribs or protrusions on each side of strip center.
- F. Corrugated or tapered type water stops are not acceptable.
- G. Thickness: Constant from bulb edge to outside stop edge.
- H. Minimum Weight per Metre of Water Stop:
 - 1. 2.30 kg for 10 mm by 150 mm.
 - 2. 3.40 kg for 10 mm by 230 mm.
 - 3. 3.30 kg for 10 mm/5 mm by 230 mm (split bulb).
- I. Fabrications: Use only shop factory fabricated splices for flat ell, flat tee, flat cross, vertical ell, vertical tee and vertical cross. Only butt splices will be permitted in the field.
- J. Manufacturers and Products:
 - 1. Vinylex Corp.; Catalog No. 03250/VIN: No. RB6-38H (150 mm by 10 mm) and No. RB9-38H (230 mm by 10 mm).
 - 2. Greenstreak Plastic Products; Catalog No. 03150/GRD: Style 732 (150 mm by 10 mm), Style 735 (230 mm by 10 mm), and Style 727 (230 mm by 10 mm/ 5 mm) split bulb.
 - 3. Durajoint Concrete Accessories; Type 9 (150 mm by 10 mm), and Type 10 (230 mm by 10 mm).
- K. Wire Looped Plastic Water Stop:
 - 1. Furnish as alternative to plastic water stops.
 - 2. Same material and geometry as plastic water stops.

3. Furnish with continuous galvanized wire looping at edge, for convenience in positioning and securing stop in place in forms.
4. Manufacturer and Product: Paul Murphy Plastics; “Wire Stop Water Stop”; geometry numbers ACR 6380, ACR 9380, as shown on Paul Murphy Plastics Co. Drawing No. CCP-120-12M.

L. Retrofit Water Stop:

1. Manufacturers and Products:
 - a. Vinylex Corp.; No. RET638.
 - b. Greenstreak Plastic Products; No. 609.

2.2 INJECTION WATER STOP SYSTEM

A. Manufacturers and Products:

1. De Neef Construction Chemicals Inc.; Injecto Water Stop System consisting of Injecto tube with accessories and Hydro Active Flex LV Grout.
2. Multiurethanes Ltd., DWIN Injectable Tubing System consisting of DWIN injection tubing with accessories and Flexible Water – Reactive Polyurethane Resin.

2.3 TAPE FOR JOINTS

A. Polyethylene or coated paper

- B. Tape for Joints: Adhesive-backed glazed butyl or polyethylene tape, same width as joint that will adhere to premolded joint material or concrete surface.

2.4 PREMOLDED JOINT FILLER

A. Self-expanding Cork:

1. ASTM D1752, Type III.
2. Manufacturer and Product: WR Meadows; Self-expanding cork.

B. Bituminous Type: ASTM D994 or D1751.

C. Sponge Rubber:

1. ASTM D 1752, Type 1 Density not less than 480 kg per m³ by W.R. Grace Ltd.

2.5 PREFORMED CONTROL JOINT

A. One-Piece, Flexible, Polyvinyl Chloride Joint Former:

1. Manufacturer and Product: Greenstreak Plastic Products; Style Number 854 Transverse Control Joint.

B. Furnish in full-length, unspliced pieces.

2.6 POURABLE JOINT FILLERS

- A. Filler for Liquid Containment Structures:
 - 1. Pourable, two-component, cold-applied compound meeting ASTM C920, Type M, Grade P, Class 25, Use T.
 - 2. Color: Black.
 - 3. Manufacturer and Product: W.R. Meadows, Inc.; Gardox.

2.7 ACCESSORIES

- A. Joint Sealants: As specified in Section 07 92 00, Joint Sealants.
- B. Nonshrink Grout: As specified in Section 03 60 00, Grouting.
- C. Roofing Felt: CSA A123.3, Type 2, No. 30 asphalt-saturated felt.
- D. Reinforcing Steel: As specified in Section 03 21 00, Reinforcing Steel.
- E. Nails: Galvanized, as required for securing premolded joint filler.
- F. Masking Tape: As required to temporarily adhere to concrete at each side of joint to receive filler.
- G. Galvanized Rebar at Control Joints: CAN/CSA-G30.18-M Grade 400W prior to galvanizing.
- H. Ties for PVC Water Stop: "Hog Rings" or grommets for each edge at 300 mm maximum spacing.

2.8 HOT-DIP GALVANIZING

- A. Galvanize steel where noted in accordance with ASTM A123.
- B. Galvanize bolts, nuts, washers, and anchor bolts for connections to galvanized steel in accordance with ASTM A123.
- C. Complete fabrication, and prepare surfaces of steel by removing weld spatter, flux and residue, burrs, and surface defects before galvanizing.
- D. Tap threads of nuts after galvanizing.

PART 3 EXECUTION

3.1 GENERAL

- A. Commence concrete placement after joint preparation is complete.

- B. Construction Joints in Unrestrained Slabs on Ground:
1. Slabs may be placed continuous from outside edge to outside edge, outside edge to expansion joint, or from expansion joint to expansion joint, unless shown otherwise.
- C. Construction Joints in Suspended Slabs Restrained by Connecting Walls:
1. Place slab in alternate strips with the larger dimension of any single placement no greater than the following:
 - a. 10,000 mm for slabs forming part of liquid holding structure.
 - b. 15,000 mm for slabs of other than liquid holding structure.
 2. Locate construction joints in suspended slabs near the middle quarter of the spans of slabs and beams, unless indicated otherwise on the Drawings. If a beam intersects a girder at this location, offset the construction joint in the slab and girder by a distance equal to two times the width of the beam.
- D. Construction Joints in Girders and Beams:
1. Construct concrete beams and suspended slabs monolithically, unless indicated otherwise of the Drawings.
 2. If vertical construction joints are required provide shear key, and additional inclined shear reinforcing steel.
- E. Construction Joints in Walls:
1. Locate construction joints:
 - a. 2000 mm minimum and 6000 mm maximum away from junction of two or more walls,
 - b. Away from a column or beam supported on wall,
 - c. Away from nearest edge of an opening wider than 600 mm,
 - d. Away from construction joint in a slab on which the wall rests.
 2. Place wall in alternate portions with a distance between vertical construction joints not exceeding the following:
 - a. 10,000 mm for walls forming part of liquid holding structure.
 - b. 15,000 mm for walls of other than liquid holding structure.

3.2 SURFACE PREPARATION

- A. Construction Joints:
1. Prior to placement of abutting concrete, clean contact surface:
 2. Perform cleaning so as not to damage water stop, if one is present.
- B. Expansion Joint:
1. Use wire brush or other motorized device to mechanically roughen and thoroughly clean concrete surfaces on each side of joint from plastic water stop to top of joint.
 2. Use dry high pressure air to remove dust and foreign material, and dry joint.
 3. Prime surfaces as required before placing joint filler.
 4. Avoid damage to water stop.
- C. Construction joint with Injection Water Stop System:
1. Cut key in concrete.

2. Remove splatter from reinforcing steel and dowels.
3. Mechanically roughen surface to provide thorough bonding.

3.3 INSTALLATION OF WATER STOPS

- A. General:
1. Install continuous water stop in all construction joints in walls and slabs of hydraulic structures and below grade structures, unless specifically noted otherwise.
 2. Join water stops at intersections to provide continuous seal.
 3. Locate water stop in the centre of the joint.
 4. Secure water stop in correct position. Tie water stop to reinforcing steel using grommets, "Hog Rings," or tie wire at maximum spacing of 300 mm. Do not displace water stop during concrete placement.
 5. Repair or replace damaged water stop.
 6. Place concrete and vibrate to obtain impervious concrete in vicinity of joints.
 7. Joints in Footings and Slabs:
 - a. Ensure that space beneath plastic water stop is completely filled with concrete.
 - b. During concrete placement, make visual inspection of water stop area.
 - c. Limit concrete placement to elevation of water stop in first pass, vibrate concrete under water stop, lift water stop to confirm full consolidation without voids, then place remaining concrete to full height of slab.
- B. Plastic Water Stop:
1. Install in accordance with manufacturer's printed instructions and as shown on drawings.
 2. Splice in accordance with water stop manufacturer's printed instructions.
 - a. Provide finished splices with cross-sections that are dense and free of porosity with tensile strength of not less than 80 percent of unspliced materials.
 - b. Use only shop made water stop fabrications for all splices except noted below.
 - c. Field splice is permitted only for straight butt welds.
 3. Wire looped plastic water stop may be substituted for plastic water stop.
- C. Injection Water Stop System:
1. Prepare surfaces, and install water stop system in construction joint in accordance with manufacturer's printed instructions.
 2. Fasten tube to concrete at a spacing of 300 mm.
 3. Limit length of grout tube to a maximum of 8000 mm.
 4. After the concrete is installed and cured, inject grout in the tube to completely seal the joint and make the joint watertight. Cut ends of tube recessed into concrete surface and plug with cementitious mortar.

3.4 EXPANSION JOINT INSTALLATION

- A. Self-Expanding Cork Premolded Joint Filler:
1. Install for all water retaining structures

2. Install per manufacturer's written instructions.
 3. Affix self-expanding cork to face of concrete immediately prior to second placement. Remove coatings and debris. Keep cork dry to prevent premature expansion of cork.
- B. Premolded Joint Filler:
1. Installed in dry areas only.
 2. Sufficient in width to completely fill joint space.
 3. If water stop is in joint, cut premolded joint filler to butt tightly against water stop and concrete face.
 4. Precut premolded joint filler to required depth at locations where joint filler or sealant is to be applied.
 5. Form cavities for joint filler with either precut, premolded joint filler, or smooth removable accurately shaped material.
 6. Vibrate concrete thoroughly along joint form to produce dense, smooth surface.
- C. Pourable Joint Filler:
1. General: Install in accordance with the manufacturer's written instructions, except as specified below:
 - a. Apply primer prior to pouring joint filler.
 - b. Fill entire joint above the water stop with joint filler as shown.
 - c. Use masking tape on top of slabs at sides of joints; clean spillage. Remove masking tape afterwards.
 - d. Coordinate with Section 07 92 00, Joint Sealants.
- 3.5 PROTECTION OF WATERSTOP FOR FUTURE EXPANSION
- A. Provide protection boxes, hardware, and fasteners as required to protect end of waterstop at expansion and construction joints for future expansion.
- 3.6 CONCRETE INSERTS
- A. Install concrete inserts with plastic setting plugs.
 - B. Leave setting plugs in place.
- 3.7 SETTING ANCHOR BOLTS FOR EQUIPMENT, AND FITTINGS
- A. Receive, handle, and set anchor bolts in accordance with the requirements of the trade supplying them. Protect anchor bolts after setting to maintain correct alignment and level.
- 3.8 FRAMES FOR COVERS AND OPENINGS
- A. Set frames at locations and required elevations.
- 3.9 EQUIPMENT CASTINGS AND PIPE FITTINGS
- A. Set castings and pipe fittings at locations and elevations required.

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- B. Repair hot-dip galvanized surfaces damaged by welding, cutting, handling during shipping or erection, or otherwise, in accordance with ASTM A780 using a zinc-rich coating. Dry film thickness on repairs to exceed original coating thickness by 25 percent minimum.

END OF SECTION

SECTION 03 21 00

REINFORCING BARS

PART 1 GENERAL

1.1 SUMMARY

- A. Products supplied but not installed under this section:
 - 1. Reinforcing bars for grouted in dowels.
 - 2. Reinforcing bars for reinforced masonry.

1.2 REFERENCES

- A. Comply with the latest edition of the following statutes codes and standards and all amendments thereto.
 - 1. Canadian Standards Association (CSA):
 - a. A23.1, Concrete Materials and Methods of Concrete Construction.
 - b. A23.3, Design of Concrete Structures.
 - c. G30.18-M, Carbon Steel Bars for Concrete Reinforcement.
 - d. W47.1, Certification of Companies for Fusion Welding of Steel.
 - e. W186-M, Welding of Reinforcing Bars in Reinforced Concrete Construction.
 - 2. American Society for Testing and Materials International (ASTM):
 - a. A1064/A1064M, Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete.
 - 3. Reinforcing Steel Institute of Canada (RSIC):
 - a. Reinforcement Steel Manual of Standard Practice.
 - 4. International Conference of Building Officials (ICBO):
 - a. ICBO Research Report.

1.3 SUBMITTALS

- A. Samples and Product Data Sheets:
 - 1. Submit three samples and three copies of manufacturer's product data sheets including installation and maintenance instructions for:
 - a. Chairs, bolsters, bar supports, and side form spacers.
 - b. Dowel bar splicer.
 - c. Mechanical splices.
- B. Shop Drawings:
 - 1. Reinforcing Bars:
 - a. Submit reinforcing bar placement drawings prepared in accordance with Reinforcement Steel Manual of Standard Practice by the Reinforcing Steel Institute of Canada and as specified below.
 - b. Indicate reinforcing bars that form part of an individual concrete placement and reinforcing bars that extends into adjacent placements.

- c. For each reinforcing bar placement shop drawing, submit a separate bar list and bending schedule showing size, shape, dimensions, and numbers of bars required for each bar type.
 - d. Identify reinforcing bars in the bar list and bending schedule with a separate bar mark that corresponds to bar marks shown on reinforcing bar placement drawings.
 - e. If bar list and bending schedule contain details of bars of more than one reinforcing bar placement drawing, then arrange bar marks in separate groups for each placement drawing. Clearly indicate for each bar mark the corresponding reinforcing bar placement drawing number.
 - f. For slabs, show a separate plan indicating concrete thicknesses, reinforcing bars, and dowels for walls and columns cast in slab.
 - g. For walls, show separate elevations indicating concrete thicknesses, reinforcing bars, and dowels for slabs and adjacent walls cast in wall.
 - h. Do not add new information on previously reviewed shop drawings.
 - i. Reinforcing bar placement shop drawings will be reviewed for bar sizes, locations, and spacing, and will receive submittal stamp and signed. Reviewed bar list and bending schedule will be dated only.
2. Submit shop drawings of dowel bar splicers detailing locations, size, and type.
- C. Quality Control Submittals:
1. Submit certified mill test reports of steel reinforcing bars: Determine physical and chemical properties of steel reinforcing in accordance with requirements of CAN/CSA-G30.18-M.
 2. Dowel Bar Splicers:
 - a. Current International Conference of Building Officials (ICBO) Research Report or equivalent code agency report listing findings to include acceptance, special inspection requirements, and restrictions.
 - b. Verification that device threads have been tested and meet requirements for thread quality, in accordance with manufacturer's published methods.
 3. Submit welding certificate in accordance with CSA W47.1 and CSA W186-M.

1.4 QUALITY ASSURANCE

- A. Welder Qualifications: CSA W47.1 and CSA W186-M certified.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Ship bundles of reinforcing bars identified by tags containing bar marks along with bar list.
- B. Store materials to prevent deterioration or contamination. Deteriorated or contaminated materials will be rejected and must be removed from site.

PART 2 PRODUCTS

2.1 MATERIALS

- A. Reinforcing Bars:
1. Deformed steel bars: CAN/CSA-G30.18-M; Grade 400R except Grade 400 W where welding is indicated or specified. Do not substitute with epoxy-coated bars.
- B. Mechanical Splices:
1. Mechanical Threaded Connections: Furnish metal coupling sleeve with internal threads engaging threaded ends of bars, capable of developing in tension or compression 125 percent of yield strength of bar.
 - a. Manufacturers and Products:
 - 1) DB-SAE by Dayton/Richmond by Dayton Superior.
 - 2) Lenton Form Saver by Erico Canada Inc.
 - 3) D150 DBR Coupler and DBR Setting-Splice Bar, with size equivalent to DB-SAE, by Dayton Superior Canada Limited.
- C. Dowel-in bar: Suitable for existing dowel bar splicer with rolled UNC or tapered threads as required:
1. DI by Dayton/Richmond by Dayton Superior.
 2. Splice bar by Erico Canada Inc.
 3. D-51, D-52, or D-53, with size equivalent to DI, by Dayton Superior Canada Limited.
- D. Welded Wire Reinforcement:
1. ASTM A1064 wire of 517 MPa (75 ksi) minimum tensile strength.
 2. Furnish flat sheets only, rolled sheets not permitted.

2.2 ACCESSORIES

- A. Tie Wire:
1. Black, soft-annealed 1.6 mm diameter wire.
 2. Nylon-, epoxy-, or plastic-coated wire.
- B. Bar Supports and Spacers:
1. Adequate for accurate placing and as required for construction loads.
 2. Provide non-conductive bar supports in contact with exposed surfaces that has geometry and bond characteristics that prevents moisture movement from the surface to the reinforcement.
 3. In beams, columns, walls, and slabs exposed to view after form removal: Small concrete blocks made up of same color and strength as concrete being placed around them.
 4. Precast concrete supports of same strength as concrete for reinforcing in concrete placed on grade.
 5. Do not use plastic or stainless steel bar supports or side form spacers.
 6. Design and fabricate special bar supports for top reinforcing bars in slabs where standard bar supports are not high or strong enough.

7. Precast Concrete Support: Total Bond Precast high performance concrete bar supports as supplied by Con Sys Inc Pinawa, Manitoba, Canada.

2.3 FABRICATION

- A. Reinforcing Bars
 1. Comply with CSA A23.1 Clause 6.0 and CSA A23.3.
 2. Tolerances:
 - a. Length: Plus or minus 25 mm.
 - b. Height of truss bar: Plus 0 to minus 10 mm.
 - c. Outside dimensions of stirrups, ties, and spirals: Plus or minus 10 mm.
 - d. Other bends: Plus or minus 25 mm.
 3. Use longest bar possible.
 4. Keep number of splices to a minimum.
 5. Do not weld chairs, bolsters, bar supports, or spacers to reinforcing bars.
- B. Reinforcing Splices:
 1. Lap Splices:
 - a. Splice by lapping reinforcing bars, unless specified otherwise.
 2. Welded Splices:
 - a. Full-penetration direct butt-splice welds in accordance with CSA W186-M and as specified.
 3. Splices in Welded Wire Reinforcement:
 - a. Provide lap of 1-1/2 times the spacing of the bar or minimum 200mm.

PART 3 EXECUTION

3.1 PREPARATION

- A. Notify Contract Administrator when reinforcing is ready for inspection and allow sufficient time for inspection prior to placing concrete.
- B. Clean reinforcing bars of loose rust, mill scale, dried cement paste, mud, oil, or other coatings that will affect adhesion in accordance with CSA A23.1-04, Clause 6.1.5 Surface Conditions of Reinforcement, prior to placing concrete.
- C. Coat wire projecting from bar supports with dielectric material, epoxy, or plastic.

3.2 REINFORCING BAR INSTALLATION

- A. Place reinforcement within tolerances specified in CSA A23.1-09 Clause 6.6.8 Tolerances for location of reinforcement.
- B. Splicing:
 1. Use lap splices, unless otherwise shown or permitted in writing by Contract Administrator.
 2. Welded Splices: Accomplish by full penetration groove welds and develop a minimum of 125 percent of yield strength of bar in tension and compression.

3. Stagger splices in adjacent bars where indicated a minimum of 1500 mm.
- C. Dowel Bar Splicers:
1. Use only in areas specifically approved in writing by Contract Administrator.
 2. Install threaded rods as recommended by manufacturer with threads totally engaged into coupling sleeve and in accordance with ICBO Research Report.
 3. Install dowel bar splicers with plastic setting plugs.
 4. Lightly grease internal threads in accordance with manufacturers printed instructions.
 5. Maintain minimum edge distance and concrete cover.
- D. Mechanical Splices:
1. Install mechanical splices in accordance with manufacturer's printed instructions. Request presence of manufacturer's representative to verify proper installation.
- E. Tying Reinforcing Bars:
1. Bend tie wire away from concrete surface. Ensure a cover for tie wires, form tie bolts etc are same as the reinforcing bars. Do not let reinforcing tie wire touch formwork or be exposed in the finished concrete structure.
- F. Reinforcement around Openings: On each side and above and below pipe or opening, place an equivalent area of steel bars to replace steel bars cut or disrupted for opening. Extend steel reinforcing a standard lap length beyond opening at each end.
- G. Welding Reinforcement:
1. Only Type W bars may be welded.
 2. Do not perform welding until welder qualifications are approved.
- H. Dowels Threaded Into Dowel Bar Splicers in Existing Structures
1. Expose existing dowel bar splicers.
 2. Remove plastic setting plugs and clean threads.
 3. Thread dowel-in bars into the dowel bar splicers and tighten securely to develop required strength in tension and compression.
 4. If the existing dowel bars are damaged or not usable inform Contract Administrator immediately.
- I. Straightening and Rebending: Field bending of reinforcing steel bars is not permitted.
- J. Unless permitted by Contract Administrator, do not cut reinforcing bars in field.

3.3 WELDED WIRE REINFORCEMENT INSTALLATION

- A. Use only where specifically shown.
- B. Extend reinforcement to within 50 mm of edges of slab, and lap splices at least 1-1/2 courses of wire spacing or minimum 200 mm.
- C. Tie laps and splices securely at ends and at least every 600 mm with tie wire.

- D. Install 15M reinforcing bars at 2000 mm maximum spacing in each direction, supported on chairs, to securely support welded steel wire reinforcement during concrete placement. Ensure the reinforcement remains at intended clearances as specified or indicated.
- E. Do not use reinforcement that has been rolled. Install flat sheets only.

3.4 TESTS AND INSPECTION

- A. An independent testing agency will be retained by The City to visually inspect and test reinforcing steel welds as specified in Section 05 05 23, Welding-Quality Assurance.
- B. An independent testing agency will be retained by The City to inspect each mechanical splice and dowel bar splicer and verify each component is installed in accordance with manufacturer's instructions and ICBO Research Report.

END OF SECTION

SECTION 03 30 00

CAST-IN-PLACE CONCRETE

PART 1 GENERAL

1.1 SUMMARY

- A. Comply with Division 1, General Requirements.
- B. Comply with requirements of CSA A23.1 and A23.2, except where noted otherwise in this Specification.
- C. The following sections form part of this Section:
 - 1. Section 03 10 00, Concrete Forming and Accessories
 - 2. Section 03 21 00, Reinforcing Bars
 - 3. Section 03 15 00, Concrete Joints and Accessories
 - 4. Section 03 39 00, Concrete Curing
 - 5. Section 03 60 00, Grouting.
- D. Do not use materials that are toxic in installed condition. Do not use volatile organic compounds where not permitted by law. Where use of volatile organic compounds is permitted, provide adequate ventilation and take necessary safety precautions.
- E. Section Includes:
 - 1. Normal-density concrete.
 - 2. Fill concrete.
 - 3. Bonded concrete toppings.
 - 4. Repair of cracks that develop in concrete.

1.2 DEFINITIONS

- A. Exposed Concrete: Visible concrete surfaces inside or outside of structures, including surfaces above liquid level.
- B. Hydraulic Structures: Liquid holding or containment structures whether above and/or below grade and includes roofs of the containment structure.
- C. Habitable structures: Structures that are accessible and may be used for storage or conveyance or utilities.
- D. Below Grade structures: Structures that are below or partially below grade. Below grade habitable structures, for water tightness requirements, are considered hydraulic structures.
- E. Defective Areas: Surface defects that include honeycomb, rock pockets, indentations greater than 5 mm, cracks 0.1 mm or wider as well as any crack that leaks in hydraulic structures and below grade habitable spaces; cracks 0.25 mm and wider in non-hydraulic structures, spalls, chips, air bubbles greater than 10 mm in diameter, pinholes, bug holes

greater than 4 mm in diameter, embedded debris, lift lines, sand lines, bleed lines, leakage from form joints or penetrations or openings, fins and other projections, form pop outs, texture irregularities, and stains and other color variations that cannot be removed by cleaning.

- F. New Concrete: Less than 60 days old.
- G. Type of concrete: Project specific concrete type and shall not be confused with type of cements or finishes.
- H. Exposure classes of concrete: As defined in Table 1 CSA A23.1-09
- I. Water/Cementing Material Ratio (W/C): A weight ratio of total water content including admixtures over the weight of all cementing materials.

1.3 REFERENCES

- A. Comply with the latest edition of the following statutes codes and standards and all amendments thereto.
 - 1. Canadian Standards Association (CSA):
 - a. A23.1, Concrete Materials and Methods of Concrete Construction.
 - b. A23.2, Test Methods and Standard Practices for Concrete.
 - c. A3001, Cementitious Materials for Use in Concrete.
 - d. A3002, Masonry and Mortar Cement.
 - e. A3003, Chemical Test Methods for Cementitious Materials for Use in Concrete and Masonry.
 - f. A3004, Test Methods and Standard Practices for Cementitious Materials for Use in Concrete and Masonry.
 - g. A3005, Test Equipment and Materials for Cementitious Materials for Use in Concrete and Masonry.
 - 2. American Concrete Institute (ACI):
 - a. 304.2R, Placing Concrete by Pumping Methods.
 - 3. American Society for Testing and Materials International (ASTM):
 - a. C157 Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete.
 - b. C260, Standard Specifications for Air-Entraining Admixtures for Concrete.
 - c. C494/C494M, Standard Specification for Chemical Admixtures for Concrete.
 - d. C900, Standard Test Method for Pullout Strength of Hardened Concrete.
 - e. C1017/C1017M, Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete.
 - f. C1074, Standard Practice for Estimating Concrete Strength by the Maturity Method.

1.4 PERFORMANCE REQUIREMENTS

- A. Concrete for the project is used in waste water facilities. Ph for the liquids is normally neutral at about 7. Various chemicals are added to help the process. Degradation of

organic material emits gases like hydrogen sulphide which when combined with moisture forms mild sulphuric acid. Life expectancy of waste water plant is 60 to 80 years.

- B. Water tightness:
1. Concrete as placed for *hydraulic structure* and *below grade habitable structure* shall be watertight.
 2. No visible leaks will be permitted in hydraulic structures and below grade structures.
 3. Roofs of hydraulic structures and below grade structures and other roofs, shall be water tight.
 4. Coordinate leakage test in accordance with requirements of Section 01 35 13, Special Project Procedures.
 5. Repair cracks in *hydraulic structures* and *below grade structures* that are leaking or are damp.
 6. Repair cracks that are wider than 0.4 mm in dry areas. Repair to match surrounding concrete surfaces.
 7. Repair joints that are leaking or are damp.
- C. Type of Concrete Class of Exposure and Compressive Strengths.
1. Normal-density concrete:
 - a. Type A: Class of Exposure S-3- 30MPa at 56 days, W/C 0.45.
 - b. Type B: Fill Concrete - Class of Exposure: N;15 MPa at 28 days W/C as required.
 - c. Type C: Class of Exposure: C-2 -32 MPa at 28 days w/c 0.45.
 - d. Type E: Bonded concrete topping: Class of Exposure: S-3; 30MPa at 56 days w/c 0.45.
- D. Performance requirement for temperatures during curing.
1. Design concrete mix taking in the account the expected ambient temperature during the curing. Peak curing temperature of concrete shall not exceed 40 degree C and shall not be less then 10 degrees C.
- E. Density.
1. Air entrained normal density concrete: As defined in CSA 23.1-09 Clause 3 except the density shall be not less than 2250 kg/m³.
- F. Concrete Shrinkage at 28 Day Drying Age:
1. 0.040 percent maximum for laboratory trial mixes of proposed concrete made with 40 mm aggregate with and without superplasticizer.
 2. 0.045 percent maximum for laboratory trial mixes of proposed concrete made with 20 mm aggregate with and without superplasticizer.
 3. If shrinkage specimen tests for concrete exceed shrinkage limits, modify concrete mix to reduce shrinkage. Repeat tests with new mix.
 4. Test shall be conducted as per modified ASTM C157 as specified herein.
- G. Bond Strength for Concrete Topping:
1. Tensile bond strength between bonded concrete topping and substrate concrete: 1.0 MPa, minimum.

- H. Construction Tolerances:
1. Comply with CSA A23.1-09 Clause 6.4 unless noted otherwise.

- I. Concrete Finishes:
1. As specified in Section 03 39 00, Concrete Curing.

1.5 SUBMITTALS

- A. Product Data Sheets:
1. Submit three copies of manufacturer's product data sheets including installation, application, and maintenance instructions for:
a. Chemical admixtures.
b. Bonding agent.
c. Crack injection material.
d. Repair materials.
- B. Concrete Mix Design:
1. Design in accordance with CSA 23.1-09 Table 5 based on performance requirements.
2. Submit proposed mix, and supplier's applicable standard deviations.
3. Tabulate concrete mixes. Indicate type of cements, size of coarse aggregate; water/cementing material ratio, admixtures used, air content, slump, and locations of use for each mix. Identify mix with pump or bucket type of discharge. Also identify mix for cold weather and hot weather concreting..
4. Submit a mix that will not result in segregation when high-slump flowing concrete is used.
5. Submit detailed plan for cold weather placement, curing and protection of concrete in weather for ambient temperatures below 5 degrees C.
6. Submit detailed plan for hot weather placements, curing and protection of concrete for ambient temperatures over 27 degrees C.
7. Concrete mix designs will be reviewed for conformance with requirements of the Specifications and will be returned with Contract Administrator's comments.
- C. Source Quality Control Submittals:
1. Provide certification that source for fine and coarse aggregates are not subject to deleterious expansion.
2. Drying shrinkage Test:
a. Perform laboratory trial mixes of concrete used on project. Make two sets of three specimens for each shrinkage test.
b. Provide test for Concrete containing:
1) 40 mm aggregate with or without the use of superplasticer.
2) 20mm aggregate with or without the use of superplasticer.
c. Prism Specimen Size: 100 mm by 100 mm by approximately 280 mm with effective gauge length of 250 mm.
d. Specimens: Fabricate, cure, dry and measure as specified in ASTM C157 and modified as follows:
1) Remove specimens from molds aged 23 hours plus or minus 1 hour after trial batching.

- 2) Place immediately in water at 22.8 degrees C plus or minus 2 degrees C for at least 30 minutes.
- 3) Measure the specimen within 30 minutes thereafter to determine original length and then submerge in saturated limewater at 22.8 degrees C plus or minus 2 degrees C.
- 4) Measure specimens at age 7 days to determine expansion expressed as percentage of original length. Length at age 7 days shall be base length for drying shrinkage calculations (0 days drying age).
- 5) Store specimens immediately in humidity control room maintained at 22.8 degrees C plus or minus 2 degrees C and 50 percent plus or minus 4 percent relative humidity for remainder of test.
- 6) Measure to determine shrinkage expressed as percentage of base length and report separately for 7, 14, 21, and 28 days of drying after the 7 days of moist curing.
- 7) Computing Drying Shrinkage Deformation of Each Specimen:
 - a) Difference between base length (at 0 days-drying age) and length after drying at each test age.
 - b) Compute average drying shrinkage deformation to nearest 0.001 percent at each test age.
 - c) If drying shrinkage of any specimen departs from average of that test age by more than 0.004 percent, disregard results obtained from that specimen.

D. Quality Control Submittals:

1. Submit Concrete quality control plan for the project. Include the following:
 - a. Certification from a professional engineer who has designed the mix based on the requirements of the Contract Documents and that concrete mix will meet the performance requirements. Where the mix designer is not a professional engineer, then the signing officer of the ready mix plant shall sign the certification.
 - b. Identify the Company and contact names of subcontractors, material suppliers, and testing companies involved with concrete manufacture and placement.
 - c. Identify concrete requirements for each element of the project.
 - d. Identify all tests that will be used for material acceptance and indicate minimum specification requirements for each test.
 - e. Identify the frequency of testing for each test.
 - f. Identify the course of action to be taken if the testing program indicates that specification requirements have not been met.
 - g. Concrete quality control plan shall not take precedence over any other Contract documents.
2. Submit concrete delivery records.

E. Concrete Placing Schedule:

1. Submit concrete placing schedule.

- F. Certificates:
1. Submit certificate of Ready Mixed Concrete Production Facilities.
 2. Submit certification that aggregates will not, nor have the potential to, react with cement to result in deleterious expansion in the concrete.
 3. Submit certification that deleterious substances in aggregate are within limits specified in CSA A23.1-09, Table 12 - Limits for Deleterious Substances and Physical Properties of Aggregates.
 4. Submit certification that proposed performance mix will produce concrete meeting the requirements of Specifications.
 5. Submit certification that proposed mix design strengths have been selected allowing for the supplier's standard deviations as indicated in CSA A23.1-09, Clause 4.4.6.6- Compressive Strength Requirements..
 6. Submit certification that proportion of supplementary cementing material in combination of General Use (GU) hydraulic cement will provide the performance of the specified cement type.
 7. Submit certification that bonding agent, if used, will meet the requirements of Specifications.
 8. Submit certification that crack injection materials are suitable for continuous submersion and that they will not release toxic materials into the water.

1.6 QUALITY ASSURANCE

- A. Ready Mixed Concrete Producer: Certified member in good standing of the local Ready Mixed Concrete Association.
- B. Concrete Testing:
- Testing of concrete for materials, compression and water content of freshly mixed concrete will be done by agencies paid for by The City.
1. Pay for additional testing required because of changes in material or the mix proportions, as well as any extra testing of concrete or materials occasioned by their failure to meet the specification requirements.
 2. The use of testing services does not relieve the Contractor of his responsibility to provide materials and construction in compliance with the Drawings and Specifications.
- C. Pre-placement Meeting:
1. Hold a meeting at least four weeks prior to the initial placement of concrete to review the detailed requirements for preparing the concrete design mixes, finishes, and procedures for concrete placement for the structures.
 2. Arrange for the attendance at the meeting of the Contract Administrator, City, and of concrete subcontractors, manufacturers, and suppliers including, but not limited, to the following:
 - a. Contractor's superintendent.
 - b. Laboratory responsible for field quality control.
 - c. Ready-mix concrete producer.
 - d. Admixture manufacturer(s).
 - e. Concrete pumping and conveying equipment supplier.
 - f. Concrete formwork and finishing subcontractors.

3. Notify the Contract Administrator at least 10 working days prior to the scheduled date of the meeting.
4. The Contract Administrator will set an agenda for the meeting at least five working days prior to the scheduled date of the meeting.
5. Contractor to provide work plan detailing:
 - a Production plant capacity
 - b Control of traffic on site
 - c Equipment to be used and availability of stand by
 - d Personnel resources
 - e Quality assurance procedures
 - f Safety on site
 - g Lighting

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Comply with manufacturers' recommendations for delivery, storage, and handling.
- B. Store materials in a manner that will prevent deterioration or contamination. Deteriorated or contaminated materials will be rejected and must be removed from site.

1.8 SITE CONDITIONS

- A. Cold Weather Requirements:
 1. The following requirements are in addition to CSA A23.1 -09, Clause 7.4.1.5 - Cold Weather Concreting.
 2. Provide temperature-controlled enclosures for areas where concrete is placed whenever ambient air temperature is 5 degrees C or lower.
 3. Protect concrete from the adverse effects of space-heated enclosures including local overheating and combustion products.
 4. Heat mix-water and, if necessary, aggregates when air temperature is at or below, or predicted to go below, 5 degrees C at any time during the next 24 hours.
 5. Maintain temperature of reinforcing bars and forms above 5 degrees C prior to placing concrete.
 6. Maintain temperature of concrete when deposited in forms not less than 15 degrees C and not higher than 25 degrees C.
 7. Maintain temperature of concrete at surfaces at least 10 degrees C for a minimum period of seven days after placing and achieving minimum 75 percent of specified strength. Concrete temperature may then be lowered to ambient air temperature at a rate of 1.2 degree C per hour or 10 degrees C per day.
 8. Keep concrete continuously moist during the curing period.
- B. High-temperature Control Requirements:
 1. The following requirements are in addition to CSA A23.1-09, Clause 7.4.1.4 - Hot Weather Concreting.
 2. Limit peak temperature during the curing period to 40 degrees C maximum. Placing temperature that will satisfy this requirement depends on ambient temperature, humidity at the time of placing, thickness of the concrete, and curing methods employed.

3. Consider use of retarders, low- heat cement, slag replacement, ice in mixing water, pre-cooling of aggregates, cooling of concrete through continuous wet curing, and similar methods in order to prevent concrete temperatures from exceeding the above specified peak temperature at any time.
 4. Monitor concrete temperatures for walls and slabs. After concrete temperature has peaked, control rate of cooling to ambient air temperature at a rate of 1/2 degree C per hour to prevent cracking.
 5. Notwithstanding requirements of subparagraphs .1 and .2 above, do not place concrete with temperature higher than 25 degrees C. Concrete with temperature in excess of 25 degrees C on arrival at the site will be rejected. Remove rejected concrete from the site.
- C. Protection:
1. Protect freshly placed concrete from damage due to construction operations and from cold, heat, rain, snow, running water, drying winds, and any other circumstances which would likely cause deterioration of concrete quality.
 2. Use waterproof insulated covers or other suitable materials to enclose freshly placed concrete under these conditions.
- D. Frost Protection for Slabs on Grade:
1. Provide continuous protection for slabs on grade to prevent subgrade below from freezing during cold weather. Provide heated enclosures and insulation as required.
 2. Sub-grade below completed tanks may be protected against frost by filling with water to a minimum depth of 2000 mm. Place log booms, 200 mm diameter, at maximum spacing of 5000 mm in each direction to abate ice pressures on tank walls. Break ice on formation.
- E. Influence of Ambient Concrete Temperature on Concrete Crack Control:
1. To minimize the formation of thermal cracks during placement and curing, maintain previously cured concrete and concrete that will be placed against it at the same temperature.
 2. Failure to minimize temperature differential between adjacent pours will result in temperature induced cracking. Repair such cracks as specified in this Section.
- F. Ground Vibration Limitations:
1. Do not place concrete if the vibration level exceeds the limits specified in Section 01 35 13, Special Project Procedures.
- G. Backfilling and Service Loads Restrictions:
1. Verify that backfill is not higher than the finished grades indicated.
 2. Verify that equipment for backfilling and compaction on top of slab will not impose loads greater than those indicated.
 3. Verify that concrete in walls, and slabs, struts, and cross walls, which frame into the walls providing lateral stability, has been placed and has attained specified compressive strength before backfilling against walls or subjecting walls to service loads.

4. Verify that concrete in slabs, and support components have reached specified compressive strengths before backfilling or subjecting slabs to service loads.
5. Verify that the leakage test is successfully completed before backfilling.

PART 2 PRODUCTS

2.1 MATERIALS

- A. Portland Cements/ Blended Hydraulic Cements:
1. CSA A23.1 Table 7 Types of blended hydraulic cement:
Type: MSb, HSb. as appropriate
 2. Supplementary Cementing materials shall be limited to ground granulated blast-furnace slag (S), fly ash (F) and silica fume (SF).
- B. Aggregates:
1. Normal-density Concrete:
 - a. Coarse aggregate: CSA A23.1, with gradation in accordance with Table 11; rough and angular gravel or crushed stone.
 - b. Fine aggregate: CSA A23.1, with gradation in accordance with Table 10; natural sand.
- C. Admixtures:
1. Compatible with each other and with other concrete materials.
 2. Calcium chloride, thio-cyanates, or admixtures containing more than 0.05% chloride ions are not permitted.
 3. Air-entraining admixture: ASTM C260; non-detergent type.
 4. Water-reducing admixtures: ASTM C494; Type A.
 5. Set-retarding admixture: ASTM C494; Type B.
 6. Superplasticizing admixture: ASTM C494; Type F 1 or G 2.
- D. Water: CSA A23.1; clear and free from oil, acid, alkali, organic matter, or other deleterious substances with a maximum soluble chloride ion content of 0.10 percent by weight.
- E. Bonding Agent: Suitable for conditions of service and performance requirements of this Section.

2.2 CONCRETE MIXES

- A. General:
1. Establish proportions of cementing materials, aggregates, water, and admixtures required to produce consistent workable concrete that when placed properly is watertight and durable with strength and other properties specified. Comply with CSA A23.1-09 Clause 4.3.6 Volume Stability Considerations.
 2. Use same type and brand of cement/cementing material throughout.
 3. Comply with and allow for the supplier's Standard Deviation as specified in CSA A23.1-04 Clause 4.4.6.6- Compressive Strength Requirements. If the concrete

supplier has no established Standard Deviations for concrete of the specified strengths, use a value of 4 MPa minimum.

4. Use high-slump concrete by addition of superplasticizing admixture for walls and columns.

B. Types of Normal-density Concrete:

1. Type A-Exposure Class S3: Concrete for structures, equipment bases, pipe supports, concrete encased duct banks, benching, and concrete wearing slab, containing reinforcing bars, unless specified otherwise.
2. Type B-Exposure Class S3: Fill concrete and mud mat unless specified otherwise.
3. Type C-Exposure Class C-2: Concrete for sidewalks, curbs and gutters
4. Type E: Concrete for bonded topping for clarifier

C. Mixes for Normal-density Concrete:

1. Cementing Materials Content:
 - a. Provide cementing materials contents as required to meet performance.
2. Coarse Aggregates:
 - a. Gradation in accordance with CSA A23.1, Table 11: Nominal size 40 mm to 5 mm, unless noted otherwise.
 - b. Gradation in accordance with CSA A23.1, Table 11 : Nominal size 20 mm to 5 mm, for walls and slabs less than or equal to 300 mm thick, beams, slabs with monolithic beams, columns, and Type B concrete.
 - c. Nominal size 10 mm to 2.5 mm, for bonded concrete topping and concrete in steel pans.
3. Air Content:
 - a. Comply with CSA A23.1-09, Table 4 - Requirements for the Air Content Categories.
 - b. Provide air content category 2, unless noted otherwise.
 - c. Provide air content category 1 for loading bays, parking areas, and below grade and hydraulic structures, sidewalks curbs and gutters. If high volume supplementary cementing material (HVSCM) is used consult with the Contract Administrator on air content requirements for steel trowelled slabs.
 - d. Provide 3 percent maximum air content for concrete forming floors where floor hardener is used.
4. Admixtures:
 - a. Use water-reducing admixture as necessary.
 - b. Use superplasticizing admixture with a retarder when required as per Clause 1.8.B.

D. Mix for Bonded Concrete Topping:

1. Type E concrete Exposure Class S3
2. Coarse aggregate: CSA A23.1; gravel or crushed stone with gradation in accordance with CSA A23.1, Table 11: nominal size 10 mm to 2.5 mm for topping thickness of 100 mm maximum.
3. Fine aggregate: CSA A23.1; natural sand.
4. Admixtures: Use superplasticizing admixture.
5. Slump: After adding superplasticizing admixture 125 plus or minus 30 mm.

6. Air Content:
 - a. Provide air content category 2, unless noted otherwise.
- E. Mix for Filling Openings and Box Outs:
 1. Refer to Specification Section 03 60 00, Grouting.
- F. Mix for Wall and Column Grout:
 1. Mix same as for wall and column placements except no coarse aggregate
- G. Mix for Pumped Concrete:
 1. Comply with ACI 304.2R and this Specification.
 2. Uniform grading curves for fine and coarse aggregate.
 3. Superplasticizing admixture may be used for pumped concrete.
 4. Do not use admixtures which promote bleeding.
 5. Successfully used previously or for new mix carry out pumping test for successful placement.

2.3 SOURCE QUALITY CONTROL

- A. Testing by an independent laboratory in accordance with CSA A23.1 and A23.2, where test results less than one year are not available, to determine:
 1. Chemical composition and physical properties of aggregates.
 2. Presence and quantity of deleterious substances in aggregates.

PART 3 EXECUTION

3.1 PREPARATION

- A. General:
 1. Determine requirements of other trades, inform concerned trades, and assume responsibility for location, installation, and quality of items which affect the work of this Section.
- B. Preparation of Surfaces:
 1. Remove water, snow, ice, loose soil, laitance, curing compound, wood, and other debris from surfaces on or against which new concrete will be placed.
 2. Roughen and clean surfaces of previously placed concrete against which subsequent concrete will be placed.
- C. Bonded Concrete Topping:
 1. Prepare surface of substrate concrete for application of bonded concrete toppings in accordance with the requirements of CSA A23.1-09 Clause 7.6.4. 1 Preparation of Base Course Surface.

3.2 PLACING CONCRETE

- A. General:
1. Do not commence concrete placing until sufficient manpower and equipment is available to complete the placement expeditiously preventing the formation of cold joints, and to produce specified surface finish.
 2. Provide standby equipment for critical items in case of equipment failure.
 3. Verify that cast-in-place accessories, inserts, and reinforcement are set correctly and are not disturbed during concrete placement.
 4. Place concrete on dry and clean substrate.
 5. Place concrete between expansion or construction joints in one continuous operation.
 6. Submit field review quality control sheet as provided in Section 01 35 13, Special Project Procedures.
- B. Depositing:
1. Deposit concrete in a manner that prevents segregation in accordance with CSA A23.1-09 Clause 7.2.4 - Depositing.
- C. Time Limitations on Concrete Placement:
1. Do not use concrete after a period of two hours has passed since first mixing of ingredients.
 2. Do not use high-slump concrete after slump falls below 100 mm for non-flowing concrete and 125 mm for flowing concrete. Where permitted, re-temper in accordance with manufacturer's printed instructions. Monitor, and correct if required, air content of concrete that has been re-tempered.
- D. Adverse Weather Conditions:
1. Make suitable arrangements to prevent damage to fresh concrete, under adverse weather conditions.
 2. Do not allow rain, sleet, or snow to increase mixing water or damage surface finish.
 3. Plan placement frequency such that lift lines will not be visible in exposed concrete finishes.
 4. Provide windbreaks, shading, fog spraying, sprinkling, ice, wet cover, or other means as necessary to maintain concrete at or below specified temperature.
 5. Do not place concrete when ambient temperature is below 5 degrees C or approaching 5 degrees C and falling, without special protection.
 6. Do not place concrete against frozen earth or ice, or against forms and reinforcement with frost or ice present.
 7. Provide heated enclosures when air temperatures are below 5 degrees C.
 8. Maintain surface temperature of concrete above 5 degrees C.
 9. External Heating Units:
 - a. Vent heating units to atmosphere and do not locally heat or dry concrete. Where water cure is specified, maintain wet condition.
 - b. Do not exhaust heater flue gases, directly into enclosed area
 10. Temperature Monitoring:
 - a. Provide thermocouple wires in concrete for temperature monitoring.

- E. Wall and Column Grout:
1. Deposit 75 mm of wall and column grout evenly along horizontal construction joints in bottom of form through an elephant trunk immediately before placing wall or column concrete.
- F. Time Interval Between Concrete Placements:
1. Construction Joints: 7 days wet cure continuously.
 2. Control Joints: 6 days.
 3. Expansion Joints/Contraction Joints: 1 day.
 4. Wait at least 2 hours after depositing concrete in long columns and walls thicker than 200 mm before depositing concrete in beams, girders, or slabs supported thereon.
 5. For columns and walls 3 m in height or less, wait at least 45 minutes prior to depositing concrete in beams, girders, brackets, column capitals, or slabs supported thereon
- G. Consolidation:
1. Consolidate the concrete during and immediately after depositing, thoroughly and uniformly by means of tamping, hand tools, finishing machines, and vibrators in order to obtain dense, watertight, homogeneous concrete well bonded to reinforcing bars.
 2. Carefully vibrate concrete around waterstops, to make sure thorough contact.
 3. Bend edge of horizontal waterstops slightly upward allowing concrete to flow under and completely fill space below the waterstop. Verify no air is trapped below waterstop and concrete is in contact with waterstop over its entire surface area.
 4. Provide sufficient windows in forms or to allow for concrete placement through windows and for visual observation of concrete.
 5. Vibration consolidation not to exceed distance of 1 m from point of placement.
 6. Do not allow concrete to form cold joints.
- H. Bonded Concrete Toppings:
1. Place bonded concrete topping complete with embedded items as indicated on the Drawings within specified tolerances.
 2. Comply with the requirements of CSA A23.1-09 Clause 7.6.4.2 Bonding Systems, except that the responsibility of inspecting the substrate concrete surface and selecting a bonding procedure rests with the Contractor.
 3. Do not place concrete topping in inclement weather.
 4. Verify tensile bond strength of topping with the substrate concrete by testing.
- I. Maximum Size of Concrete Placements:
1. Limit size of each placement to allow for strength gain and volume change due to shrinkage
 2. Consider beams, girders, brackets, column capitals, and haunches as part of floor or roof system and place monolithically with floor or roof system.
 3. Should placement sequence result in cold joint located below finished water surface, install water stop in joint.

3.3 REPAIR OF TEMPERATURE AND SHRINKAGE INDUCED CRACKS

- A. Repair cracks in the completed structures employing a suitable polyurethane injection technique to make such cracks completely watertight after repair.
- B. Remove surface injection materials following completion of work and finish affected areas to match surrounding concrete.
- C. For dry areas, propose repairs to meet the specifications.

3.4 REPAIR OF JOINTS

- A. Repair joints in the completed structures employing a suitable polyurethane injection technique to make such joints completely watertight after repair.
- B. Remove surface injection materials following completion of work and finish affected areas to match surrounding concrete.

3.5 REPAIR OF BONDED CONCRETE TOPPING

- A. If topping is poorly bonded or delaminated, remove and replace the topping over the affected area.
- B. Pay for such remedial work at no expense to The City.

3.6 CONCRETE BONDING

- A. Horizontal Construction Joints in Reinforced Concrete Walls:
 - 1. Thoroughly clean and saturate surface of joint with water.
 - 2. Limit wall and column grout placement to maximum 75 mm and minimum 30 mm thickness.
 - 3. Do not deposit grout from pump hoses or large concrete buckets, unless specified placement thickness can be maintained and verified through inspection windows close to joint.
 - 4. Limit concrete placed immediately on top of grout to 300 mm thick. Thoroughly vibrate to mix concrete and grout together.
- B. To Existing Concrete:
 - 1. Thoroughly clean and mechanically roughen existing concrete surfaces to roughness profile of 6 mm.
 - 2. Saturate surface with water for 24 hours prior to placing new concrete.

3.7 FIELD QUALITY CONTROL

- A. General:
 - 1. Tests will be made throughout progress of the Work and will be paid for by The City to determine concrete quality. Tests will be in accordance with CSA A23.1 and A23.2. Provide labour, concrete, and other facilities for making the test specimens.

2. Provide and maintain facilities for storing and initial curing of test cylinders, and provide suitable crates for shipping test cylinders in accordance with CSA A23.2-09 Test Method A23.2-3C - Making and Curing Concrete Compression and Flexural Test Specimens. Provide microwave oven and facility of carrying out test in field.
 3. The testing laboratory shall provide the test results to The City, Contract Administrator, Contractor and material supplier within 5 days of availability. For test that fails to meet the Specification inform Contract Administrator, Contractor and material supplier within 48 hours of the test.
 4. Testing company in coordination with the Contractor shall consider using on line secured website such as CMATS to record, view and distribute concrete test data. Data shall be entered in standard format as designed by the software. Protocol for distribution and filing of test results shall be agreed upon at the pre-placement meeting.
- B. Standard Strength Tests:
1. Provide concrete for one standard strength test consisting of 4 cylinders for each 100 m³ of concrete of each type placed in any day. If the amount placed, for each type of concrete is less than 100 m³ in a day, provide concrete for one standard strength test of 4 cylinders . One cylinder will be tested at 7 days and one at 28 days and two cylinders at 56 days.
- C. Concrete Temperature Monitoring:
1. Monitor temperature of concrete starting immediately after placement until the end of 7 days curing period.
 2. Record ambient temperature during concrete monitoring period also.
 3. Install thermocouple wire sensors in sufficient numbers, into each concrete pour in excess of 20 cubic metres poured in one day, to truly represent the concrete temperatures of the pour.
 4. Connect thermocouple wires to central temperature logger that records the temperatures at regular interval of one half hour.
 5. Provide records of temperatures daily of previous 24 hours.
 6. For each pour, at the end of the curing period, provide temperature graphs of the concrete and the ambient temperature.
 7. Consider the use of temperature monitoring system such as Hobo U12 Outdoor Thermocouple Temperature Logger with software and thermocouple wire sensors supplied by Onset Computer Company.
- D. Air Content Tests:
1. Testing agency will carry out air content tests in accordance with CSA A23.1 and A23.2.
- E. Slump Tests:
1. Testing agency will carry out slump tests in accordance with CSA A23.1 and A23.2.

- F. Failure to Meet Strength, Air Content, or Slump Requirements:
1. When measured slump or air content falls outside of required limits, carry out a check test immediately on another portion of the same sample. In the event of a second failure, the concrete will be considered to have failed to meet the requirements. Remove the whole batch, from which the samples were taken, off the site.
 2. When the strength requirement provisions are not met, carry out one or more of the alternatives:
 - a. Change the mix proportions
 - b. Carry out nondestructive testing
 - c. Provide additional curing on portions of the structure represented by the test specimen.
 - d. Core drill portion of the structure in question and test cored cylinder in accordance with CSA 23.2-09 Test method A23.2-14C Obtaining and testing drilled cores for compressive strength.
 - e. Load test structure to design loading
 - f. Other test The City may require for acceptance.
 3. When, after carrying out these requirements, there is still doubt about of the adequacy of the concrete, strengthen or replace, as directed, portions of the Work which failed to develop the required strength.
- G. Uniformity of Mixed Concrete
1. If the results of slump, slump flow, air content or density for any mix design do not comply with CSA A23.1-09, Table 13 - Determination of Within-Batch Uniformity, alter mixing operations and equipment until tests indicate that the requirements are satisfied.
- H. Bonded Concrete Topping:
1. Bonded concrete topping floor finishes will be inspected 60 days after completion to verify that a continuous bond between the substrate concrete and the topping has been achieved. The topping will be chain dragged or tapped with a blunt metal object. Detection of a hollow sound will be considered as inadequate bonding.
 2. Core each hollow sounding area as requested by the Contract Administrator, to determine bonding adequacy. Pay for coring which may be necessary.
 3. Resolve disputes regarding tensile bond strength between substrate concrete and topping, including extent of affected areas by conducting tests.
 1. Determine bond strength in accordance with procedure outlined in CSA A23.2-09, CSA A23.2-09 -6B-Determination of bond strength of bonded toppings and overlays and direct tensile strength of concrete mortar and grout.
 2. Only tests meeting the strength requirements will be paid by The City. Pay for cost of unsuccessful tests.
- I. Concrete Delivery Records:
1. Submit with each batch of concrete before unloading, a typed delivery ticket prepared at the ready mix plant containing following information:
 - a. Name of ready-mix batch plant.
 - b. Date and serial number of ticket., truck plate number

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- c. Name of Contractor.
 - d. Project Name.
 - e. Specific class of concrete with identifying mix number.
 - f. Amount of concrete in cubic metres
 - g. Time loaded or of first mixing of cement and aggregates.
 - h. Amount of admixtures, or water added on site.
2. Keep records of the time when each load arrives at the site and when discharge is completed. Record the temperature of fresh concrete.

END OF SECTION

SECTION 03 39 00

CONCRETE CURING AND FINISHES

PART 1 GENERAL

1.1 SUMMARY

- A. Comply with Division 1, General Requirements.
- B. This Section forms part of Section 03 30 00, Cast-in-Place Concrete.

1.2 REFERENCES

- A. The following is a list of standards which may be referenced in this section:
 - 1. Canadian Standards Association: CSA A23.1-09 Concrete Materials and Methods of Concrete Construction.
 - 2. American Concrete Institute: ACI 309.2R Identification and Control of Visible Effects of Consolidation on Formed Concrete Surfaces
 - 3. American Society for Testing and Materials International (ASTM):
 - a. C309, Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.
 - b. C1315, Standard Specification for Liquid Membrane-Forming Compounds having Special Properties for Curing and Sealing Concrete.
 - 4. American Society of Concrete Contractors: Guide for Surface Finish of Formed Concrete.

1.3 DEFINITIONS

- A. Aggregate transparency: Mottled surface appearance resulting from deficiencies in the mortar.
- B. Air surface voids: Also termed as air pockets or bug holes. Small regular or irregular cavities resulting from entrapped air bubbles in the surface of formed concrete. Air surface voids less than 12 mm in diameter or depth may be acceptable unless specified otherwise.
- C. Fin /form streaking: A narrow linear projection on foamed concrete surface resulting from mortar flow into spaces in the formwork.
- D. Finish: The texture of a surface after consolidating and finishing operation has been performed.
- E. Form offsets: An abrupt change in alignment, either horizontally or vertically.
- F. Honeycomb: Condition of irregular voids due to failure of the mortar to effectively fill the space between coarse aggregate particles generally in formed concrete.

- G. Laitance: A thin weak brittle layer of cement and aggregate fines on concrete surface.
- H. Layer lines: Dark lines on formed surfaces indicating boundary between concrete placements. Cold joints are one form of layer lines.
- I. Soundness: A quantitative measure of suitability of concrete to perform as a solid substrate or base for a coating or patching material. Sound concrete substrates usually exhibit strength and cohesiveness without excessive voids or cracks.
- J. Subsidence cracking: Tension cracking when concrete settles after initial set.
- K. Surface defects: Includes air surface voids, form streaking, sand streaking, aggregate transparency, colour variation, layer lines, cold joints, soft areas, offsets and bulges. Air surface voids or bug holes smaller than 12 mm are not considered as defects as long as they are generally spaced out.
- L. Porosity: Small voids that allow fluids to penetrate an otherwise impervious material.

1.4 SUBMITTALS

- A. Quality Control Submittals:
 - 1. Manufacturer's representative and application personnel. Names and phone number.
 - 2. Manufacturer's certificate of compliance for products furnished.
 - 3. Statement of Qualifications.
 - 4. Manufacturer's product service record.
 - 5. Manufacturer's printed procedures for preparation, product application, protection of finished surface, and post-application cleanup.
 - 6. Manufacturer's site specific installation instructions.
 - 7. Manufacturer's certificate of proper installation.
- B. Product Data Sheets
 - 1. Submit three copies of manufacturer's product data sheets including installation, application, and maintenance instructions for:
 - a. Curing compound
 - b. Floor Surface sealer
 - c. Non metallic shake on floor hardener
 - 2. Evaporation retardant.
- C. Shop Drawings
 - 1. Submit shop drawings indicating finishes for floors and walls.
 - 2. Curing methods proposed.

1.5 QUALITY ASSURANCE

- A. Concrete finishers: Skilled personnel with a minimum of five years proven satisfactory experience finishing concrete of comparable size and scope.

- B. Engage manufacturers' representative for on site supervision prior to, during, and after applications. Verify that specified products are correctly applied; amount and finishing procedures comply with manufacturer's printed instructions for project.
- C. Pre-installation Training: Manufacturer-approved training of application personnel and quality control inspectors for finishes.
- D. Conference Prior to Slab Placement:
 - 1. Conducted by Contractor.
 - 2. Agenda:
 - a. Concrete mix design.
 - b. Placing techniques.
 - c. Finishing techniques.
 - d. Product application procedures.
 - e. Equipment required for the procedures.
 - 3. Attendees:
 - a. Contractor's superintendent.
 - b. Subcontractor's representative involved in concrete placement and finishing.
 - c. Resident Inspector from Contract Administrator's Office.
 - 4. Note pre-concrete conference is also conducted under Section 03 30 00, Cast-in-Place Concrete.
- E. Mockups: Install one 1.800 mm by 1.800 mm area for each type of floor and wall finish to demonstrate that the material and methods produce a finished product acceptable to the Contract Administrator.
 - 1. Mockup will establish the standard of quality for finishes.
 - 2. Use specified materials at a location designated by Contract Administrator or The City.
 - 3. Notify Contract Administrator 5 days in advance of commencement of mockup.
 - 4. Make mockups for following finishes:
 - a. Slab
 - 1) Steel Trowel Finish Type S1
 - 2) Wood Float Finish Type S2
 - 3) Nonslip Finish Type S3
 - 4) Dry shake Floor Hardener Finish Type S3B
 - 5) Bonded Concrete topping Type S6
 - b. Wall
 - 1) Smooth Wall finishing for Painting Type W2A
 - 2) Smooth Wall finishing for Waterproofing Type W2B
 - 3) Controlled Permeability Form Liner Type W3A
 - 4) Smooth Rubbed Finish Wall W4
 - 5) Sack Rubbed Finish Type W5

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Prevent deterioration or contamination of stored materials. Deteriorated or contaminated materials will be rejected and must be removed from site.

1.7 SITE CONDITIONS

- A. Comply with special requirements of Section 03 30 00, Cast-in-Place Concrete. for work under cold weather and high temperature conditions.
- B. During curing, ensure the temperature is kept uniform over the whole surface and across the cross section of the concrete. A temperature gradient across the member may cause cracking. Protect the concrete surface from rapid drying due to high concrete and or ambient temperatures, low humidity, high winds, or heated interiors.

PART 2 PRODUCTS

2.1 MATERIALS

- A. Curing Compound:
 - 1. ASTM C309 1.
- B. Combination Curing and Sealing Compound:
 - 1. Conforming to ASTM C1315, Clear, non yellowing compound.
 - 2. Manufacturer and product:
 - a. Sika Canada Inc., Florseal WB 25.
 - b. BASF; MasterkureCC 1315WB.
 - c. Euclid Admixture Canada, Inc., Super Diamond Clear.
 - d. Dayton Superior Canada Limited; Day Chem Cure & Seal: 1315 (J 22).
- C. Floor Surface Sealer:
 - 1. Clear, liquid surface sealer and dust-proofer.
 - 2. Manufacturer and product
 - a. Sika Canada Inc., Sikafloor 3S.
 - b. Dayton Superior Canada Limited, Sure Hard Densifier J 17.
- D. Evaporation Retardant:
 - 1. Fluorescent color tint that disappears completely upon drying.
 - 2. Manufacturers and Products:
 - a. BASF; MasterKure ER 50.
 - b. Euclid Chemical Co.; Eucobar.
- E. Shake on Floor Hardener:
 - 1. Premixed blend of mineral aggregates, emery particles, wetting and densifying agents, and Portland cement, shake on type;
 - 2. Manufacturer and Product
 - a. Sika Canada Inc.; Sika Emericrete SH,
 - b. Euclid Admixture Canada, Inc.; Surflext
 - c. BASF; MasterTop 110ABR
 - d. Dayton Superior Canada Limited; Quartz Tuff
- F. Polyethylene sheet: CGSB 51 GP 51M; 0.15 mm thick.

- G. Wet curing materials: Non-staining waterproof curing paper, burlap, or canvas coverings.
- H. Bonding agent: Suitable for conditions of service and performance requirements of this Section.

PART 3 EXECUTION

3.1 PREPARATION

- A. Review the requirements for applied finishes.

3.2 TOLERANCES

- A. General
 - 1. Comply with CSA A23.1- 09, Clause 7.5.1 – Surface Tolerances for slabs and floor.
- B. Straightedge Method:
 - 1. Very Flat: Finish tolerance 3 mm in 3000 mm. Surface of base slab applied bonded concrete toppings in clarifiers.
 - 2. Flat: Finish tolerance 5 mm in 3000 mm. Surfaces to receive a vinyl tile, epoxy floor finish or other thin applied floor finish; surfaces to receive ceramic tile or quarry tile on thin set bond coat; surfaces of concrete toppings; and exposed surfaces of concrete floors.
 - 3. Moderately Flat: Finish tolerance 8 mm in 3000 mm. Surfaces to be covered with cladding or to receive insulation, built up roofing, or membrane waterproofing; top of roof slabs of structures, tanks, tunnels, conduits, and similar areas to be covered with backfill.
 - 4. Conventional: Finish tolerance 12 mm in 3000 mm. Surfaces where a bonded concrete topping will be applied.

3.3 CONCRETE FINISHING

- A. General:
 - 1. Concrete finishing effort is directly dependent on forming, concrete placing, and curing techniques. Perform finishing procedures until specified finishes are achieved.
 - 2. Complete concrete finishing in areas where mechanical and electrical equipment will be installed prior to commencement of such installation.
 - 3. Where floor slopes and drains are indicated on the drawings, the floor must be constructed so that water flows to the drain(s) without ponding.

- B. Slab or Floor Surfaces:
1. General:
 - a. Carry out finishing operations in accordance with CSA A23.1 09, Clause 7.5.3 – Initial Finishing of Horizontal Surfaces.
 - b. Initial finishing operations consist of placing, spreading, consolidation vibrating, and screeding, immediately followed by bull floating, or darbying.
 - c. Complete leveling and consolidation before free moisture or bleeding of free water rises to top surface.
 - d. Provide at least one standby power trowel. Provide sufficient finishers and equipment for the work.
 - e. Take precautions necessary to protect the finish against inclement weather.
 - f. Commence final finishing operations by finishing the edges and grooving as required followed by floating and trowelling, when concrete has stiffened sufficiently to prevent the working of excess mortar to the surface and is able to sustain foot pressure, and after removing free bleed water.
 - g. Straighten with straightedge as often as necessary to achieve specified floor tolerances.
 2. Steel Trowel Finish (Type S-1):
 - a. Trowel surface with steel hand or power trowel in accordance with CSA A23.1-09, Clause 7.5.4.3. Trowelling, keeping blade flat at first and raising blade angle a little more on subsequent passes. Leave surface smooth, dense, of fine uniform texture without a swirl and free of blemishes.
 - b. Do not use dry cement or additional water during trowelling. Do not over finish.
 - c. Do not use power machine when concrete has not attained necessary set to allow finishing. Do not introduce high and low spots in slab during trowelling.
 3. Wood Float Finish (Type S-2):
 - a. Bring surface to required finish plane.
 - b. Wood float concrete surface in accordance with CSA A23.1-09, Clause 7.5.4.2 Floating.
 - c. Remove laitance and leave surface clean.
 4. Nonslip Finish (Type S-3):
 - a. Provide nonslip surface finish by swirl-trowelling the surface in accordance with CSA A23.1-09, Clause 7.5.6.1 – Nonslip Surfaces.
 5. Broom Finish (Type S-4):
 - a. Provide nonslip surface finish by brooming the surface in accordance with CSA A23.1-09, Clause 7.5.6.1 - Nonslip Surfaces with application of steel or fibre brooms at least 450 mm wide.
 - b. Pull broom gently over the surface from side to side at right angles to direction of traffic, with adjacent strokes slightly overlapping.
 - c. Produce a broom finish surface free from porous spots, irregularities, depressions, or rough spots with uniform corrugations less than 3 mm.

6. Scratch Finish Type (S-5):
 - a. Provide scratch finish. Produce closely spaced grooves approximately 5 mm in accordance with CSA A23.1-09, Clause 7.5.6.2 - Scratch Finish.
7. Bonded Concrete Topping (Type S-6):
 - a. Wood float and screed with straightedge float, and finish producing a smooth even surface.
 - b. In the clarifiers install bonded concrete topping in accordance with the scraper mechanism supplier's requirements.
 - c. Wood float and screed with straightedge connected to the clarifier rake arm.
 - d. Produce a smooth even surface throughout
8. Dry shake on powder application (Type S-7):
 - a. After initial finishing of horizontal surface as stated above wait for concrete to set to a point that leaves an indentation of 6 to 10 mm when walked upon.
 - b. Concrete should be bleed free and can support the weight of the power trowel
 - c. Float open the surface.
 - d. Apply portion of dry shake powder evenly over the area as specified for the application by hand or mechanical spreader.
 - e. Power float the surface as soon as the dry shake material absorbs the moisture from the base slab.
 - f. As soon as concrete is hardened sufficiently power trowel to specified Type S-1 finish/Type S-3 finish./
 - g. Application Rate:
 - 1) For capillary waterproofing Type S-7A:
 - a) Shake apply capillary waterproofing powder at the rate of 1.3 kg/m² on concrete slabs.
 - b) Float into surface until uniformity in coverage is obtained.
 - c) Comply with manufacturer's printed instructions for installation and curing.
 - 2) Floor hardener Type S-7B:
 - a) Shake apply floor hardener at a minimum rate of 7.5 kg/m². Apply the shake mix in two separate applications using approximately two thirds of the total amount specified for the first application and the balance for the second.
 - b) Apply hardener evenly over the floor surface in one direction.
 - c) Machine float just enough to bring moisture completely through the shake and to embed and compact the shake into the base concrete.
 - d) Immediately following the floating of the first shake apply the balance of the hardener. Spread shake evenly and in direction perpendicular to the first shake. Float as specified for the first shake.

- e) Comply with manufacturer's printed instructions for installation and curing.
9. Type S-8 Formed underside of slab
- a. See under formed surfaces.
10. Floor Surface Sealer:
- a. Treat surfaces subject to traffic in the finished structure, such as slabs, stairs, landings, walkways, and similar locations, with a surface sealer except if the surfaces have been cured with dual purpose curing and sealing compound.
 - b. Apply sealer in accordance with the manufacturer's printed instructions.
 - c. Do not use surface sealer where bonded finishes or waterproofing is scheduled.
- C. Formed Surfaces:
- 1. General Finishing:
 - a. Finish in accordance with CSA A23.1-09, Clause 7.7 Finishing of formed surfaces unless noted otherwise.
 - 1) Remove face formwork as soon as practical to facilitate repair of surface defects. Remove nails and remnant of form and form oils. Repair surface defects.
 - 2) Avoid damaging corners and keep edges sharp.
 - b. Formwork Tie Holes:
 - 1) Cut formwork ties 25 mm from surface of concrete.
 - 2) Make edges of depressions sharp.
 - 3) Fill depressions with pre-blended non shrink non ferrous grout of same colour as the concrete.
 - c. Irregularities:
 - 1) Grind smooth fins, projections, irregularities, and offsets, including those at construction joints.
 - 2) Where irregularities and offsets cannot be remedied by grinding, chip concrete surface sufficiently deep and apply thoroughly bonded pre-blended non shrink non ferrous grout in similar procedure for repair of honeycomb and defective concrete.
 - d. Surface Depressions:
 - 1) Fill surface voids size greater than 12 mm and other surface depressions with a sand cement mortar to match the surface of surrounding concrete.
 - e. Spalled Corners:
 - 1) Use repair materials of similar appearance and strength as the surrounding concrete to reconstruct corner to match adjacent corners.
 - f. Honeycomb, Soft Areas, and Defective Concrete:
 - 1) Do not repair honeycomb, soft areas, and defective concrete until reviewed by Contract Administrator and permission granted to proceed with the repair work.
 - 2) Remove honeycomb, soft areas,, and defective concrete down to sound concrete with edges slightly undercut or perpendicular to

- the surface. Remove a minimum depth of 25 mm. No feather edges are permitted.
- 3) Pre-dampen patch area.
 - 4) Use pre blended non shrink non ferrous grout of same colour as the concrete for exposed concrete surfaces.
 - 5) Use bonding agents in patching work.
 - 6) Patch surface slightly higher than the surrounding concrete.
 - 7) Wet cure patches to equivalent of 10 days minimum.
 - 8) When patched surface has hardened, rub surface with carborundum brick to a true surface, free from streaks, discolourations, and other imperfections, to match flush with surrounding concrete.
- g. Subsidence cracking:
- 1) Depending on the depth, locations and function of the structure the repair system may require injection grouting and repairs similar to the defective concrete.
2. Type W -1 (Ordinary Wall Finish)
 - a. Carry out general finishing as specified above.
 3. Type W -2 (Smooth Wall Finish)
 - a. Carry out general finishing as specified above.
 - b. Fill air surface voids greater than 3 mm.
 - c. Fill nail head depression more than 2mm deep.
 - d. Provide wall finish similar to Photo 1 P1 Finish as presented in Guide for Surface Finish of Formed Concrete.
 4. Type W -2 A (Smooth Wall Finish for Painting).
 - a. Prepare surfaces to Type W-2 finishing standard.
 - b. Coordinate finish with the requirement for painting specification
 5. Type W -2 B (Smooth Wall Finish for Application of Waterproofing)
 - a. Prepare surfaces to Type W-2 finishing standard.
 - b. Coordinate finish with the requirement for water proofing specification
 6. Type W -3 (Form Liner Finishes)
 - a. Type W-3A (Controlled Permeability Form Liner):
 - 1) Coordinate installation and stripping of Form Liner, in accordance with manufactures recommendation and as specified in Section 03 10 00, Concrete Forming and Accessories.
 - 2) Strip forms as soon as possible to ensure the textured surface finish is not damaged
 - 3) Carry out general finishing as specified above.
 7. Type W-4 (Smooth Rubbed Finish):
 - a. Provide smooth rubbed finish of uniform appearance as specified in CSA A23.1-09, Clause 7.7.4.3 Smooth Rubbed Finish.
 - b. Do not commence rubbing or grinding until surface defects are repaired and patching materials are hardened.
 - c. Dress surfaces by rubbing or grinding with bricks of carborundum, emery, or other abrasive material to a smooth and even surface to the best grade of architectural concrete work. Wet and rub surfaces until surfaces are even and of uniform smooth appearance. Prevent rounding

- edges, obliterating the bevel lines on edges and corners, and chipping or cracking the finished edges.
- d. Water cure walls to receive smooth rubbed finish.
 - e. If the rubbed finish work cannot start in timely manner then the specified surfaces shall receive Sack- rubbed Finish.
8. Type W-5 (Sack rubbed Finish):
- a. Repair form offsets, sand streaking and layered lines.
 - b. Complete Type W2 finishing as specified.
 - c. Fill all air surface voids.
 - d. Sack rub cement finish to form a smooth finish of uniform appearance as specified in CSA A23.1-09, Clause 7.7.4.4 - Sack Rubbed Finish.
 - e. Clean sand for finishing mortar shall pass 630 micron sieve size.
 - f. Completed finished surface shall be uniform in appearance free of blemishes, discolorations or surface voids or dimples. Surfaces not meeting the requirements shall be corrected to the satisfaction of the Contract Administrator.
 - g. Apply a second coat of sack rubbed cement finish to produce a smooth uniform appearance if required to obtain acceptance.
 - h. On completion thoroughly wash the surfaces with clean water
9. Type W-6 (Abrasive blast Finish):
- a. Intent of this procedure is to remove surface skin to depth no more than 1.5 mm, and expose only fine aggregate and air holes near surface, thus producing uniform texture.
 - b. Perform abrasive blasting on building or on concrete surfaces in same area of view at same time and obtain uniformity of appearance.
 - c. Same person must accomplish abrasive blasting on one structure and on concrete in same area.
 - d. Perform abrasive blasting to match approved mockup panel.
 - e. Abrasive: Use clean silica sand, free of foreign materials, and supplied in sealed sacks.
 - f. Provide samples with different degree of effort for approval of the Contract Administrator.
10. Columns, Beams and Curbs, sides of equipment and pipe saddle supports:
- a. Provide Type W-2 or W-4/5 finish.
11. Type S- 8 (Formed Underside of Slab Finish):
- a. When forming is removed, grind off projections on underside of slab and patch defective areas, including small shallow air pockets.
12. Related Unformed Surfaces:
- a. Screed and float tops of walls or buttresses, horizontal offsets, and similar unformed surfaces occurring in units cast in forms to a texture consistent with that specified for the formed surface unless some different finish is specified elsewhere.

3.4 CURING CONCRETE

- A. Begin curing immediately following placing and finishing in accordance with CSA A23.1-09 clause 7.4.2 except as noted below.

- B. Rate of evaporation is depend on relative humidity, concrete temperature and winds velocity; for rate of evaporation of moisture from concrete surface covered with water see CSA A23.1 appendix D Guidelines for curing and protection.
- C. Wet cure for 10 consecutive days at a minimum temperature of 10 degrees C. This requirement supersede CSA23.1 -09 Table 20 Allowable curing regimes.
- D. Control initial drying shrinkage and plastic shrinkage for slabs. Provide wind breaks and or shades as required. Provide continuous fog mist when drying shrinkage is likely due to heat or wind. Cover the concrete surface with wet burlap when finishing is complete to start continuous wet curing.
- E. Establish the requirements of specified finishes for concrete surfaces before applying curing compound. Verify that curing compound is compatible with applied finishes.
- F. Do not use curing compounds on surfaces:
 - 1. Where concrete or bonded concrete topping will be applied.
 - 2. Where high temperature control requirements are in force.
- G. Formed Surfaces (Walls and Columns)
 - 1. Wet cure as specified by pouring water between the formwork and concrete surface where possible.
 - 2. As an alternative, cure as specified above until formwork is removed. Immediately after removal of formwork, provide 24 hours saturation followed by application of curing compound in accordance with manufacturer's printed instructions.
- H. Unformed Surfaces (Slabs)
 - 1. Cover with absorbent material kept continuously saturated as soon as cement will not wash out or finish be damaged.
 - 2. As an alternative, wet cure for 24 hours then seal with two complete coats of curing compound applied in accordance with the manufacturer's instructions. Maintain coating during the curing period.
- I. Bonded Concrete Toppings
 - 1. Wet cure for 10 consecutive days if no bonding agent has been used.
 - 2. If a bonding agent has been used, employ curing methods for the concrete topping which will produce a cure equivalent to 10 days wet curing and which is in accordance with the bonding agent manufacturer's printed instructions.
 - 3. Protect and prevent damage to concrete topping floor finishes. Repair damaged sections.
 - 4. Protect topping from freezing for a minimum of 14 days after placing.

3.5 PROTECTION

- A. Keep traffic, which would affect or disturb the curing procedures, off the finished surfaces for a period of seven days.

- B. Protect exposed concrete finishes against damage until acceptance of the work by The City. Do not allow rain, sleet, or snow to increase mixing water or damage surface finish.
- C. Protect floors which are to receive architectural finishes against contamination by oil, paint, or other deleterious materials which may affect finish.
- D. Protect items set into floors from damage. Verify that alignment is not disturbed.

3.6 TESTS AND INSPECTION

- A. Vapor Transmission Test: Conduct test on new and existing concrete to show that no surface moisture exists prior to application of specified special floor treatment, as follows:
 - 1. Place polyethylene plastic sheet, minimum 1.2 m by 1.2 m and sealed along four sides with duct tape to prevent moisture transmission by evaporation, over concrete floor area for 24 hours.
 - 2. Indication of moisture transmission will be apparent by accumulation of moisture on enclosed surface of polyethylene sheet.
 - 3. Do not apply concrete bonding agent until test results indicate moisture is not being transmitted from concrete surface.

3.7 MANUFACTURER'S SERVICES

- A. Provide services of manufacturer's representative at site in accordance with in Section 01 43 33, Manufacturer's Field Services, for installation assistance, inspection and certification of proper installation, and training of application personnel.
 - 1. Technical assistance with design and adjustment of concrete mixes to receive floor finishes and toppings.
 - 2. Technical assistance to assure and certify application and installation of system being used.
 - 3. Consultation, direction, and certification of mockup, for full-scale application of floor finishes, and at other times as needed.
 - 4. Attendance at the conference prior to slab placement to finalize proper methods and procedures.

3.8 FIELD QUALITY CONTROL

- A. Measure floor flatness and levelness. Report deficiency. Propose method to remediate. Repair as required.
- B. Flood the sloped floor surface with water to a depth necessary and allow the water to flow into drain(s). Observe all areas of ponding. Repair all depressed area exceeding the following:
 - 1. For dry areas ponding depth greater than 3 mm.
 - 2. For tank floors ponding depth greater than 20 mm.

3.9 SCHEDULE OF CONCRETE FINISHES

A. Provide concrete finishes as scheduled:

Area	Type of Finish	Notes
EXTERIOR SLABS		
Roof slab/exposed	S-3	
Roof slab/covered with roofing and waterproofing material	S-1	
Water-holding tanks and basins/top of wall	S-1	
Other water-holding tanks and basins	S-1	
Stairs and landings	S-3	
Sidewalks	S-4	
Other exterior slabs	S-2	
Approach slab	S-2	
INTERIOR SLABS		
Buildings, pipe galleries, and other dry areas	S-1	
Hydraulic channels	S-1	
Underside of elevated slabs	S-8	
Equipment bases	S-1	
Surface to receive bonded topping	S-5	
Bonded topping	S-1	
Loading docks	S-7B	
Where shake on hardener is applied	S-7B	
EXTERIOR WALL SURFACES		
Above grade/exposed (above a point 150 mm below finish grade)	W-2	
Above grade/covered with brick veneer or other finish material	W-1	
Backfilled (below a point 150 mm below finish grade)	W-3A	
INTERIOR WALL SURFACES		
Pipe supports, and equipment bases in dry areas	W-2	

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Area	Type of Finish	Notes
Water-holding tanks, channels, troughs and basins	W-3A	
Buildings, pipe galleries, and other dry areas	W-5	

END OF SECTION

SECTION 03 40 00

PRECAST CONCRETE

PART 1 GENERAL

1.1 REFERENCES

- A. The following is a list of standards which may be referenced in this section:
1. National Building Code of Canada (2010) with 2011 Manitoba Amendments (NBC).
 2. Canadian Standards Association (CSA):
 - a. A23.4, Precast Concrete – Materials and Construction.
 3. ASTM International (ASTM):
 - a. A167, Standard Specification for Stainless and Heat-Resisting Chromium – Nickel Steel Plate, Sheet, and Strip.
 - b. A416, Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete.
 - c. C31, Standard Practice for Making and Curing Concrete Test Specimens in the Field.
 4. Precast/Prestressed Concrete Institute (PCI):
 - a. MNL-120, PCI Design Handbook, 7th Edition.

1.2 SUBMITTALS

- A. Action Submittals:
1. Sealer for Exterior Surfaces: Product data with mixing/application instructions.
 2. Form Liners: Manufacturer's literature and product data.
 3. Calculations and Technical Data: Proposed details and design calculations for stresses in all critical sections of precast members for all loading conditions including transportation, handling, and erection.
 - a. Shop drawings and design calculations stamped and sealed by a Structural Engineer registered in the Province of Manitoba.
- B. Informational Submittals:
1. For Precasting Manufacturers Not Listed in Article Quality Assurance:
 - a. Experience record on production of precast concrete as shown, with information on precasting plant, that will indicate capability to satisfactorily perform the Work.
 - b. Evidence of current PCI plant certification.
 2. Certificate of Compliance: Certify admixtures and concrete do not contain calcium chloride.
 3. Test Reports:
 - a. For precast manufacturer's concrete test cylinders.
 - b. Inspection of installed members.

1.3 QUALITY ASSURANCE

- A. Qualifications of Precasting Manufacturers:
 - 1. Manufacturer: Certified to Canadian Precast / Prestressed Concrete Institute (CPCI) Certification Program.
 - 2. Precast Concrete and Precast Prestressed Concrete: Product of manufacturer with 3 years' experience producing precast concrete products of quality specified.
 - 3. Precast Plant: PCI certified plant with current certification.
 - 4. Calculations stamped and signed by an engineer registered in the Province of Manitoba.

PART 2 PRODUCTS

2.1 MATERIALS

- A. Formwork:
 - 1. One-piece, full-length, and without seams.
 - 2. As specified in Section 03 10 00, Concrete Forming and Accessories.
- B. Reinforcing Steel: As specified in Section 03 21 00, Reinforcing Steel.
- C. Cement: As specified in Section 03 30 00, Cast-in-Place Concrete.
- D. Pretensioning Strands: Seven-wire, uncoated, stress relieved, ASTM A416, Grade 270.
- E. Aggregates: As specified in Section 03 30 00, Cast-in-Place Concrete, for 20 mm maximum size. Furnish of consistent quality, and gradation.
- F. Admixtures: As specified in Section 03 30 00, Cast-in-Place Concrete.
- G. Embedded Items:
 - 1. ASTM A167 with minimum yield stress of 227 MPa.
 - 2. Anchor Studs: Headed anchor studs (HAS), deformed bar anchors (DBA), or threaded studs as manufactured by Nelson Stud Welding Co..
 - 3. Furnish inserts for lifting, bolting stiffeners, attaching braces, and as otherwise required.
 - 4. Embedded items must be stainless steel, Type 316L.
- H. Grout: Nonshrink, nonmetallic Type II grout as specified in Section 03 60 00, Grouting.
- I. Sealer for Exterior Surfaces:
 - 1. Silane Sealer: One-component penetrating sealer, hydrophilic (isopropyl alcohol as a carrier) with 40 percent active ingredients.
 - 2. Manufacturers:
 - a. BASF.
 - b. Euclid Chemical Co.
- J. Precast Prestressed Concrete Members: double tees, hollow core slabs.

2.2 CONCRETE MIX

- A. Type A, as specified in Section 03 30 00, Cast-in-Place Concrete, except as noted below.
- B. Design Strength: 35 MPa at 28 days.
- C. Water/Cement Ratio: 0.38 maximum.

2.3 DESIGN REQUIREMENTS

- A. Precast items include:
 - 1. Hollow core roof slabs
 - 2. Double tee roof slabs
- B. Design for post-disaster requirements.
- C. Meet applicable sections of PCI MNL-120.
- D. Design roof as diaphragm. Design for wind loads shown.
- E. Design for spans and superimposed live and dead loads shown plus dead loads of members.
- F. Unfactored superimposed live loads for floor members shall be 4.8 kPa (100 psf) minimum, unless noted.
- G. Unfactored superimposed live loads for roof members shall be 2.4 kPa (50 psf) minimum unless noted.
- H. Roof and floor members shall design for additional concentrate live loads of 1000 kg (2000 lbs) apply anywhere on members unless noted.
- I. Calculated tension at full service loads shall not exceed six times the square root of design strength except that in wet or corrosive service conditions the calculated tension due to live load and dead load shall not exceed zero.
- J. Limit long-term camber growth to span length divided by 360.
- K. Prestress member shall be designed to receive composite topping.
- L. Where precast members are required to be cut for openings, provide steel support below cut openings and transfer loads to adjacent members. Adjacent members shall be designed to support additional loads due to load transfer.
- M. Design precast member for a minimum of 2 hours fire-rating. Provide concrete covers to reinforcing and prestress strands in accordance with NBC requirements.

2.4 FABRICATION

- A. General:
1. Reinforcing Steel and Pretensioning Strands:
 - a. Place in position before concrete is cast.
 - b. Keep clean and free from form oil or other substances harmful to bond.
 2. Pretensioning Force, if Used: Determine by elongation and by gauge pressure.
 - a. Method: Meet requirements of Prestressed Concrete Institute.
 3. Forms: Produce smooth surfaces.
 4. Concrete: Deposit, vibrate, finish, and cure in accordance with recommended practices of CSA A23.4. Steam curing is permitted.
 5. Release Strength for Pretensioning Method: Minimum 28 MPa, unless otherwise approved.
 6. Coordinate dimensions, determine type, quantity, size, and location of, and furnish necessary embedded items in precast concrete. Coordinate location of embedded items in cast-in-place concrete necessary to connect precast items.
- B. Surface Finish for Precast Structural Units: Furnish concrete finish, as specified in Section 03 30 00, Cast-in-Place Concrete, to additional concrete field placed on precast units.
1. Other Surfaces: Smooth screeded finishes, unless otherwise shown.
 2. Top surface of the precast slab is to be raked (roughened) for bonding of composite topping.
- C. Sealer:
1. Apply to surfaces as noted in Room Schedule in accordance with manufacturer's instructions.
 2. Protect surface until installed in the Work.
 3. Repair damage as approved by manufacturer.
- D. Embedded Steel:
1. Provide embedded steels to be casted into precast members for the support of other trades.
 2. Embedded steels to anchor precast members shall have sufficient strength and shall design to allow movements.
 3. Anchor locations for precast members must be reviewed and approved by Contract Administrator before fabrication and construction.
 4. Steel cast into concrete frames or weld to steel frames for the purpose of anchoring precast members shall be supplied and installed by this Section.

2.5 SOURCE QUALITY CONTROL

- A. Prepare minimum three standard concrete test cylinders for each 50 cubic yards or fraction thereof of concrete placed in the precast work in accordance with ASTM C31.
- B. Test and record concrete strengths.

PART 3 EXECUTION

3.1 ERECTION

- A. Verify that anchorage inserts are in correct locations.
- B. Handle and erect precast concrete with care as recommended by manufacturer.
- C. Erect precast units plumb, straight, level, square, and in proper alignment.
- D. Fasten units securely in place and brace to maintain position, stability, and alignment until permanently connected and structure is complete and stable.
- E. Field Cutting: Not allowed without prior approval of precast concrete manufacturer and Contract Administrator.
- F. Where insufficient bearing area provide along edges of walls, beams, columns or support elements, provide bearing area using steel channels, angles, beams, etc. and drill in anchors with sufficient strength to support the precast loads.

3.2 PATCHING

- A. Mix and place patching mixture to match color and texture of surrounding concrete and to minimize shrinkage.
- B. Demonstrate patching method and obtain acceptance and approval.

3.3 CLEANING

- A. After installation, clean soiled precast concrete surfaces with detergent and water, using fiber brush and sponge.
- B. Use acid solution only to clean particularly stubborn stains after more conservative methods have been tried unsuccessfully.
- C. Use extreme care to prevent damage to precast concrete surfaces and to adjacent materials.
- D. Rinse thoroughly with clean water immediately after using cleaner.

3.4 FIELD QUALITY CONTROL

- A. Inspection:
 - 1. With Contract Administrator, inspect precast for chips, cracks, and other damage.
 - 2. Record location and condition of damaged or nonmatching members.
- B. Resolution:
 - 1. Repair damage to satisfaction of Contract Administrator and City.

2. Remove members with damage or repairs not acceptable to Contract Administrator.
3. Install new acceptable members in place of those removed.
4. Perform reinspection and obtain acceptance by Contract Administrator.

3.5 PROTECTION

- A. Protect precast units from chipping, spalling, cracking, or other damage to the units after delivery to Site.
- B. After erection, protect units from damage.

END OF SECTION

SECTION 03 60 00

GROUTING

PART 1 GENERAL

1.1 SUMMARY

- A. This Section forms part of Section 03 30 00, Cast-in-Place Concrete.
- B. Section Includes
 - 1. Grouting including:
 - a. Filling tie holes.
 - b. Filling openings and blockouts.
 - c. Grouting under base plates for equipment and fittings, and structural steel.
 - d. Through bolt openings.
 - e. Machine bases 26 hp and up.
 - f. Grouted-in dowels for connecting to existing concrete.
 - 2. Alterations and modifications to existing structures, including:
 - a. Removing existing concrete.
 - b. Cutting construction joint keys in existing structures.
 - c. Finishing of existing concrete.
 - d. Refinishing.
 - 3. Miscellaneous concrete work, including:
 - a. Treads for steel stairs.
 - b. Removable slabs.
 - c. Concrete encased conduits (duct banks).
 - 4. Product Installed But Not Supplied Under the Work of This Section
 - a. Reinforcing bar for grouted - in bar.

1.2 REFERENCES

- A. Comply with the latest edition of the following statutes codes and standards and all amendments thereto.
 - 1. American Society for Testing and Materials International (ASTM):
 - a. C230/C230M, Standard Specification for Flow Table for Use in Tests of Hydraulic Cement.
 - b. C939, Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method).
 - c. C1107, Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink).

1.3 SUBMITTALS

- A. Shop Drawings:
 - 1. Product data of grouts including installation, application, and maintenance instructions.

2. Proposed method for keeping existing concrete surfaces wet prior to placing hydraulic cement grout.
 3. Forming method for fluid grout placements.
 4. Curing method for grout.
- B. Quality Control Submittals:
1. Manufacturer's printed Instructions:
 - a. Adding fibre reinforcing to batching.
 - b. Water/Cementing material ratio of grout.
 - c. Mixing of grout.
 2. Manufacturer's proposed training schedule for grout work.
 3. Manufacturer's Certificate of Compliance:
 - a. Grout free from chlorides and other corrosion-causing chemicals.
 - b. Nonshrink hydraulic cement grout properties of Types II and III, verifying expansion at 3 or 14 days will not exceed the 28-day expansion and nonshrink properties are not based on gas or gypsum expansion.
 4. Manufacturer's Certificate of Proper Installation.
 5. Statements of Qualification: Nonshrink grout manufacturer's representative.
 6. Test Reports for Nonshrink Hydraulic Cement Grout:
 - a. Field test reports and laboratory test results for field-drawn samples.
 7. Load Test Results for Grouted in Dowels:
 - a. Submit load test results of grouted - in dowels.

1.4 QUALIFICATIONS

- A. Nonshrink Grout Manufacturer's Representative: Authorized and trained representative of grout manufacturer. Minimum of 1 year experience that has resulted in successful installation of grouts similar to those for this Project.

1.5 GUARANTEE

- A. Manufacturer's guarantee containing disclaimer on the product data sheet, grout bag, or container limiting responsibility to only the purchase price of products and materials furnished will not be accepted.
- B. Manufacturer guarantees participation with Contractor in replacing or repairing grout found defective due to faulty materials, as determined by industry standard test methods.

PART 2 PRODUCTS

2.1 NONSHRINK HYDRAULIC CEMENT GROUT SCHEDULE

- A. Furnish nonshrink hydraulic cement grout of type specified for applications in the following schedule:

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Application	Temperature Range	Maximum Placing Time	
		20 minutes	Greater than 20 minutes
Filling tie holes	I	I	I
Blockouts for gate guides	I or II		II
Column base plates single-storey	I or II		II
Machine bases 25 hp or less	II	II	II
Base plates for columns over one storey	II	II	II
Through-bolt openings	II	II	II
Machine bases 26 hp and up	III	III	III
Baseplates and/or soleplates with vibration, thermal movement, etc.	III	III	III

2.2 NONSHRINK HYDRAULIC CEMENT GROUT

A. Type I:

1. Nonmetallic and nongas-liberating.
2. Prepackaged natural aggregate grout requiring only the addition of water.
3. Test in accordance with ASTM C1107:
 - a. Flowable consistency 140 percent, five drops in 30 seconds, in accordance with ASTM C230.
 - b. Flowable for 15 minutes.
4. No bleeding of grout at maximum allowed water.
5. Minimum strength of flowable grout,
 - a. 20 MPa at 3 days,
 - b. 35 MPa at 7 days,
 - c. 48 MPa at 28 days.
6. Manufacturers and Products:
 - a. BASF.; MasterFlow 100.
 - b. Euclid Chemical Co.; NS Grout.
 - c. Dayton Superior Corp.; 1107 Advantage Grout.

B. Type II:

1. Nonmetallic, nongas-liberating.
2. Prepackaged natural aggregate grout requiring only the addition of water.
3. No segregation or settlement of aggregate at fluid consistency at specified times or temperatures.
4. Test in accordance with ASTM C939 and ASTM C1107, Grade B:
 - a. Fluid consistency 20 to 30 seconds using flow cone method.

- b. Temperatures of 5, 27, and 38 degrees C.
- 5. 1 hour after mixing, pass fluid grout through flow cone with continuous flow.
- 6. Minimum strength of fluid grout,
 - a. 25 MPa at 1 day
 - b. 30 MPa at 3 days
 - c. 52 MPa at 28 days.
- 7. Maintain fluid consistency when mixed in 1 to 7 m³ loads in ready-mix truck.
- 8. Manufacturers and Products:
 - a. BASF.; MasterFlow 928.
 - b. Euclid Chemical Co.; Hi-Flow Grout.
 - c. Dayton Superior Corp.; Sure-Grip High Performance Grout.

C. Type III:

- 1. Metallic and nongas-liberating.
- 2. Prepackaged aggregate grout requiring only the addition of water.
- 3. No segregation or settlement of aggregate at fluid consistency at specified times or temperatures.
- 4. Test in accordance with ASTM C939 and ASTM C1107, Grade A:
 - a. Fluid consistency 20 to 30 seconds using flow cone method.
 - b. Temperatures of 5 and 38 degrees C.
- 5. 1 hour after mixing, pass fluid grout through flow cone with continuous flow.
- 6. Minimum strength of fluid grout,
 - a. 28 MPa at 1 day
 - b. 35 MPa at 3 days
 - c. 62 MPa at 28 days.
- 7. Maintain fluid consistency when mixed in 1 to 7 m³ loads in ready-mix truck.
- 8. Manufacturer and Product:
 - a. BASF; MasterFlow 885
 - b. Euclid Chemical Co.: Hi Flow Metallic Grout

D. Nonshrink Epoxy Grout:

- 1. Minimum strength of grout: 62 MPa at 1 day.
- 2. Manufacturers and Products:
 - a. Euclid Chemical Co.; E3-HP.
 - b. Dayton Superior Corp.; Sure-Grip Epoxy Grout (J-55).
 - c. BASF; Masterflow 649.

2.3 DOWELLING GROUT

A. Hydraulic Cement Grout:

- 1. MasterEmaco T 545 by BASF.

B. Epoxy grout:

- 1. Sikadur Injection Gel by Sika Canada Inc.
- 2. Liquid Roc 500 by Mkt Fastening.

PART 3 EXECUTION

3.1 NONSHRINK GROUT

- A. General: Mix, place, and cure nonshrink grout in accordance with grout manufacturer's representative's printed training instructions.
- B. Form Tie or Through-Bolt Holes: Provide nonshrink hydraulic cement grout, Type I and II, fill space with dry pack dense grout hammered in with steel tool and hammer. Through-bolt holes coordinate dry pack dense grout application with vinyl plug.
- C. Grouting Machinery Foundations:
 - 1. Use nonshrink hydraulic cement grout except where equipment supplier specifically recommends nonshrink epoxy grout.
 - 2. Block out original concrete or finish off at distance shown below bottom of machinery base with grout. Prepare concrete surface by abrasive blasting, chipping, or by mechanical means to remove any soft deleterious material.
 - 3. For nonshrink hydraulic cement grout, thoroughly clean concrete surface and metal surfaces to be in contact with grout to remove all paint, oil, grease, loose rust, and all other foreign matter.
 - 4. For nonshrink epoxy grout, thoroughly clean concrete surface and abrasive blast metal surfaces to be in contact with grout unless grout manufacturer states in writing that abrasive blasting is not necessary.
 - 5. Set machinery in position and wedge to elevation with steel wedges or use cast-in leveling bolts.
 - 6. Form with watertight forms at least 50 mm higher than bottom of plate.
 - 7. Fill space between bottom of machinery base and original concrete in accordance with manufacturer's representative's training instructions.

3.2 GROUTED-IN DOWEL FOR CONNECTING TO EXISTING CONCRETE

- A. Using a Hydraulic Cement Based Dowelling Grout:
 - 1. Drill hole in existing concrete of diameter equal to diameter of dowel bar plus 20 mm.
 - 2. Clean hole of dust and debris.
 - 3. Fill hole to surface with dowelling grout.
 - 4. Install dowel bar and wipe away overflow.
 - 5. Secure dowel bar firmly in position and do not disturb bar for minimum of 24 hours after installation.
- B. Using an Epoxy Type Dowelling Grout:
 - 1. Drill hole and install dowel in accordance with manufacturer's printed instructions.

3.3 ALTERATIONS TO EXISTING CONCRETE

- A. General:
 - 1. Cut out, remove, or modify parts of existing concrete structures, roughen surfaces, cut keys, weld bars, and carry out other items of work as required.

2. Use satisfactory methods which will not result in damage to equipment or other parts of the structures by vibration, dust, water, or other contaminants.
 3. Verify actual conditions before beginning alterations.
 4. After alterations are done, repair surface defects and damaged areas and finish surface to match adjacent areas.
- B. Finishing of Existing Concrete Surfaces:
1. As a result of alterations where previously exterior faces become interior, abrasive blast and clean entire surface.
 2. Patch surface depressions with sand-cement mortar.
 3. Grind smooth fins and protrusions.
 4. Apply sack-rubbed finish to entire exposed surface to match adjacent interior surfaces in accordance with Section 03 39 00, Concrete Curing.
- C. Refinishing:
1. Refinish cut edges of openings flush and smooth, with a bonding agent and concrete or with a non-shrink non-ferrous pre-blended hydraulic cement grout of same colour as adjacent concrete.
 2. Cut back exposed reinforcing bars 25 mm from the finished surface level. Fill voids at each bar with grout. Grind edges smooth after repairs and modifications have been completed.
- D. Existing Reinforcing Dowels Encased in Lean Concrete or Lime Mortar:
1. Break out existing encasement and expose reinforcing dowels. Clean individual bars to bare metal by abrasive blast cleaning. Straighten bars as required.
 2. Report any missing or damaged reinforcing bars to the Contract Administrator before proceeding further.

3.4 SCHEDULE OF MISCELLANEOUS CONCRETE WORK

- A. Removable Slabs:
1. Provide concrete slabs with minimum two stainless steel lifting inserts per slab. Provide matching stainless steel plugs and lifting rings for each insert.
 2. Weld end of reinforcing bars to cross bars.
- B. Concrete Encased Conduits (Ductbanks):
1. Provide Type A concrete, as specified in Section 03 30 00, Cast-in-Place Concrete, complete with formwork, reinforcement, and accessories as required.
 2. Secure conduits to prevent flotation or displacement during concrete placement. Take corrective actions immediately if conduits become displaced during concrete placement.
 3. Carefully place and consolidate concrete around individual conduits.
 4. Protect conduits against breakage, damage, or disturbance during placing and consolidating of concrete.
- C. Filling Openings and Box-outs:
1. Fill openings and box-outs in walls with concrete made with non shrink non-ferrous pre-blended hydraulic cement grout, placed under pressure.
 2. Inject epoxy grout at the interfaces if required to make concrete watertight.

3.5 FIELD QUALITY CONTROL

- A. Evaluation and Acceptance of Nonshrink Hydraulic Cement Grout:
1. Provide a flow cone and cube molds with restraining plates onsite. Continue tests during Project as demonstrated by grout manufacturer's representative.
 2. Perform flow cone and bleed tests, and make three 50 mm by 50 mm cubes for each cubic metre of each type of nonshrink grout used. Use restraining caps for cube.
 3. For large grout applications make three additional cubes and one more flow cone test. Include bleed test for each additional cubic metre of nonshrink grout placed.
 4. Consistency: Grout with consistencies outside range requirements will be rejected.
 5. Segregation: Grout when aggregate separates will be rejected.
 6. Tests must show that strength attained by non shrink grout cubes is equal to or greater than minimum strength specified.
 7. Strength Test Failures: Remove and replace non shrink grout work failing strength tests.
 8. Perform bleeding test to demonstrate grout will not bleed.
 9. Store cubes at 21 degrees C.
 10. Independent testing laboratory to prepare, store, cure, and test cubes.
- B. Load Testing of Grouted-in Dowels for Connecting to Existing Concrete:
1. To demonstrate proper installation of grouted-in dowels carry out tension tests on two vertical and two horizontal installations for each size of dowel bar before proceeding further installation.
 2. Apply an axial test load of 75 percent of the yield strength of the dowel bar. Prevent possible failure of the concrete in the vicinity of the dowels tested.
 3. Dowel bar will be considered acceptable if there is no slippage of the dowel bar.
 4. If improper installation procedures are suspected additional load tests may be ordered.

3.6 MANUFACTURER'S SERVICES GENERAL

- A. Coordinate demonstrations, training sessions, and applicable site visits with grout manufacturer's representative.
- B. Provide and conduct onsite, demonstration and training sessions for all measurements, testing, application, and curing for each type and type of nonshrink grout.
- C. Ensure necessary equipment and materials are available for demonstration.
- D. Training:
1. Training is required for all Type II and Type III and epoxy grout installations.
 2. Grout manufacturer's representative to train Contractor to perform grout work.
 3. Establish location at site and schedule time for grout manufacturer's demonstration and training session of proposed nonshrink grouts. Mix nonshrink grouts to required consistency, test, place, and cure on actual Project, e.g., baseplates and tie holes to provide actual on-the-job training.

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4. For nonshrink hydraulic cement grout, use minimum of five bags for each grout Type II and Type III. Mix grout to fluid consistency and conduct flow cone and two bleed tests, make a minimum of six cubes for testing of two cubes at 1, 3, and 28 days. Use remaining grout for final Work.
5. Training to include methods for curing grout.
6. Mix and demonstrate patching through-bolt holes and blockouts for gate guides, and similar items.
7. Transport test cubes to independent test laboratory and obtain test reports.

END OF SECTION