Section W - Construction Specifications

Scope

This section provides directions, procedures, materials and equipment requirements that BC Hydro considers necessary for completing the work specified in other sections of the ES54 Standards. It provides descriptions of the quality of material, processes and workmanship required to complete the work specified in other sections.

It also serves as a basis for the civil construction work provided to BC Hydro for underground distribution facilities, either by a BC Hydro contractor or customer. It is developed to be part of the contract documents, which also include the agreement forms, general conditions, scope of work, class of work, drawings, etc. Any site specific requirements should be provided in the drawings and specification appendix of the contract. The information contained in the contract should be complementary with this section with no duplication or overlap between these documents.

Construction Specifications

These standards are based on minimum quality requirements specified for each class of work. The specifications consist of two separate functions — quality control and acceptance. Quality control is a contractor's process control that consists of inspection, sampling and testing necessary to assess and adjust the construction process. Quality control ensures and documents that the final product shall meet the required quality. Acceptance consists of visual inspections, document review, sampling and testing necessary to determine the degree of quality for final acceptance. Quality control is provided by the Contractor and accepted by BC Hydro at pre-determined construction stages of the Work (hold points).

For customer projects, quality control and acceptance are provided by the customer. The customer is responsible for the final product quality, and BC Hydro either accepts or rejects the final product. BC Hydro requires the customer to take entire responsibility for supply fabrication, construction and quality of the final product.

Interpretations

Any reference to “these Standards” shall mean the ES54 series standards.

To ensure consistency and uniformity with the Contract documents, cross-reference abbreviations and capitalized terms used in these Standards are defined in the Definitions section of the Contract General Conditions.

DESIGNED	RECOMMENDED	ACCEPTED	ENGINEER OF RECORD	CONSTRUCTION SPECIFICATIONS GENERAL INTERPRETATIONS	
S. ABBAS	L. STEVANOVIC	F. DENNERT	PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA S. H. ABBAS # 33329 2017-02-24		
DISTRIBUTION STANDARDS BC Hydro	ISSUED:MAR 2016 REPLACES:N/A ORIGINALLY ISSUED: MAR 2016			PAGE 1 OF 1	ES54 W0-03 R 0

REVISIONS:

Definitions

Notwithstanding any cross-referenced definitions as provided in the Contract General Conditions, the following definitions apply to these Standards:

ABCLS: Association of British Columbia Land Surveyors.

APEGBC: Association of Professional Engineers and Geoscientists of British Columbia.

Authority Having Jurisdiction (AHJ): Any governmental, federal, provincial, municipal, crown, Aboriginal (First Nations) agency or sub-agency that has legal jurisdiction over the project and/or regulates the construction process for the project. In most cases, the AHJ is the municipality in which the project is located. Where the project includes construction on streets or highways under the jurisdiction of the Province of B.C., the AHJ is the B.C. Ministry of Transportation and Infrastructure (MoTI). Where the project includes construction that can affect a railway or a pipeline, the AHJ is the applicable railway authority, or the corporation that owns or operates the pipeline.

Design: Drawings, plans, calculations, specifications and other material produced by the Professional of Record or Designer necessary to define the Work.

Designer: A person having adequate qualifications, training and experience to apply BC Hydro Distribution standards and provide Design on behalf of BC Hydro.

Customer: An entity responsible for the design and construction of underground residential distribution (URD) electrical infrastructure for primarily residential work on private property.

Design Build External Service Provider (DB ESP): Consulting firm approved by BC Hydro to provide engineering and construction management services to the Customer.

Engineering Service Provider (ESP): Consulting firm retained by BC Hydro to deliver engineering and/or construction projects.

Engineers and Geoscientists British Columbia (EGBC) - The Association of Professional Engineers and Geoscientists BC (APEGBC)

Final Design and Record Drawing – means Final Design and Record Drawings as defined in APEGBC Guidelines for Professional Structural Engineering Services for Part 3 Building Projects.

> **Final Design Drawings**: *"Design drawings prepared by a registered professional to reflect design changes made during construction of a building project. These drawings are intended to incorporate addenda, change orders and other significant design changes, but not necessarily site instructions."*
>
> **Record Drawings: "***Drawings prepared as a record to confirm what was constructed. The types of information provided vary, but can include measurements, elevations and sizes. They are typically prepared by a general or sub-contractor. They can be signed, sealed and dated by a member retained by a general or sub-contractor, but are typically not signed,*

sealed or dated by the registered professional responsible for the particular aspect of the design reflected in the drawings, unless provided for in their contractual obligations."

Limits of Excavation: The location and three-dimensional shape (depth, length and width) of any trench or excavation as shown in the construction issue Design, or otherwise required for the performance of the Work. BC Hydro's Representative may change the Limits of Excavation.

Plant: Any structure or thing constructed, manufactured, or installed in accordance with the Design, and not including any structure or thing of a temporary nature.

Professional Land Surveyor (PLS): A Professional Land Surveyor who is a registered member in good standing as regulated by the ABCLS.

Professional of Record (POR): A Professional Engineer responsible for the Design, or a specific portion of the Design, practicing in an appropriate discipline, and whose seal appears on the Design. The POR is responsible for ensuring that the Design (including any changes made during construction) meets applicable Design standards and that the Work constructed substantially comply with the Design and the construction standards.

Standards: Design requirements, specifications, reference documents and other technical requirements for the Design.

The following standards shall apply, including amendments published thereto.

CSA (Canadian Standards Association)

CAN/CSA A3000, Cementitious Materials Compendium

CSA A23.1, Concrete Materials and Methods

CAN/CSA A23.2, Methods of Tests and Standard Practices for Concrete

CAN/CSA A23.4, Precast Concrete — Materials and Construction

CAN/CSA A660, Certification of Manufacturers of Steel Building Systems

CSA-A23.5-M, Supplementary Cementing Materials

CSA A176 Masonry Standards

CSA A179 Mortar and Grout for Unit Masonry

A283 Quality Code for Concrete Testing Laboratories

A371, Masonry Construction for Buildings

CSA C22.2 No. 211.1 and 211.2 Rigid Types PVC Conduit

CAN/CSA G30.5, Welded Steel Wire Fabric for Concrete Reinforcement;

CAN/CSA G30.18, Billet-Steel Bars for Concrete Reinforcement

CAN/CSA G40.21, General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel

CAN/CSA G189, Sprayed Metal Coatings for Atmospheric Corrosion Protection

O80 Series, Wood Preservation

CAN/CSA-S269.1 and S269.3. Concrete Falsework and Formwork Standard

S304.1, Design of Masonry Structures

W59, Welded Steel Construction

W186-M Welding of Reinforcing Bars in Reinforced Concrete Construction

CPCI (Canadian Precast Prestressed Concrete Institute)

Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete

AASHTO (American Association of State Highway and Transportation Officials)

M 306 Standard Specifications for Drainage, Sewer Utility, and Related Casting

ASTM International (American Society for Testing and Materials)

A 36/A 36M Standard Specification for Carbon Structural Steel

A 153/A 153M Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 276 Standard Specification for Stainless Steel Bars and Shapes

A 325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 490 Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength

A 653/A 653M Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

C478 Standard Specification for Precast Reinforced Concrete Manhole Sections

C990 Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants

C1244 Standards for Negative Pressure Tests for Manholes

D1557 Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (Modified Proctor)

D2922 Density of Soil and Soil-Aggregate in Place by Nuclear Methods

Application

This standard describes excavation and backfill construction materials.

Revision Notes

Added *Application*, *Revision Notes*, and *References* sections. Updated values in Table 1 column 'MMCD granular base type 2'. Substantive changes are marked by green vertical revision lines in the left margin.

References

External Documents

ASTM C88	Standard Test Method for Soundness of Aggregates by use of Sodium Sulfate or Magnesium Sulfate
ASTM C117	Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C136	Standard Test Method for Seive Analysis of Fine and Coarse Aggregates
ASTM D1557	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
ASTM D2419	Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate
ASTM D6928	Standard Test Method for Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
CSA A23.2	Test Methods and Standard Practices for Concrete
CSA-A3000	Cementitious Materials Compendium (contains content from former CSA-A5 Portland Cement)

Notes

1. Excavation

The excavation shall be to the lines, grades, elevations, and dimensions specified in the drawings, and shall not be larger than is reasonably necessary to install the structures and equipment. Sloughing of the trench sides shall be avoided. The width of the trench shall not increase as the trench gets deeper.

The distance from a pavement cut to the edge of the trench shall be at least 150 mm, or sufficient to ensure the pavement shall not be undermined by the excavation. During removal or replacement of any existing curb, gutter, or sidewalk, the edges of the work shall be saw-cut to provide a clean and even joint.

Soft yielding or unsuitable materials at the bottom of the excavation shall be removed to a depth satisfactory to BC Hydro's representative. Extreme care shall be taken not to disturb the bottom of the excavation unless unsuitable materials are discovered. If the base of the excavation is disturbed, a minimum depth of 150 mm aggregate shall be placed and compacted. Irregularities and cavities in the base of the excavation shall be levelled at a tolerance no greater than ±25 mm.

Designed: L. Stevanovic, P. Eng		Professional of Record EGBC Permit 1002449 PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA L. STEVANOVIC 2024-01-29	Construction Materials Excavation and Backfill
Checked: L. Stevanovic, P. Eng			
Reviewed: H. Giesbrecht, P. Eng			DISTRIBUTION STANDARDS BC Hydro / ES54 W1-01 R2
Approved: H. Giesbrecht, P. Eng		Issued: 2024-01-29 Effective: 2024-01-29	

2. Common Excavation

Common excavation shall include such materials as are commonly called earth, pavement, loam, silt, ashes, debris, clay, sand, gravel, hardpan, muck, gumbo, boulders, fractured rock that can be removed by ripping, till, frozen materials and boulders each less than 1 m^3 in volume, and all other materials of every description not defined as “rock excavation.” Common excavation shall include disposal of all surplus excavated materials.

3. Rock Excavation

Rock is defined as any sound or solid mass material including but not limited to solid formations of dense homogeneous sedimentary, igneous, or metamorphic material in excess of 1 m^3 of such hardness and texture that, in the judgement of BC Hydro’s representative, cannot be effectively loosened or broken down by mechanical ripping equipment (with a minimum drawbar pull of 360 kN) and that requires breaking by continuous drilling, blasting, or wedging for removal.

Breaking and removal of road or sidewalk pavements or frozen material, regardless of thickness, shall not be considered rock excavation.

4. Backfill Material

Backfill means approved material used to fill the excavation and provide uniform support for the structures and base for traffic surface construction. Backfill material shall be selected native material, aggregate material imported from a source acceptable to BC Hydro’s representative, or consolidated density fill, as applicable.

Unless otherwise specified in this standard, backfill material complying with the authority having jurisdiction requirements and accepted by BC Hydro’s representative may be used from the elevation 300 mm above the BC Hydro duct bank and below the finished grade.

4.1 Aggregate

Aggregate shall be granular material from a source accepted by BC Hydro’s representative and composed of inert, clean, tough, durable, highly angular, 100% mechanically crushed fragments, with two or more fractured faces having a rough surface texture and capable of withstanding the deleterious effects of exposure to water, freeze-thaw, handling, spreading, and compacting. It shall be uniform in quality and free from an excess of flat or elongated particles, wood, shells, coatings of clay, or any other deleterious material.

Aggregate gradation shall be determined in accordance with ASTM C136 and, for material passing the 0.075 mm sieve, ASTM C117. Gradations shall fall within the limits for the specified classification, as shown in Table 1.

Table 1 – Aggregate gradation

Sieve opening size (mm)	Present passing by weight (%)					
	MOTI open graded base (OGB)	MMCD granular base type 1	MMCD granular base type 2	MMCD pipe bedding	MMCD pit run sand	Coarse drain rock
25.0	100	-	100	100	-	100
19.0	75–100	100	80–100	90–100	-	0–100
12.5	-	75–100	-	65–85	100	-
9.50	30–65	60–90	50–85	50–75	-	0–5
4.75	5–30	40–70	35–70	25–50	35–100	-
2.36	0–10	27–55	25–50	10–35	20–70	-
1.18	-	16–42	15–35	6–26	13–50	-
0.600	-	8–30	-	3–17	8–35	-
0.300	0–8	5–20	5–20	-	5–25	-
0.150	-	-	-	-	2–15	-
0.075	0–5	2–8	0–5	0–5	0–6	-

Table definitions:
MOTI: BC Ministry of Transportation and Infranstructure
MMCD: Master municipal contract documents
MMCD pit run sand: Clean well-graded or crushed aggregate. If maximum particle size is restricted to 4.75 mm by the authority having jurisdiction, use pit run 100% passing 4.75 mm sieve and meeting other gradations.
Coarse drain rock: Highly permeable, clean, round stone or crushed rock

Table 2 – Aggregate acceptance

Test description	Test methodology	Minimum test frequency	Acceptance criteria
Sieve analysis	ASTM C136 and ASTM C117 for 0.075 mm sieve	1 per 1000 m^3 for each type of backfill material	Generally uniform gradations within the limits in Table 1
Sand equivalent	ASTM D2419		Equal to or greater than 40
Laboratory compaction	ASTM D1557		Meets gradation requirements
Micro-Deval loss factor	ASTM D 6928		Equal to or less than 25%
Soundness	ASTM C88		Loss after five cycles is less than 20% (25% for 4.75 mm)
Rut resistance	Rolled with a fully loaded tandem axle truck		Shall not rut

4.2 Selected Native Material

Selected native material is the material removed from an excavation and accepted by the BC Hydro representative for return to the same excavation as backfill material. Selected native material shall be granular material free from frozen lumps, ashes, refuse, vegetable, organic or foreign matter, granular material over 100 mm in any dimension, or other deleterious materials. Native material is not acceptable if it is impracticable to control its water content or to compact to the specified density.

Selected native material shall be separated from unsuitable excavated material.

4.3 Controlled Density Fill

Controlled density fill (CDF) is low strength concrete material used for pipe bedding and backfilling. It is composed of water, Portland cement, fine aggregate, and air entraining admixture. Portland cement shall be type 10 in accordance with CSA A5. To allow future excavation, CDF compressive strength at 28 days shall be below 1 MPa. Air entrainment shall be 4% to 6% and slump 150 mm to 200 mm. Material sampling and testing shall comply with CSA A23.2.

CDF shall be placed in lifts to prevent the pipes from floating. Internal vibration or compaction is not needed to consolidate mixtures. Its flowability and weight are sufficient for consolidation.

4.4 Lightweight Fill

Lightweight fills include but are not limited to expanded polystyrene (EPS, also known as extruded polystyrene, Styrofoam™, GeoFoam™, and other trade names), pumice; cellular lightweight concrete (e.g. Cell-Crete™), lightweight expanded clay aggregate, and wood waste (hog fuel). Lightweight fills restrict heat dissipation and are not permitted in the area adjacent to and above the duct banks.

5. Backfill Construction

Backfill material shall be placed uniformly and compacted in lifts not exceeding 200 mm loose thickness. Frozen material shall not be used as backfill, shall not be placed on frozen ground, and shall be compacted in dry conditions.

Backfill shall extend a minimum 150 mm below the base of the structure and duct bank. All irregularities and cavities in the base shall be properly backfilled, compacted, and levelled at a tolerance no greater than ±10 mm. The contractor shall not proceed with further work until the bottom of the excavation and prepared base have been inspected and accepted by BC Hydro's representative. No structure shall be placed where the base of the excavation is not a suitable material.

Any soft areas or materials deemed inappropriate by BC Hydro's representative encountered at the bottom of the excavation shall be excavated and replaced with appropriate material.

Table 3 – Backfill compaction acceptance

Location	Modified proctor corrected compacted dry density (%)
Non-traffic area (where the distance from excavation to roadway, sidewalk, curbs, walls, or structures is greater than the excavated depth, otherwise section (b) below shall govern) except within 300 mm depth above feeder duct bank	85%
All other areas and within 300 mm depth above feeder duct bank	95%

The contractor shall provide test results of gradation, compaction, and thermal resistivity, if applicable, to BC Hydro's representative for acceptance.

Blasting

Qualifications and Experience of Contractor: The Contractor shall provide a statement of the qualifications, experience and work function of all personnel assigned to drilling and blasting duties, and a statement of previous work experience on similar projects. This statement shall include the project name, location, volume of rock, year constructed and the owner/client contact name. The company, the driller and the blaster shall each demonstrate a minimum of five consecutive years of experience in drilling and controlled blasting work on at least three projects.

Blasting Consultant: The Contractor shall retain a blasting consultant, acceptable to the Ministry's Representative, to provide quality control. The consultant shall not be an employee of the Contractor, explosives manufacturer or explosives distributor. The blasting consultant shall demonstrate a minimum of five consecutive years of experience in preparing successful blast designs on at least three projects.

Vibration Specialist: The Contractor shall retain a vibration specialist to provide blast vibration monitoring if required. The specialist shall not be an employee of the Contractor, explosives manufacturer or explosives distributor. The vibration specialist shall demonstrate a minimum of five consecutive years of experience in the field of vibration monitoring for at least three projects.

Permits and Regulations: The Contractor shall obtain all necessary permits and shall comply fully with the laws, rules and regulations of municipal, provincial and federal agencies related to the use, transportation, storage and handling of explosives. The Contractor is responsible for preparing and submitting a suitable blasting plan, and for obtaining approval for the blasting plan, as required by the appropriate authorities. The Contractor shall submit the final approved blasting plan to BC Hydro's Representative at least five business days prior to the start of blasting, for review and acceptance.

Pre-Blast Survey: The Contractor shall conduct a pre-blast survey a minimum of one day before blasting operations commence. The pre-blast survey shall include a complete description of the existing condition of any nearby buildings, structures, wells and utilities that potentially may be damaged by blasting operations. The survey method used shall be acceptable to the Contractor's insurance company.

Before doing any blasting, the Contractor shall ascertain whether there are, in the neighbourhood, any railway, power or other lines, or water or other pipes, etc., which are likely to be in danger of being damaged. The Contractor shall give the AHJ timely notice of the intention to blast in accordance with their requirements.

Supporting Rock: The Contractor shall exercise care and use appropriate methods to prevent breaking, loosening or otherwise damaging supporting rock below the designed hole base and the bottom of the trench. The Contractor shall be responsible for the methods used and for any damage to the rock structure resulting from the operations.

Vibration Control Records: As required, the Contractor shall provide all seismograph records of vibration monitoring and interpretation of results within one day after each blast.

Structural Steel

Structural steel shall conform to CSA G 40.21, grade 350 W. The steel fabricator shall be certified by the Canadian Welding Bureau to CSA W59. Welding operators shall be certified by the Canadian Welding Bureau or the American Welding Society to the requirements of CSA Standard W47.1 Division 3 or W47.2 or AWS Code, as applicable.

Steel Hardware and Inserts

Steel hardware shall conform to CSA G40.21. Steel welding shall conform to CSA W59. All steel hardware shall be hot dip galvanized after complete fabrication, in accordance with CAN/CSA G164. Any steel hardware damaged in galvanized coatings prior to concrete casting shall be replaced. Steel coating damaged after concrete casting shall be repaired by sandblasting to “near white” and repaired in accordance with CSA G189. The zinc coating thickness shall not be less than 0.3 mm.

Inserts and lifting devices shall be Dayton Superior Utility, or an equivalent acceptable to BC Hydro. Pulling irons shall be Dayton Superior Utility Anchor P75. Lift anchors shall be embedded in the floor of the vault.

Cable support channels shall be UNISTRUT P-3270, or an equivalent acceptable to BC Hydro. The channels shall be embedded into the concrete as shown in the standard drawings.

Geotextiles

Geotextiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect or drain. They shall be specified by a geotechnical engineer as mitigation measures against common geotechnical issues with respect to BC Hydro facilities, such as construction of facilities on soft soils, excessive settlement of ducts or vaults, erosion and sediment controls, drainage, containment, slope reinforcement, etc.

A non-woven geotextile shall be provided between different backfill materials as a permeable separator, to prevent migration of fine particles and to allow the passage of water while retaining the in-situ soil without clogging. The geotextile material shall conform to the physical requirements as shown in the table below.

Properties	ASTM	Acceptance
Grab tensile strength and elongation	ASTM D4632 ASTM D4632	800 N 50%
California Bearing Ratio (CBR) puncture	ASTM D6241	2000 N
Trapezoidal tear	ASTM D4533	300 N
Apparent opening size	ASTM D4751	0.25 mm
Water flow permittivity	ASTM D4491 ASTM D4491	4000 l/m/m2, & 1.5 sec-1
Ultraviolet resistance	ASTM D4355	70% @500 hrs

Application

This standard applies to cast-in-place concrete construction of distribution structures. Product-specific requirements are specified in the relevant product standards. In case of conflict the requirements in the relevant product standards shall apply.

This standard contains commentary and explanations on interpreting technical requirements.

Revision Notes

Updated references. Added information on test strength results to note 1. Removed curing type from Table 1. Added information on volumetric and bagged mix to notes 1 and 2 and Tables 4 and 5. Changed time from seven business days to two weeks in note 3. Simplified note 6 on general use limestone cement. Removed reference to ASTM C1017/C1017M from note 7. Updated note 12 to remove three day minimum. Substantive changes are marked by green vertical revision lines in the left margin. This revision released concurrently with Standards and Equipment Advisory 2026-012 *Revised ES54 W1-05 Construction Materials Concrete*.

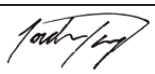
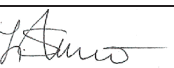
References

BC Hydro Distribution Standards

ES54 H0-02	Duct General Notes

External Documents

ASTM C387/C387M	Standard Specification for Packaged, Dry, Combined Materials for Concrete and High Strength Mortar
ASTM C881/C881M	Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
ASTM C260/C260M	Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C494/C494M	Standard Specification for Chemical Admixtures for Concrete
ASTM C1064	Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C685/C685	Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing
ASTM D648	Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
CSA A23.1/A23.2	Concrete materials and methods of concrete construction / Test methods and standard practices for concrete
CSA A23.4	Precast concrete – Materials and construction
CSA A283	Qualification code for concrete testing laboratories
CSA A3000	Cementitious materials compendium
CSA G30.18	Carbon steel bars for concrete reinforcement
CSA S269.1	Falsework and formwork
CSA S269.3	Concrete Formwork
BC Workers Compensation Act	

Designed: J. Yang, P.Eng		Professional of Record 	Construction Materials Concrete	
Checked: J. Yang, P.Eng				
Reviewed: L. Stevanovic, P.Eng				
Approved: H. Giesbrecht, P.Eng		Issued: 2026-05-22 Effective: 2026-05-22	DISTRIBUTION STANDARDS BC Hydro	ES54 W1-05 R7

Notes

1. Materials

Concrete shall comply with CSA A23.1/A23.2 and Table 1.

Volumetric mix concrete may be used for duct elbows, pilasters, and non-structural duct banks. Volumetric mix concrete shall be defined as concrete produced by volumetric batching and continuous mixing of ingredients in a mobile mixer at the point of delivery. The cement, aggregates, water, and admixtures are stored separately and proportioned by volume per mix design to produce fresh concrete.

See ES54 H0-02 for bagged concrete mix. Bagged concrete mix shall meet the requirements of ASTM C387/C387M.

Table 1 – Concrete requirements

Property	Structurally reinforced concrete	Other structures
Class of exposure	C1	F2
Air content category	1	2
Compressive strength at 28 days	35 MPa	25 MPa (see table note 1)
Table note 1. Concrete for duct bank encasement shall have individual strength test results between 21.5 MPa and 28.5 MPa.		

Concrete temperature from the time of batching to complete discharge shall remain between 10°C and 25°C.

2. Certification

The ready-mix concrete supplier shall be certified with Concrete BC or an equivalent acceptable to BC Hydro. The volumetric-mix concrete supplier shall have their trucks certified with Concrete BC. Field test personnel shall be certified in accordance with CSA A23.1/A23.2. Laboratory testing shall be carried out by a testing laboratory certified in accordance with CSA A283.

3. Mix Design

The correct proportions of concrete admixtures shall be determined by trial mixes and adjusted to suit the placing conditions. The concrete mix design for ready-mix and volumetric mix concrete shall be submitted to BC Hydro for acceptance at least two weeks before concrete placement. At a minimum, the concrete mix design submittal shall include:

a. Proposed supplier name and location;
b. Distance and expected travel time from the batch plant location to the site;
c. Expected method of batching, transporting, and placing concrete;
d. Admixtures type and source, including expected dosage rates, point of addition to the mix, compatibility documentation, and individual technical data sheets;
e. Concrete proportions including water to cementing materials ratio, air content, slump, and maximum aggregate size; and
f. Certified quality control testing laboratory and certified testing personnel names and contact information.

Trial mix test results shall be provided for information and shall include:

a. Setting time;
b. Temperature development; and
c. Strength.

4. Delivery Tickets

The concrete supplier shall provide delivery tickets with the following information, as applicable, before unloading each truck:

a. Batch plant name and location;
b. Ticket date and serial number;
c. Contractor name;
d. Truck driver identification;
e. Job designation (name and location);
f. Exposure class and concrete mix identification;
g. Concrete volume in cubic metres;
h. Truck number, cumulative total, or load number;
i. Time stamped when loaded or cement and aggregate first mixed; and
j. Ordered slump or slump flow and air content.

The following shall be written on the delivery ticket after concrete discharge:

a. Time load arrived on site;
b. Time load discharge was started;
c. Time load discharge was completed;
d. Water amount added after batching and units used;
e. Admixture amount added after batching;
f. Testing and inspection company and on-site personnel performing the inspection, if available;
g. Test location, if available; and
h. Slump or slump flow and air content test results, if available.

5. Reinforcement

Reinforcement shall conform to CSA G30.18-09 (R2019). Mill certificates including physical and mechanical characteristics shall be provided. Reinforcement is usually shipped to the site in bundles marked with tags. The contractor shall verify each shipment has been mill certified, has the specified grade and size, and is not damaged or excessively rusted. A light coating of rust is acceptable as it improves bonding to concrete. A heavy rust coating with flakes or scales that fly off when the bar is bent or struck with a hammer should be removed. Reinforcement shall be stored in clean dry condition protected from debris, oil, and mortar.

Epoxy coated rebar is not allowed.

Reinforcement bars shall be supplied precut and bent to the shapes shown in the design. Bars shall not be field bent. Reinforcement shall be accurately placed, and intersecting bars shall be tied at alternate intersections with steel wire to form a rigid cage or mat that maintains its shape and position both before and during concrete placing. Sufficient supporting devices shall be used to ensure the correct concrete cover. Continuous bars shall not be spliced unless they are greater than standard mill lengths. Splices shall be staggered so no more than one-third of the reinforcing steel in a member shall be spliced in any transverse section. Lap splice lengths are specified in the design drawings.

Concrete framework and other fixtures shall be accurately fixed in position before pouring.

6. Portland Cement

Cement shall conform to the requirements of CSA A3000-18 type GU (general use) or GUL (general use limestone).

Concrete with a minimum section thickness greater than 1000 mm shall have temperature controls per CSA A23.1 clause 5.2.5.4 *Temperature control*. The methods used for maintaining temperature controls shall not exceed the specified water-to-cementing materials ratio.

7. Admixture

The use and choice of concrete admixtures shall be subject to advance acceptance by BC Hydro. The expense of using admixtures shall be borne by the customer. Chemical admixtures shall conform to ASTM C494/C494M.

Air-entraining admixtures shall conform to the requirements of ASTM C260/C260M.

Fly ash shall comply with CSA A3000 for type F and shall not exceed 30% rate by mass of cementitious material.

Water-reducing admixtures may be used to achieve the required slump. Type and dosage of water-reducing admixtures shall be reported in the mix design.

8. Construction Joints

Construction joints shall be provided at locations indicated in this standard. Before fresh concrete is placed against hardened concrete at construction joints, the joint surface of the hardened concrete shall be well roughened and cleaned by removing loose and soft material and laitance. Construction joints shall be bonded with a water-cement slurry or epoxy-type bonding agent conforming to ASTM C881/C881M, applied in strict accordance with the manufacturer's specifications. Slurry shall have a water-to-cementing materials ratio equal to that of the concrete being placed and shall be brush-applied to a 3 mm to 5 mm thickness over the entire joint surface within five minutes of placing new concrete.

9. Falsework and Formwork

Falsework and formwork shall be designed, supplied, installed, and removed in accordance with CSA S269.1 and S269.3. Falsework and formwork shall be built to the full length and height of the concrete structure. Forms shall be designed and built mortar-tight and of sufficient rigidity to prevent distortion due to the pressure of vibrated concrete and other loads incidental to the construction operation. Falsework and formwork shall be completely removable, and no stay-in-place formwork shall be permitted.

10. Placing

Concrete shall be discharged and placed within 120 minutes after initial mixing. BC Hydro may accept the use of set retarders or hydration stabilizers to extend discharge time.

Water and debris shall be removed from foundations and forms before any concrete is placed. Concrete shall be poured in approximately uniform horizontal layers as near as practicable to its final position to avoid rehandling.

Concrete shall be constructed using internal mechanical vibrators. A minimum of two vibrators shall be used for each concrete placing member and a maximum of 8 m^3 concrete shall be placed per one vibrator within 15 minutes. Vibrators shall be 30 mm to 60 mm in diameter with 150 Hz to 225 Hz frequency for walls and slabs 200 mm to 300 mm thick. The vibrator shall be inserted vertically and shall not be inserted between the reinforcing steel and formwork or directly onto the reinforcing steel.

The top surface of the concrete slab shall be finished smoothly after consolidation using a strike-off steel bar.

Table 2 – Construction tolerances

Dimension	Structural concrete	Non-structural duct bank concrete
General dimensions	CSA A23.1, clause 6.4.6	
Plumb variation	1:400 but less than 30 mm	1:10 but less than 100 mm
Slope variation of exposed surface	2.5%	
Reinforcement spacing	± 30 mm	N/A
Reinforcement cover	± 12 mm but less than 30% cover depth	N/A
Duct plugs spacing	± 6 mm	
Duct plugs out of line	± 6 mm	

Dimension	Structural concrete	Non-structural duct bank concrete
Slab on grade thickness	Not less than 10 mm	N/A
Formed slab wall thickness	± 8 mm	N/A
Duct bank cross section	± 12 mm	+100mm

11. Water Addition on Site

As concrete temperature increases there is a loss in slump that is often compensated for by adding water to the concrete at the job site. A greater amount of water is required to hold slump constant at higher temperatures than at lower temperatures.

Water may be added at the start of discharge when the following conditions are met:

a. Specified water-to-cementitious materials ratio is not exceeded;
b. No more than 14 L/m^3 or 10% of mixing water shall be added;
c. Measured slump is less than that specified;
d. Mixer drum shall be turned at maximum speed for minimum 30 revolutions;
e. No more than 60 minutes have passed after water and cement have been combined; and
f. Volume of added water shall be recorded on the delivery ticket.

12. Curing

Materials and equipment needed for adequate protection and curing shall be on hand and ready for use prior to concrete placement. Curing shall start immediately after placement and cooled to a concrete-to-ambient temperature differential of 12°C.

Freshly deposited concrete shall be protected from:

a. High wind;
b. Freezing;
c. Low and high temperatures;
d. Large temperature differentials;
e. Premature drying;
f. Precipitation;
g. Low humidity;
h. Heavy shocks; and
i. Excessive vibrations and high stresses.

13. Cold and Hot Weather Construction

The contractor shall develop procedures and measures for concrete curing work in cold or hot weather environments and shall submit them to BC Hydro for review and acceptance a minimum of 10 business days before starting construction.

CSA A23.1 limits concrete temperature to between 10°C and 30°C (32°C for less than 300 mm thickness) and requires the concrete be protected from the effects of hot and dry weather conditions when the ambient temperature is 27°C or higher, and from cold weather when the ambient temperature drops below 5°C.

The cement in concrete reacts with water in a chemical exothermic process (called hydration) that produces heat. During cold weather, a temperature gradient occurs between the interior of the concrete element, where the heat is trapped, and the exterior surface that is transferring heat to the atmosphere. Concrete should be protected from cold to prevent the surface from cooling more rapidly than the core, thereby keeping a low thermal gradient. Fresh concrete will stop gaining strength when the temperature drops below 10°C and will not regain strength if exposed to freezing temperatures before gaining a strength of 3.5 MPa. Concrete can

resist the effects of one freezing and thawing cycle when it is air-entrained, not exposed to external water, and has reached a compressive strength between 3.5 MPa and 25 MPa. Reaching 3.5 MPa does not provide protection from repeated exposure to freezing and thawing cycles. Concrete needs to gain a minimum 25 MPa strength for exposure to freezing and thawing cycles.

Cement and aggregate settle when concrete is placed, causing water to rise to the surface. This is called bleeding. Bleeding is a normal characteristic of fresh concrete. During hot, dry, and windy weather, water evaporates from the surface faster than it can rise to the surface (bleed), causing exposed surfaces to stiffen and harden before all bleed water rises. The bleed water will be trapped beneath the hard surface layer and cause surface scaling and irregular cracks.

Floating and troweling should not be performed until bleeding is completed as it increases risk for later bleed water being trapped beneath the finished surface.

The type and duration of curing depends on the concrete mixture proportions, expected construction loads, and environmental conditions the member will be exposed to during the curing period. Effective protection allows the concrete to gain strength and prevents early age damage from freezing or developing a high temperature and moisture gradient.

14. Cold Weather Construction

Cold weather concreting procedures shall be used when there is a probability of the ambient temperature falling below 5°C within 24 hours of placing concrete. All snow and ice shall be removed before concrete is placed on any surface. Calcium chloride or other de-icing agents shall not be used in the forms.

Ice, snow, and frost shall be completely removed from forms before any concrete is placed. The temperature of cold contact surfaces shall be raised to and maintained at a minimum of 5ºC for at least one hour prior to concrete placement. If fresh concrete is being placed on cold granular bedding, rock, or existing concrete, the rock or existing concrete temperature shall be raised to and maintained at a minimum of 5ºC for a time sufficient to raise the entire mass of rock or concrete to this temperature. Frozen bedding shall be thawed and re-compacted prior to placing concrete.

Heat shall be applied uniformly and at a rate that shall not induce excessive thermal stresses in the section being heated. Fresh concrete shall be kept above 13°C until it has reached a minimum compressive strength of 25 MPa or 75% designed strength, whichever is greater. An underground concrete duct bank buried below freezing depth and backfilled immediately upon removal of protection, may be kept above 10ºC until it has reached a minimum compressive strength of 3.5 MPa. If adequate curing and protection is provided but strength is not determined, the curing period shall extend to 72 hours (48 hours for a duct bank buried below freezing depth).

Completely insulating or enclosing fresh concrete and heating the enclosed area is the preferred method of protection at low temperatures. One solution is to cover the concrete with polyethylene and then with protective blankets or other insulation designed for this purpose, then heat with low-pressure steam or electric or fuel-burning heaters. Heat should be applied evenly so no sections differ in temperature by more than 28°C. If steam is used, the enclosure should be tight and the area saturated to prevent the concrete from drying rapidly and shrinking.

Air and concrete temperatures shall be continuously recorded to verify compliance with cold weather requirements. Surface temperatures should be measured by thermometers or thermocouples embedded in the concrete with 1.5 mm to 3 mm of cover. At the end of the protection period, wet curing shall be stopped soon enough to allow the concrete to dry before freezing protection is removed. Protection shall be removed slowly to allow gradual cooling of concrete surfaces, with a temperature difference maintained below 12ºC for duct encasement and 25ºC for walls.

The restricted temperature difference for a duct bank is lower than for thinner members as higher mass concrete develops higher thermal gradients and is more susceptible to thermally induced cracking.

15. Hot Weather Construction

Hot weather concrete construction applies when the ambient temperature exceeds, or there is a probability to exceed, 27°C, but it also includes conditions involving any combination of the following:

a. High ambient temperature;
b. High concrete temperature;
c. Low relative humidity;
d. High wind velocity; and
e. Solar radiation.

The contractor shall prepare and submit a hot weather concreting plan to BC Hydro for acceptance a minimum ten days prior to commencing construction. The plan shall include measures to accelerate cement hydration and prevent moisture loss in any of the conditions listed above. The contractor shall prepare and keep concrete protection records, including measured surface temperatures and curing type and duration. Concrete used in elements having a minimum section thickness greater than 1000 mm shall have temperature controls as per CSA A23.1.

The following measures shall be considered:

a. Modify the concrete mix design for hot weather;
b. Schedule concrete placements to avoid extreme temperature, such as at night or during early morning hours when ambient temperatures and wind velocity are lower and humidity levels higher;
c. Reduce the time of transporting, placing, and finishing as possible;
d. Assure adequate equipment and placement crew size. Have all curing materials staged and ready for immediate use after the concrete has been placed and finished. Plan for any incidental work that will need to be performed;
e. Use a concrete consistency that allows rapid placement and consolidation;
f. Protect formwork, reinforcement, and concreting equipment from direct sun exposure, spray with water mist, and dampen the subgrade prior to placing concrete;
g. Start curing immediately after concrete placement and finishing. Protect the concrete with temporary coverings, such as polyethylene sheeting, between placing and finishing;
h. Prevent exposure of fresh concrete to direct sun and wind by shading; and
i. Protect exposed surfaces from drying by spraying mist water or cover with wet burlap and polyethylene sheets or wet backfill.

If water-curing sprays are planned, moist burlap or other cover should be used until there is no danger of surface erosion by the curing sprays. Wet backfill used for moist curing should be kept continuously wet.

Wet burlap is inexpensive and can be applied without damage to the surface almost immediately after concrete is finished. Wet cotton mats and other highly absorbent materials can also be used. More than one thickness of burlap should be used, and the burlap should be maintained in contact with the concrete surface, especially during hot, sunny weather. Burlap on formed surfaces should be kept wet with a soaker hose placed along the top of the work or by other means. The burlap or other cover should be allowed to dry before removal, particularly if weather conditions are dry. The concrete will then dry more slowly and be less prone to cracking.

Polyethylene can provide effective moist curing if it is kept tight to the concrete surface. Waterproof paper also can be used as a moisture barrier if seams between adjacent sheets are tightly sealed or overlapped and protected from damage. Dark coloured (black) material absorbs heat and shall be avoided in hot weather for surfaces exposed to sun. In cold weather, dark coloured cover material is advantageous. The concrete surface should be inspected beneath the cover occasionally and wetted if dry.

16. High Concrete Temperature

If concrete temperature is likely to exceed 30°C (32°C for less than 300 mm thickness), the contractor shall submit a thermal control plan to BC Hydro for approval as follows:

a. Specified temperature limits;
b. Predicted adiabatic temperature rise of the concrete;
c. Concrete placing temperature considerations;
d. Calculated maximum concrete temperature;
e. Calculated maximum concrete temperature difference;
f. Ambient temperature and weather considerations;
g. Insulation and curing recommendations;
h. Temperature monitoring devices and locations;
i. Requirements to avoid thermal shock (24-hour concrete surface temperature drop);
j. Criteria to terminate thermal control;
k. Recommendations to meet temperature limits; and
l. Possible corrective measures.

17. Grout

Grout shall be non-shrink material conforming to CAN/CSA A23.1. Grout shall have a compressive strength of 35 MPa at 28 days and a maximum water to cement ratio of 0.45.

18. Quality Control and Acceptance

The contractor is responsible for quality control, sampling, and testing necessary to confirm compliance with standards and specifications. The contractor shall document inspection at the hold points specified in Table 3 as a minimum and submit records to BC Hydro for review upon request.

All parties including the concrete supplier, construction contractors, and BC Hydro are responsible for monitoring and documenting concrete construction quality. Concrete suppliers provide quality control for concrete materials and products to meet national CSA standards requirements. Contractors provide quality control to ensure construction meets contract specifications. BC Hydro civil inspectors conduct quality assurance to review suppliers' and contractors' quality control processes, plans, and results. For customer projects, the customer conducts quality assurance and BC Hydro civil inspectors provide audits by inspection and review of quality control and assurance records at their discretion.

Quality acceptance shall be as shown in Table 3. Sampling and testing shall be as shown in Table 4.

Table 3 – Concrete acceptance

Acceptance item	Acceptance criteria	Hold point
Mix design	CSA A23.1	Prior to material ordering
Falsework and formwork	CSA S269.1 and S269.3	Prior to concrete placing
	Workers Compensation Act and occupational health and safety regulations	Prior to work
	Engineering design	Prior to work
Reinforcement and steel hardware	Mill certificates and placement tolerances	Prior to concrete placing
Slump	CSA A23.1 accepted mix design	Prior to concrete placing
Surface finish	CSA A23.1 visual inspection for defects and dimensions	Prior to shipping

Acceptance item	Acceptance criteria	Hold point
Dimensional tolerances	CSA A23.4 and 5 mm for concrete edges to frame and lid assemblies	Prior to pouring and prior to shipping
Compressive strength	CSA A23.2 (1C, 3C, 4C, and 6C)	Sampling during pouring. Testing at time of removing formwork, handling, shipping, and after 28 days.

Table 4 – Concrete sampling and testing

Test description	Test methodology	Testing frequency
Compressive strength Making and curing concrete compression and flexural test specimens	CSA A23.2-9C CSA A23.2-3C	Ready mix: One set for every 35 m^3 or portion thereafter for each classification of concrete placed within an individual structural element or component and placed on one calendar day from a single supplier. Volumetric mix: One set for every 20 m^3 or portion thereafter for each classification of concrete placed within an individual element or component and placed on one calendar day from a single supplier. If less than 20 m^3, a minimum of one set for a single mix placed on one calendar day.
Slump	CSA A23.2-5C	Every individual load/batch
Temperature of fresh concrete	ASTM C1064 Permissible concrete temperatures at placing CSA A23.1 section 5.2.5.4	Every individual load/batch
Air content	CSA A23.2-4C	Ready mix: Every individual load. Volumetric mix: At the start of every batch until satisfactory control is established and with every strength test.
Density, yield, and cementing materials	CSA A23.2-6C	Density and yield tests shall be performed with every air content test and compressive strength test

19. Mix Design Review

The concrete mix design should be within the limits provided in Table 5.

Table 5 – Mix design limits

Mixture identification	Mix 1	Mix 2	Comments
Specified exposure class	F2	C1	E54 specifies exposure class F2 for duct bank and C1 for all structures
Distance from batch plant to project site	Max 100 km		Distance is used for assessment of travel time
Time from initial mixing to complete discharge	Max 2 hours		The concrete supplier should state maximum mixing from initial mix to complete discharge
Supplied quantity (m^3)			

Mixture identification	Mix 1	Mix 2	Comments
Batching method	Plant / volumetric	Plant	Check Concrete BC website for plant and volumetric registration
Specified strength at 28 days	25 MPa	35 MPa	
Air content range	4% to 7%	5% to 8%	
Water to cement ratio	Max 0.55	Max 0.40	Water may be added at the site before concrete placement if the measured slump is below target value provided the maximum amount of water added indicated on the delivery ticket is not exceeded
Nominal maximum aggregate size	14 mm		Mix 1 aggregate size and slump are limited to ensure proper distribution of concrete around the ducts. Aggregate size may increase to 19 mm and slump decrease to 100 mm if, in the opinion of the BC Hydro civil inspector, workability and methods of consolidation are such that the concrete will fill all voids between and underneath the ducts. Accelerating admixtures shall be approved by BC Hydro prior to use. If slump <80 mm, tolerance is ± 20 mm. If slump is 80 mm to 180 mm, tolerance is ± 30 mm. If slump >180 mm, tolerance is ± 40 mm.
Slump or slump flow-tolerance	Min 130 mm		
Method of placement	Bucket or pump		
Setting time - strength/ age (MPa/hour)			
Portland cement type	GU/GUL		Concrete mix1 shall be designed to ensure the heat of hydration does not overheat and deform the conduits
Fly ash (% of cement)	< 30%		
Air entraining admixture			
Water-reducing admixture			
Other			

20. Proportioning

Material mass shall be expressed in kilograms (kg) and the absolute volume in cubic metres (m^3) contributed by each material in the mixture.

Solid material quantity shall be expressed as kilograms per cubic metre (kg/m^3), and liquids shall be expressed as litres per cubic metre (L/m^3).

Water quantity shall be expressed as kilograms or litres per cubic metre (kg/m^3 or L/m^3) of cementitious material based on the water to cement ratio, corrected to account for any water contributed by other materials added in the mix.