

CW 2160 - CONCRETE UNDERGROUND STRUCTURES AND WORKS**TABLE OF CONTENTS**

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CW 2160 - CONCRETE UNDERGROUND STRUCTURES AND WORKS**1. DESCRIPTION****1.1 General**

- .1 This specification covers the construction of concrete underground structures and works including formwork, reinforcement, sleeves and inserts, water stops, curing, finishing, waterproofing and other related operations.

1.2 Referenced Standard Construction Specifications

- .1 CW 1110 General Instructions
- .2 CW 2030 Excavation, Bedding and Backfill

1.3 Referenced Industry Standards

- .1 ASTM D6103 Standard Test Method for Flow Consistency of CLSM
- .2 CSA A23.1 Concrete Materials and Methods of Construction
- .3 CSA A23.2 Methods of Test for Concrete
- .4 CSA S269.3 Concrete Formwork

2. MATERIALS**2.1 Portland Cement**

- .1 Portland cement: in accordance with CSA A5 A3001 **Type GU/GUL and Type HS/HSL.**
- .2 The Contract Administrator may make random check tests of previously approved cement for compliance with Clause 2.1.1. Replace cement that fails to meet the specified requirements.

2.2 Aggregate

- .1 Aggregate: in accordance with CSA A23.1.
- .2 Grading to be in accordance with the requirements of CSA A23.1.
- .3 Quarried limestone and dolomite will not be acceptable as aggregate.
- .4 Provide the Contract Administrator with the location of sources where aggregate will be obtained to allow for inspection and tentative approval. Obtain approval from the Contract Administrator to change the source of aggregate supply during the course of the Work.

2.3 Supplementary Cementing Materials

- .1 Supplementary cementing materials: in accordance with CSA A3001 Class CI Fly Ash.
- .2 Fly ash must be tested with the cement and comply with the sulphate expansion requirements for **Type HSb/HSLb** blended hydraulic cement in CSA A3001. Limit fly ash content to 25% of cementitious materials except for cement stabilized fill which can have up to 70 kilograms of fly ash in the mix.

- .3 Provide material and testing information for fly ash to the Contract Administrator and obtain written approval before using.

2.4 Water

- .1 Water: in accordance with CSA A23.1 and equal to potable water in physical and chemical properties.

2.5 Admixtures

- .1 Admixtures to be as follows.
 - .1 Air-entraining agent: in accordance with ASTM C260.
 - .2 Water-reducing agent: in accordance with ASTM C494.
 - .3 Other admixtures: in accordance with the Specifications.
 - .4 Obtain approval from the Contract Administrator before using additional admixtures.
 - .5 Admixtures that contain chloride will not be permitted.

2.6 Reinforcing Steel

- .1 Reinforcing steel: in accordance with CSA G30.18 Grade 400W.
 - .1 Stirrups, ties and bar mats up to 10 millimetres in diameter: Grade 400R and 400W plain bars.
 - .2 Chairs, bolsters, bar supports, spacers and accessories: in accordance with CSA A23.1.
- .2 Remove reinforcing steel the Contract Administrator has determined exhibits flaws in manufacture or fabrication. Rust, surface seams, or surface irregularities will not be cause for rejection provided minimum dimensions, cross-sectional area and tensile properties of a hand wire-brushed specimen are not less than requirements of CSA G30.18.

2.7 Water Stops

- .1 Water stops: extruded Polyvinyl Chloride (PVC) in accordance with CGSB 41-GP-35M and the following unless otherwise indicated in the Specifications.
 - .1 Minimum 125 millimetres wide by 9.5 millimetres thick.
 - .2 Multi-ribbed with center bulb.
 - .3 Minimum 12 MPa tensile strength.
 - .4 275% allowable elongation.
 - .5 -45 degree C to 80 degree C working temperature range.

2.8 Curing Compound

- .1 Curing compound: liquid membrane forming compound in accordance with ASTM C309 as approved by Contract Administrator unless otherwise indicated in the Drawings and Specifications.

2.9 Grout and Mortar

- .1 Grout and mortar: one part **Type GU/GUL** cement and one part sand with sufficient water to produce a stiff mortar-like consistency capable of developing a 20 MPa compressive strength after 28 days.

2.10 Bonding Agent

- .1 Bonding agent: in accordance with the Specifications.

2.11 Formwork

- .1 For concrete without special architectural features use Douglas Fir plywood made with waterproof glue specifically manufactured for concrete formwork in accordance with CSA O121.
- .2 For concrete with special architectural features use formwork materials in accordance CSA A23.1.
- .3 For surfaces and rough work that will not be exposed to view use square edge dimension lumber.
- .4 Use other types of formwork in accordance with the Specifications

2.12 Form Ties

- .1 For concrete without special architectural features use removable or snap-off metal ties of fixed or adjustable length free of devices that will leave holes larger than 25 millimetres in diameter in concrete surfaces.
- .2 For Architectural concrete use snap-off ties complete with plastic cones and light grey concrete plugs.
- .3 Use other types of snap-off ties in accordance with the Drawings and Specifications.

2.13 Form Coating

- .1 Form coating to be colourless, non-staining mineral oil free of kerosene compatible with concrete surfaces that will have a permanent finish coating unless otherwise indicated in the Drawings and Specifications.

2.14 Waterproofing

- .1 Waterproofing: to be emulsified asphalt in accordance with CAN/CGSB 37.1 or CANCGSB 37.2 unless otherwise indicated in the Specifications.

2.15 Storage of Materials

- .1 Store materials in accordance with the requirements of CSA A23.1.
- .2 Provide a method of storage to readily permit inspection, sampling and identification of material by the Contract Administrator.

2.16 Concrete Mix Design

- .1 Proportion fine aggregate, coarse aggregate, cement, water, air-entraining agent, and water-reducing agent to yield concrete having required strength, water/cement ratio, slump, air content, cement content and workability in accordance with Table CW 2160.1.

TABLE CW 2160.1 DESIGN REQUIREMENTS FOR CONCRETE USED FOR UNDERGROUND STRUCTURES

Type of Structure or Use	A) Monolithic sewers and reinforced structures.	B) Pipe foundations, skin coats, base blocks, thrust blocks, buttresses and anchors	C) Cement - Stabilized Fill	D) Flowable Cement - Stabilized Fill
Maximum Size of Aggregate (mm)	20	20	20	5
Cement Type	Type HS/HSL		Type GU/GUL	
Maximum Water/Cementing Materials Ratio	0.45	0.45	Not Applicable	
Compressive Strength at 28 days	32 MPa	32 MPa	1.5 to 2.5 MPa	
Slump/Flow	80 +/- 20 mm	100 +/- 30 mm	Not Applicable	200 mm Minimum
Air Content	4 to 7%		Not Applicable	20% Minimum
Minimum Cementing Materials Content	As Required to Meet Specified Compressive Strength			

- .2 Provide a “Mix Design Statement” for each type of concrete to be used certifying constituent materials and mix proportions to the Contract Administrator at least 2 weeks before delivery of concrete to the Site. Supply reasonable evidence to the Contract Administrator that mix proportions selected will produce concrete meeting the specified strength, workability and yield.
- .3 If used, water-reducing agent not to exceed the manufacturer's recommended quantity.
- .4 Do not make changes to approved mix designs without approval of the Contract Administrator.

2.17 Concrete Inspection and Testing

- .1 Inspection and testing of concrete and concrete materials will be in accordance with CSA A23.1 and carried out by a Testing Laboratory designated by the Contract Administrator. Quality control tests for concrete will be used to determine the acceptability of the concrete supplied.
- .2 Provide without charge samples of concrete and constituent materials required for quality control tests and provide assistance and use of tools and construction equipment as is required.
- .3 The frequency and number of concrete quality control tests will be in accordance with the requirements of CSA A23.1.
- .4 Non-destructive methods for testing concrete will be in accordance with CSA A23.2.
- .5 An outline of the quality control testing is as follows.
 - .1 Samples of concrete for test specimens will be taken in accordance with CSA A23.2-1C.
 - .2 Slump tests will be performed in accordance with A23.2-5C. If measured slump falls outside limits specified in Table CW 2160.1 a second test will be made. In the event of a second failure the Contract Administrator reserves right to refuse the batch of concrete represented.
- .6 Air content test will be performed in accordance with CSA A23.2-4C. If measured air content falls outside limits specified in Table CW 2160.1 a second test will be made at any time within the specified discharge time limit for the mix. In the event of a second failure the Contract Administrator reserves the right to reject the batch of concrete represented.
- .7 Compressive strength test specimens will taken in accordance with CSA A23.2-3C.
- .8 Compressive strength tests at 28 days will be the basis for acceptance of all concrete supplied. For each 28 day test the strength of two companion standard-cured test specimens will be determined in accordance with CSA A23.2-9C. Test result will be the average strength of both specimens.

2.18 Shop Drawings

- .1 Submit Shop Drawings for reinforcement in accordance with Specification CW1110.
- .2 Prepare reinforcement drawings in accordance with “Reinforcing Steel Manual of Standard Practice” by the Reinforcing Steel Institute of Canada and include the following information.
 - .1 Bar bending details, lists, quantities of reinforcement, sizes, spacing, locations of reinforcement.
 - .2 Location and details of mechanical splices approved by the Contract Administrator.
 - .3 Identifying code marks to permit correct placement of reinforcement without reference to structural drawings.
 - .4 Sizes, spacing and locations of chairs, spacers and hangers.
 - .5 Detail lap lengths and bar development lengths in accordance with CAN3-A23.3.

3. CONSTRUCTION METHODS

3.1 Excavation

- .1 Excavate for underground structures in accordance with CW 2030.

3.2 Concrete Formwork

- .1 Fabricate and erect concrete formwork in accordance with CSA S269.3 and CSA A23.1. Finished concrete to conform to shape, dimensions, locations and elevations as shown on the Drawings and within the tolerances required by CSA A23.1.
- .2 Ensure sheets and pieces of lumber are of uniform thickness sized to prevent sagging between supports and withstand the action of vibrators. Align form joints to be flush and tight to prevent water and mortar leakage.
- .3 Provide a minimum 25 millimetre fillet at interior corners and a 25 millimetre chamfer at exterior corners.
- .4 Brace, support and tie forms together to prevent displacement and movement during steel reinforcement and concrete placement.
- .5 Thoroughly clean formwork, remove loose particles or dried concrete and coat with non-staining mineral oil in accordance with CSA A23.1 before erecting. Do not use chemicals to remove ice or foreign materials from forms.
- .6 Earth structures will be permitted as formwork for concrete monolithic sewers, Type B) structures as indicated in Table CW 2160.1 and other structures indicated in the Specifications or directed by the Contract Administrator.

3.3 Formed Openings

- .1 Form openings in walls and floors at the locations and to the dimensions shown on the Drawings. Provide water stop and keyway in the face of openings where fill-in concrete will be placed after pipe, frame, fitting or sleeve is installed.

3.4 Fabrication and Placing of Steel Reinforcement

- .1 Fabricate steel reinforcement in accordance with CSA A23.1, ANSI/ACI 315, "The Reinforcing Steel Manual of Standard Practice" by the Reinforcing Steel Institute of Canada and in accordance with the Specifications.
- .2 Obtain the Contract Administrator's approval for steel reinforcement splices at locations other than those shown on the Shop Drawings. Splice laps to be in accordance with CSA A23.3.
- .3 Clearly identify steel reinforcement in accordance with the bar bending details and lists shown on the Shop Drawings.
- .4 Do not field bend or field weld steel reinforcement except where shown on the Shop Drawings or authorized by the Contract Administrator. Bend steel reinforcement without using heat when field bending is authorized. Replace bars that develop cracks or splits.

- .5 Locate and place steel reinforcement as shown on the Shop Drawings and in accordance with CSA A23.1.
- .6 Adequately support and secure steel reinforcement against displacement and maintain the required cover from forms during concrete placing using methods and products in accordance with CSA A23.1.

3.5 Construction and Control Joints

- .1 Form construction and control joints in accordance with CSA A23.1 at the locations shown on the Drawings.
- .2 Obtain approval from the Contract Administrator to place construction and control joints in locations other than where shown on the Drawings. Locate and make approved control joints to least impair strength of structure.

3.6 Sleeves and Inserts

- .1 Cast in sleeves, anchors, frames, conduit, bolts, pipes and other inserts as shown on the Drawings. Obtain approval from the Contract Administrator to install sleeves and openings not shown on the Drawings that are greater than 100 millimetres x 100 millimetres in size.

3.7 Water stops

- .1 Install water stops at the locations shown on the Drawings to provide a continuous water seal.
- .2 Adequately secure water stops against displacement during concrete placing using methods that will not distort, pierce or hamper performance of the water stop or displace the steel reinforcement.
- .3 Overlap water stops and make required field splices using equipment and methods recommended by the manufacturer.

3.8 Supply and Placing Concrete

- .1 Provide 24 hours notice to the Contract Administrator before placing concrete to allow inspection and approval of steel reinforcement placement.
- .2 Supply concrete from a ready-mixed concrete plant unless otherwise indicated in the Specifications or approved by the Contract Administrator. Concrete up to 0.5 cubic metres in volume may be hand mixed on site as approved by the Contract Administrator.
- .3 Produce and deliver concrete to the Site in accordance with CSA A23.1 except transporting of ready-mixed concrete in non-agitating equipment will not be permitted without written permission from the Contract Administrator.
- .4 Preheat concrete aggregate and water when placing concrete at or below a temperature of 5°C or if the temperature will fall below 5°C within 24 hours after placing concrete.

- .5 Place ready-mixed concrete within 1 1/2 hours after introduction of mixing water to cement and aggregates unless the Contract Administrator approves an extension of time.
- .6 Provide delivery tickets showing time of batching to the Contract Administrator before placing concrete.
- .7 Add up to a maximum of 12 litres of additional water per cubic metre of concrete after initial mixing provided the measured slump of the concrete is less than specified in Table C 2160.1 and no more than 60 minutes have elapsed from the time of batching. Rotate the mixer drum a minimum of 30 revolutions at mixing speed after adding additional water.
- .8 Place concrete in accordance with CSA A23.1 and additional requirements indicated in the Specifications.
- .9 Allow the Contract Administrator to test the slump and air content before concrete is placed.
- .10 Have the necessary equipment needed for adequate curing of the concrete on hand and ready for use before concrete placement begins.
- .11 Remove excess water from excavations before placing concrete.
- .12 Ensure reinforcement, forms and ground which concrete will come in contact with are free of frost.
- .13 Place concrete at a rate that concrete remains plastic and flows readily into spaces between reinforcement. Concrete that has partially hardened or been contaminated by foreign material will not be allowed to be placed.
- .14 Convey concrete as rapidly as possible from the mixer to final placement using methods that will prevent separation and loss of materials.
- .15 Limit concrete free fall drop distance to not more than 1.5 metres. Use spouts or chutes approved by the Contract Administrator to place the concrete to prevent segregation of the concrete when free fall drop distance is greater than 1.5 metres.
- .16 Use internal vibrators in accordance with CSA A23.1 to consolidate concrete placement. Do not use vibrators to move concrete. Form vibrators may be used when sections are too small for internal type of vibrator. Maintain at least one extra vibrator on site. Do not disturb concrete that has become too stiff to regain plasticity when vibrated. Do not apply vibration directly to steel reinforcement that extends into partially hardened concrete.
- .17 Prepare existing concrete surfaces in accordance with CSA A23.1 where placing new concrete against existing concrete and apply approved bonding agent in accordance with manufacturer's recommendations.
- .18 Thoroughly clean and wire brush exposed steel reinforcement surfaces of laitance, foreign matter and loose particles where existing steel reinforcement is to extend into new concrete.

3.9 Curing and Protection of Concrete

- .1 Cure and protect concrete in accordance with CSA A23.1 and any additional requirements of the Specifications. Do not use curing compounds when a bond is required for subsequent topping or coating.
- .2 Apply curing compound in accordance with manufacturer's recommendations. Completely coat and seal surface in one application.
- .3 Maintain freshly placed concrete and surrounding air at a temperature of at least 10° C for a period of 5 days after placing concrete in cold weather.
- .4 Provide heating equipment as necessary to maintain the required air temperature in accordance with the following.
 - 1 Use heating equipment that is not direct-fired.
 - 2 Provide a chimney for venting heating equipment.
 - 3 Locate heating equipment in a manner that will not endanger formwork or expose areas of concrete to drying out or other damage due to excessively high temperatures.
 - 4 Apply heat continuously and uniformly for the required length of time.

3.10 Removal of Concrete Formwork

- .1 Leave formwork in place until concrete has attained sufficient strength to adequately support its own weight and the construction loads likely to be applied. Remove forms for vertical surfaces no sooner than 24 hours after placing concrete provided the curing procedure in Section 3.9 of this specification is followed.
- .2 Notify the Contract Administrator once the forms are removed for an inspection of the concrete surfaces. Provide a remedial work plan to the Contract Administrator for approval for repairing, recasting or repointing of damaged and broken concrete and surface imperfections identified in the inspection.

3.11 Concrete Finish

- .1 Finish formed surfaces of underground structures in accordance with CSA A23.1 and as follows.
 - .1 Interior walls and exterior walls not exposed to view to have a rough-form finish.
 - .2 Above grade portions exposed to view to have a smooth form finish.
- .2 Perform additional surface finish requirements in accordance with the Specifications.
- .3 Float and screed top surface of slabs to profile and elevation in accordance with the Drawings. Sprinkling or dusting the surface with a dry mixture of cement or sand will not be permitted.
- .4 Surface finishing of Type B) Structures listed in Table CW 2160.1 will not be required.

3.12 Waterproofing

- .1 Waterproof the exterior surface of underground structures below grade in accordance with CAN/CGSB 37.3 and the waterproofing compound manufacturer's recommendations.

3.13 Corrective Action for Concrete Not Meeting Strength Requirements

- .1 Perform one or more of the procedures outlined in CSA A23.1 as directed by the Contract Administrator if test results indicate concrete does not meet the strength requirements specified in Table CW 2160.1.
- .2 Replace or strengthen those portions of the structure in a manner acceptable to the Contract Administrator that after performing the procedures outlined in CSA A23.1 still do not meet the specified strength requirements.

4. MEASUREMENT AND PAYMENT

4.1 Construction of Concrete Underground Structures

- .1 Construction of concrete underground structure including formwork, steel reinforcement, sleeves and inserts, water stops, placing concrete, curing, finishing, waterproofing and related operations will be measured on a unit basis and paid for at the Contract Unit Price for "Concrete Underground Structure" of the type listed in the Schedule of Prices. The number of units to be paid for will be the total number of concrete underground structures constructed in accordance with this specification, accepted and measured by the Contract Administrator.

4.2 Concrete Testing

- .1 Initial concrete testing performed in accordance with Section 2.17 of this specification will be paid for by the City.
- .2 Additional concrete samples taken and testing performed in accordance with Section 3.13 of this specification for portions of concrete underground structures failing to meet the specified strength requirements will be at own expense.

4.3 Corrective Action for Concrete Not Meeting Strength Requirements

- .1 Corrective action taken to replace or strengthen portions of concrete underground structures failing to meet the specified strength requirements will be at own expense.