Section U - Engineering

REVISIONS: R.4 - ADDED U2-03. OCT '18 CC

DESIGNED	RECOMMENDED	ACCEPTED	ENGINEER OF RECORD
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DISTRIBUTION STANDARDS
BC Hydro

ISSUED: OCT 2018
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ENGINEERING
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Scope

This Section covers the engineering aspects of the standards, including the loading and design criteria for standard and site specific products.

Engineering Design

The engineering design includes reports, drawings and specifications, and is prepared by the Professional of Record (POR) who is registered with EGBC as a Professional Engineer in good standing.

The POR shall sign and seal the complete design and submit it to BC Hydro for review and acceptance. Any design revisions made after BC Hydro's acceptance shall be resubmitted for acceptance. The POR shall address all of BC Hydro comments on the design and any revisions.

During the construction stage, the POR shall ensure that the design is followed, and shall review any proposed changes and make appropriate revisions to the design. Where a change has been implemented in the field prior to the POR's review, the POR shall review the implemented revision as soon as practicable and notify BC Hydro of any negative impacts. Where different conditions are encountered in the field than assumed in the design, the POR shall confirm the applicability of the design or make appropriate revisions.

Field Review

Bylaw 14(b) under the Engineers and Geoscientists Act requires Professional Engineers to ensure that Feld Reviews of their designs are carried out by, or under the supervision of, a professional engineer during construction.

The purpose of Field Reviews is to confirm compliance with the Design. EGBC defines Field Review[1] as "*The reviews conducted at the site … to ascertain whether the implementation or construction of the work substantially complies in all material respects with the engineering or geoscience concepts or intent reflected in the engineering or geoscience documents prepared for the work.*" The EGBC Advisory 2018-04[2] reads: "*The Field Reviewer observes the contractor's work to ascertain whether the work substantially complies in all material respects with the engineering or geoscience concepts or intent reflected in the engineering or geoscience documents prepared for the work, and may reject nonconforming work, but leave the means and methods for achieving what is required to the contractor or others who are tasked with implementing or constructing the work.*"

The British Columbia Building Code (BCBC) has developed Letters of Assurance that are used on building projects to clearly identify all Professional Engineers involved in the project along with their responsibilities and to provide assurance that the design and the completed project are in substantial conformance with the building code. BC Hydro used the same approach to develop the Field Review process. Field Review form shall be signed and submitted to BC Hydro and Field Review reports with Record Drawings and Final Design shall be submitted upon completion of the project. Letters of assurance shall be signed and stamped for structural works.

The Field Reviewer responsibilities are:

1. Make periodic visits to the site to determine whether or not the work is in substantial compliance with the design;
2. Review any inspection and testing performed by other qualified persons;

3. Confirm that design changes required in the field have been forwarded to the POR and Hydro's Representative for acceptance;
4. Record any changed conditions encountered, observations made, and deficiencies found during site visits; and
5. Provide the Contractor, POR, and BC Hydro's Representative with a written report of the observations and deficiencies not more than 48 hours after each Field Review.

The POR shall prepare, sign and stamp the Field Review plan. The plan number of Field Reviews will be determined based on the size and complexity of construction and shall include the following activities:

1. Preconstruction meeting;
2. Layout and staking survey;
3. Bottom of excavation;
4. Foundation base preparation;
5. Backfill compaction; and
6. Pre-pour for reinforced concrete cast in place construction.

Record Drawings

Record Drawings (sometimes called As-Built Drawings) are prepared by the Contractor or Customer during execution of the Works (i.e. the original design is amended by any variations during construction). For projects designed by BC Hydro, the Contractor is responsible for submitting Record Drawings that BC Hydro will use to prepare Final Design Drawings. The Record Drawings shall present an accurate representation of what was constructed with the intent to be used for the preparation of the Final Design Drawings.

The Record Drawings shall be prepared manually and/or electronically in a clear, complete and organized form to reflect the actual constructed work as follows:

1. Record all significant revisions to the original Design including but not limited to: field modifications, geometrics, utilities location and final elevations.
2. Contain all original information plus all revisions during construction.
3. Revised original details shall be clouded and deleted details shall be crossed with "X" so that all details remain visible.
4. The design revisions shall be marked in red and sketches and notes added if necessary.
5. If a single sheet is being revised several times, an "X" shall be drawn on the original sheet and subsequent sheets until the last revised sheet has been submitted. The sheets shall be placed behind the original in chronological order and numbered using the original sheet number and the revision number.

6. Revised details shall be numbered with revision number using the triangles legend.
7. Revision number, description, date and initials of the person approving the changes shall be recorded in the revision block.
8. If additional drawing is needed, it shall be numbered with the same drawing number and includes a revision line.

Each sheet shall be submitted with signed and dated revision: “As Constructed” whether or not it has been revised.

Final Design Drawings

Note that term “Final Design” is denoted in DAD as “Record Drawings”. However, the term Final Design is preferred for use in this standard to align with EGBC terminology.

Upon completion of the construction, the POR who assumes overall responsibility for the design shall sign and stamp the Final Design drawings and submit them with the original drawings to BC Hydro. The Final Design drawings shall incorporate addenda, change orders and other significant design changes that have occurred during construction and shall be prepared using the same format, electronic form and drafting standards as the original design drawings.

The Issue For Construction (IFC) drawings shall not be changed or amended. The Final Design drawings shall be a separate set of standalone documents, and shall contain as much of the original information as possible plus all changes.

1. The original design information that has been revised should be erased and replaced by the information that represents the as-constructed works. Any abandoned underground utilities shall be marked as such in the drawings. Any utilities removed during construction shall be deleted from the drawings.
2. Each item or area on the drawing that has been changed from the original design shall have a triangle drawn adjacent to the area of the change with the number of the change in the triangle. The same number will be shown cross referenced in a drawing revisions block with a description of the change beside it. The triangle shall be drawn with the apex of the triangle pointing towards the change.
3. The drawing numbers shall remain the same as the originals for record purposes. The drawings shall indicate a revision: “Final - As Built” on each sheet and signed and sealed in accordance with EGBC regardless if revised or not.

Survey

Survey data shall include both horizontal and vertical coordinates, as well as the coordinates of all BC Hydro facilities and bend points, and offsets to the property line. Surveys shall be geo-referenced and use the North American Datum of 1983 for the Canadian Spatial Reference System (NAD83-CSRS) as the datum. Coordinates shall be returned in Universal Transverse Mercator (UTM) values, with a combined scale factor annotated, and shown on the record drawings. Horizontal data shall be in UTM coordinates, while vertical data and elevations are to be based on Geodetic.

In the event that any portion of the Work requires the location or definition of legal boundaries, the survey shall be conducted by a Professional Land Surveyor (PLS) in accordance with the General Survey Instruction Rules of the Association of British Columbia Land Surveyors (ABCLS).

REVISIONS: R1- ADDED FIELD REVIEW, FINAL DESIGN, REVISED RECORD DRAWINGS. OCT '19 LS

DESIGNED	RECOMMENDED	ACCEPTED	ENGINEER OF RECORD	GENERAL NOTES
L. STEVANOVIC		F. DENNERT	PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA L. STEVANOVIC Nov. 12 2019	
DISTRIBUTION STANDARDS BC Hydro	ISSUED:OCT 2019 REPLACES:SEP 2016 ORIGINALLY ISSUED: MAR 2016			PAGE 4 OF 4

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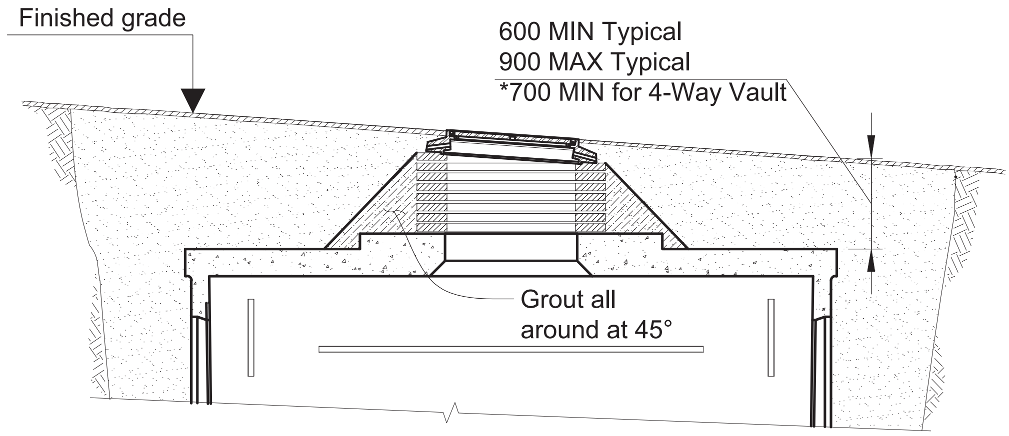
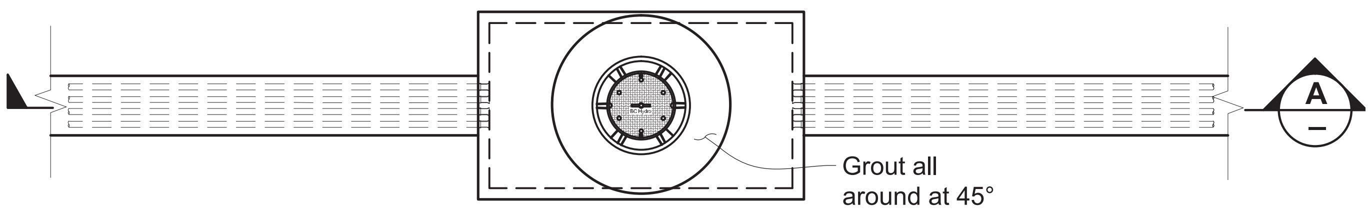
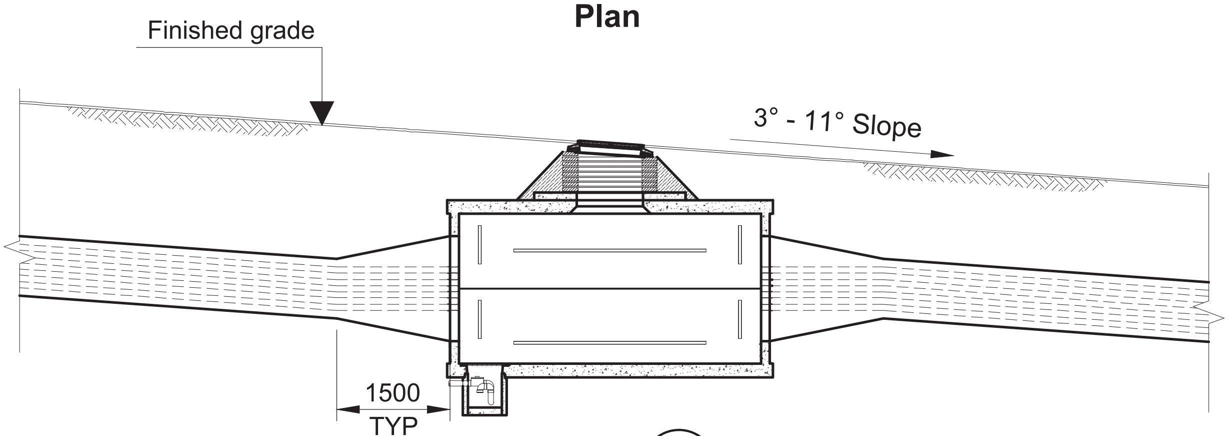


Cover Depth Limits



Plan



Section A –

Slope Limit

* 700 mm minimum burial depth for 4-Way vault is only required if ground water elevation is above vault floor.

REVISIONS: R2 - ADDED GRADE ADJUSTMENT FOR BOXES. MAR 2021 CC

DESIGNED	RECOMMENDED	ACCEPTED	ENGINEER OF RECORD
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DISTRIBUTION STANDARDS
BC Hydro

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FINISHED GRADE ADJUSTMENT AND ACCESS

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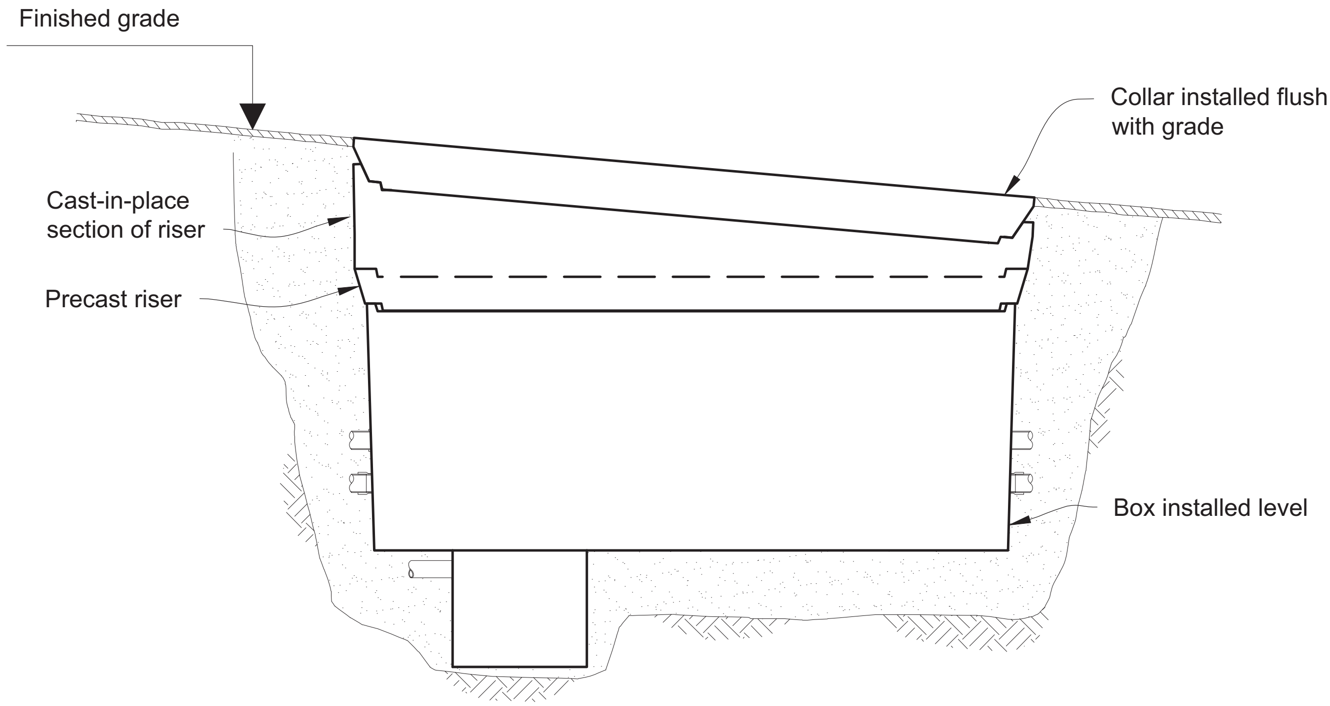
R 2



Grade Adjustment

Vaults Installed on a Grade

Concrete vaults with cast-iron frames and covers are installed with the floor leveled, walls vertical, and roof at finished grade. If the finished grade was designed at a slope, the precast riser rings shall be built up in the field to align the cover with finished grade.

Junction, Service, Pull / Splice Boxes Installed on a Grade

Concrete boxes are installed to match finished grade. If the finished grade was designed at a slope, the box and riser should be set to match the grade so the collar is flush with finished grade.

Grade Adjustment of Existing Boxes or Vaults

If the finished grade of an existing box or vault needs adjusting, the standard precast riser shall be modified, or a new custom riser shall be made to align the rooftop surface with the finished grade. The modified riser shall remain a nonintegral, removable part of the box and in full contact with collar and walls along the entire top and bottom surfaces. If the concrete riser is not used, the top of the walls shall be modified.

Material used to modify (build up) the riser or walls shall be cementitious grout or concrete, as applicable. The cement shall comply with CSA A3001 Type GU. The concrete shall comply with A23.1 or A23.4 Class of Exposure C1. Alternately, Target Traffic Patch premixed grout or an equivalent acceptable to the BC Hydro representative can be used. The minimum 28-day compressive strength shall be 35 MPa. A minimum of 20 MPa shall be achieved before exposure to vehicular traffic and 10 MPa before exposure to any other non-vehicular loads.

The following procedure shall apply to build up the riser:

1. Chip the top of the concrete surface being built up to provide a uniform rough surface.
2. Blow compressed air over the entire area to free it of any particles.
3. Form the top surface of the riser and mark finished edges on the concrete form for guidelines.
4. Cover the entire build-up area with a bonding agent prepared of cement slurry in a thin even coat. Scrub the bonding materials with a stiff brush or spray as necessary to spread the bonding agent evenly into the surface cavities.
5. Place the grout or concrete and cure as necessary until the required strength is developed.

Built-up height of the riser shall not exceed 300 mm.

Access to BC Hydro Plant

Safe, permanent access to the BC Hydro pad mount and underground plant shall be provided for equipment installation and maintenance purposes. The access shall be designed and constructed in compliance with requirements of the authority having jurisdiction, applicable codes, and standards.

Load Combinations

Underground structures shall be designed (design lifespan shall be 50 years) for fatigue limit state (FLS), ultimate limit state (ULS), and serviceability limit state (SLS) for the following load combinations, in accordance with Canadian Highway Bridge Design Code (CHBDC) CSA S6:

FLS combination 1: D + E + L

SLS combination 1: D + E + 0.9 x L + S

ULS combination 1: αD x D + αE x E + 1.7 x L

ULS combination 5: αD x D + αE x E + EQ

where:

D =	dead load
E =	earth and hydrostatic pressure loads, including surcharges but excluding dead load
EQ =	earthquake load
L =	live load (including the dynamic load allowance, when applicable)
S =	load due to differential settlement or movement of the foundation
αD, αE =	load factors. The following maximum or minimum value for each load factor shall be selected to maximize the total factored load effect:

- αD = max 1.1, min 0.95 for factory-produced components, excluding wood
- αD = max 1.2, min 0.90 for cast-in-place concrete, wood and all non-structural components
- αD = max 1.25, min 0.80 in combination with earthquake load
- αE = max 1.25, min 0.80 for earth fill and pressure, except for 0.5 for passive earth pressure when considered as a resistance
- αE = max 1.1, min 0.9 for water weight and hydrostatic pressure

Material Resistance

The material ultimate resistance shall be multiplied by the following factors:

- 0.5/0.8 for foundation bearing and passive resistance/sliding resistance;
- 0.4 and 0.6 for tension resistance of ground anchors, determined by static analysis and static tests, respectively;
- 0.95/0.90 for steel flexure, shear, tension/compression, torsion;
- 0.75 for concrete;
- 0.9 for reinforcing bars;
- 0.8 for bolts and anchors;
- 0.67 for welds; and
- 0.90 for aluminum.

Fatigue Design

For lids and covers made of steel and aluminum materials shall be designed for load-induced fatigue, $0.62 f_{sr} \leq F_{sr}$, where F_{sr} is the:

- Calculated fatigue stress range due to tandem axles no. 2 and no. 3; and
- Fatigue stress range resistance calculated in accordance with CSA S6.

Seismic Design

Underground structures and duct banks shall be designed for 10% in 50 years probability of reoccurrence (475-year return period). Structures and ducts shall be designed to site-specific soil conditions and seismic characteristics. The design shall be based on peak ground acceleration and velocity based on 2015 Natinal Building Code data provided by the Geological Survey of Canada. Spectral values are provided for site class C and shall be adjusted for local site conditions. The vertical response spectrum shall be ⅔ of the horizontal spectrum, or determined based on site-specific soil conditions and the site period.

The seismic loads acting on standard precast vaults and boxes are interpolated in this standard with equivalent static forces based on Wood's method, assuming a maximum horizontal ground acceleration ratio (Ah) equal to 0.4.

The design shall consider soil liquefaction, slope instability, increased lateral earth pressure, settlements, and the interaction of soils, duct banks, and the vault system to the seismic loading.

Equipment connections shall be designed to the BC Building Code Section 4.1.8.18 *Elements of Structures, Non–structural Components and Equipment*. The design shall be based on spectral acceleration and velocity for a fundamental period of 0.2 seconds at 2% in 50 years probability of reoccurrence (2475-year return period).

Equipment shall be designed to resist horizontal and vertical seismic forces acting simultaneously at the centre of mass of the equipment. The friction connection due to gravity loads shall not be considered to provide resistance to seismic forces.

The equivalent horizontal seismic force V is:

$$V = 0.3 F_a S_a(02) I_e S W$$

where:

Sa(0.2) = 5% damped spectral response acceleration for a fundamental period of 0.2 sec, based on a 2% probability of exceedance in 50 years. The spectral values are specified by the Geological Survey of Canada at *www.earthquakescanada.ca.*

Fa = function of site class and Sa(02), assumed 1.0

Ie = importance factor, assumed 1.5

S = CArAx/R

C = Equipment factor, assumed 1.0

Ar = equipment force amplification factor, assumed 1.0

Ax = height factor, assumed 1.0 if equipment is installed at or below grade

R = equipment response modification factor, assumed 1.0 (for expansion anchors)

W = self weight of the equipment

Applying above factors in the equation, the seismic lateral force V is:

$$V = 0.45Sa(0.2)W$$

Assuming the vertical response spectral acceleration is ⅔ the horizontal, the equivalent seismic vertical force acting in either up or down direction is:

$$N = 0.3Sa(0.2)W$$

Concrete anchors shall be designed to satisfy these three conditions:

(a) $Tr > Tf$

(b) $Qr > Qf$

(c) $Tf/Tr + Qf/Qr > 1.2$

where

Tf and Qf = tension and shear factored loads based on ULS Combination 5

Tr and Qr = tension and shear resistance of the anchor based on CSA A23.3.

Duct bank design is based on potential earthquake generated ground fault displacements caused by liquefaction, lateral spread, and slope failure. The locations of the ground displacements shall be identified at the initial design stage and the duct bank shall be adequately designed.

Live Load Configurations

Traffic loads shall be BCL 625 truck tandem axles no. 2 and no. 3 in accordance with the BC Ministry of Transportation and Infrastructure (MOTI) supplement to CHBDC. Each axle consists of two wheels spaced at 1.8 m centres, with each wheel footprint of 0.25 m x 0.6 m.

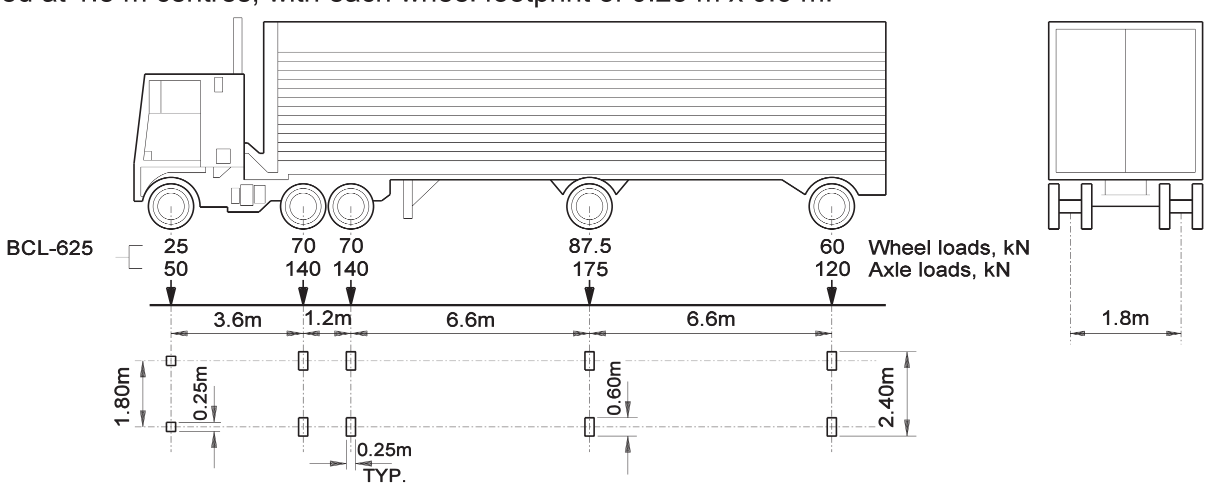


Figure 1. BCL 625 Design Truck Configuration

The clearance envelope of the truck in a traffic lane is 3.0 m. The dynamic load allowance (DLA) shall apply to all live loads and shall be 0.4 (1 - 0.5 x De) but not less than 0.1, where De denotes a depth of earth cover.

Vertical Loads

BC Hydro underground vaults and pads are designed to four load duty levels for installation within roadways, access lanes, sidewalks, and non-traffic areas. The load duties with corresponding live loads and applications are summarized in the following table in an order of highest to lowest load, top to bottom. Each standard product shall be used for the designed or lower duty applications.

Application Duty	Live Load	Application
Roadway	BCL 625 truck tandem axles nos. 2 and 3	Part of a highway or street intended for or used by full deliberate vehicular traffic, including traffic lanes, shoulders, and other adjacent areas such as those provided for clearance, pedestrians, parking, or bicycles, if these areas are not separated by a curb with a face height of at least 150 mm and a face slope not flatter than 1 horizontal to 3 vertical, or by mechanical protection.
Access lane	BCL 625 truck tandem axles nos. 2 and 3 reduced to 90%	Parking, private driveway, or street back lane intersecting roadway and restricted to deliberate slow-moving heavy vehicular traffic with speed limited to 30 km/h. Sidewalk or pedestrian walkway not separated from traffic by vertical curb.
Sidewalk	BCL 625 truck tandem axle no. 2 reduced to 70%	Pedestrian walkway or other area restricted to occasional non-deliberate vehicular traffic, located within 1.5 m of a roadway and separated from traffic by a curb with a face height of at least 150 mm and a face slope not flatter than 1 horizontal to 3 vertical.
Non-traffic	20 kN wheel load spread over 200 mm square footprint	Pedestrian and occasional non-deliberate light vehicular traffic area, not accessible by roadway vehicular traffic, and located further than 1.5 m from a roadway, or protected from vehicular traffic by mechanical protection.

Wheel Load Distribution Through Fill

When the depth of fill over a structure is 0.60 m or more, wheel loads shall be uniformly distributed at the surface of the structure over a rectangle, the sides of which are equal to the footprint of the wheels of the BCL-W truck plus 1.75 times the depth of fill. When distributed wheel loads from two or more wheels overlap, the total load of those wheels shall be uniformly distributed over the smallest rectangle that includes their individual areas, but the total width of distribution shall not exceed the total width of the structure supporting the fill. When the depth of fill over a structure is less than 0.60 m, no distribution beyond the footprints of the wheels shall be considered.

Buried Structures

Buried structures shall be designed in accordance with CHBDC section 6. The ultimate state load shall include the soil lateral pressure, groundwater hydrostatic pressure, buoyancy, compaction surcharge, and the live load as follows:

1. The live lateral load shall be equal to an equivalent fill surcharge height of 0.80 m above the finished grade and over the length of the walls. The live load factors shall apply to this load.
2. The lateral earth pressure at rest condition (Eo) is assumed to be the equivalent fluid pressure equal to 11z [kPa], where "z" is the depth below ground surface [m].
3. The compaction surcharge shall be a lateral pressure varying linearly from 12 kPa at the fill surface to 0 kPa at a depth of 1.7 m below the surface, in addition to the compaction effect on restrained structures which is equal to 15% of the lateral earth pressure.
4. The lateral groundwater pressure (Ew) is 10z [kPa], where "z" is the depth below water and ground surface [m]. Assuming the lateral earth pressure factor at rest (Ko) is 0.5, the earth pressure (Eo) is reduced due to the buoyancy effect for Ko x Ew = 05 x 10z = 5z [kPa]. The reduced earth pressure due to the buoyancy effect is applied to the groundwater pressure (Ew). This approach simplifies the application of the hydrostatic load factor to all loads resulting from the hydrostatic effect.
5. The seismic load shall be equal to an average of 7.5 z [kN/m] varying linearly, and acting at an elevation of 0.35 z below the grade.

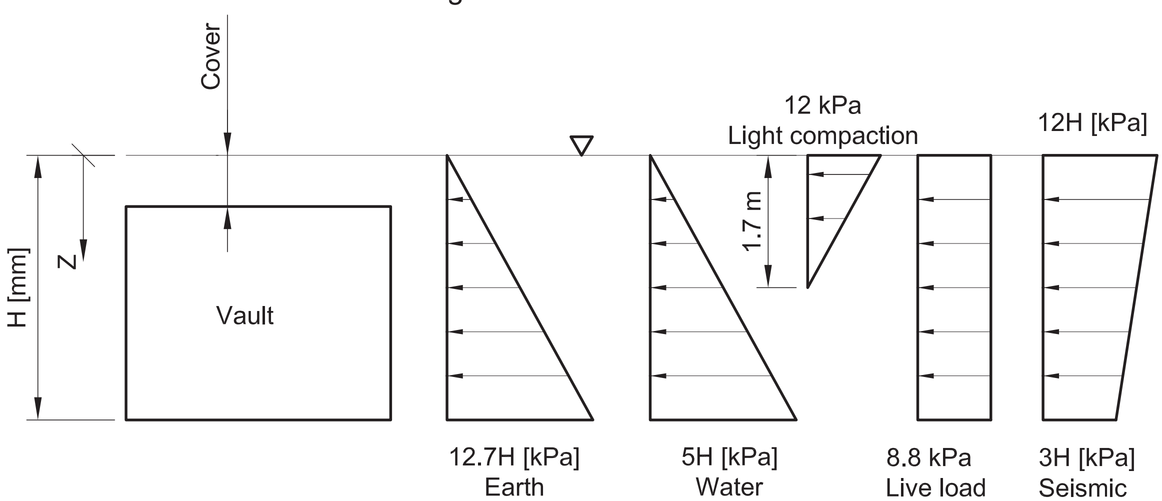


Figure 2. Vault Lateral Loads Configuration

The design shall be based on the equivalent fluid pressures method and include the following assumptions:

- The walls are vertical;
- The ground surface is levelled;
- Surrounding backfill is not susceptible to liquefaction;

- The angle of internal friction of backfill behind the wall is 30 degrees;
- The groundwater level is considered at finished grade; and
- The effect of shear resistance or friction between the wall and the soil is neglected.

Cable Pulling

Cables are pulled by using a pulling iron or jamb skid. The pulling force shall not exceed 45 kN when using the snatch block and 25 kN when using the jamb skid, including dynamic and static components.

The pulling iron is used to attach a snatch block and pull cables to a wall opposite to the pulling iron. The snatch block is rigged to an elevation to align the pulling force with the axis of the duct. The cable pulling force approximately doubles at the pulling iron. The pulling iron shall be designed for a 135 kN ultimate design force, acting in any direction as necessary to pull all cables. The ultimate design load provides a 1.5 load safety factor. See Figure 3.

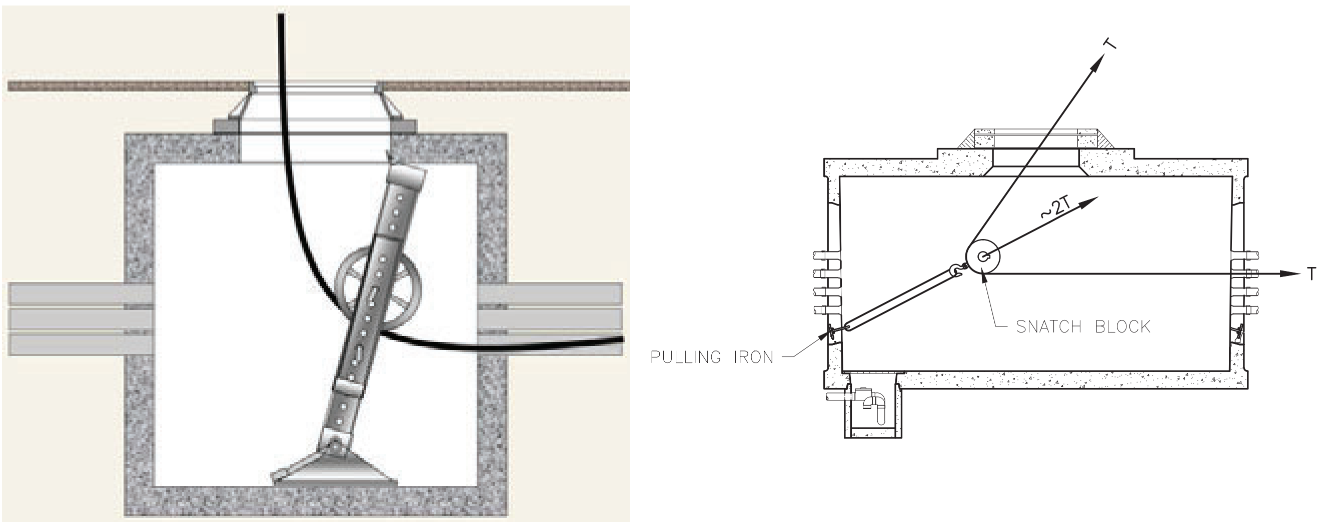


Figure 3. Jamb Skid and Pulling Iron

The jamb skid is positioned inside the vault against the concrete ceiling. The concrete vault shall be designed for a 40 kN ultimate point load acting under the vault chimney and aligned with the ducts.

Hold-Down Anchors

Anchors connecting electrical equipment (transformer, switchgear) shall be designed to transfer horizontal live load and seismic induced forces to the supporting structure (concrete slabs, foundations) for ULS combinations 1 and 5.

The minimum live load shall be equal to 1 KN horizontal static force acting at a point that produces maximum tension at the anchor.

Proof Load Test

A proof load test shall demonstrate the adequacy of products or applications to sustain loads. Some BC Hydro products or applications may require a proof of compliance by the application of both engineering calculations and proof tests.

Proof tests shall be performed on representative samples that are identical in geometric and material properties to the tested application. Only static tests are considered in this section. Dynamic load tests and fatigue tests shall be developed for each specific application.

Tests can be either confirmatory or performance types:

1. Confirmatory tests document that the serviceability and strength under the specified loads are acceptable. Serviceability tests shall be performed under the service loads that do not exceed the specified limit state. Ultimate strength tests shall be performed to determine whether the ultimate strength is adequate, and the applied force shall be that due to the factored loads, divided by the appropriate material resistance factor.
2. Performance tests determine the maximum load that can be applied to the tested application prior to it attaining an agreed level of distress (rupture, collapse, deformation).

Test Acceptance Criteria

Load Test

The load resistance of the tested application shall be considered to be one of the following, as appropriate:

- If four or less samples are tested, the load resistance shall be the lesser of:
    - the mean of the test loads multiplied by 0.9, and
    - the lowest load test.
- If more than four samples are tested, the applicable load resistance shall be the mean of the test loads minus one standard deviation.

Deformation Test

The deformation test of the tested application shall be considered to be one of the following, as appropriate:

- If four or less samples are tested, the deformation shall be the highest of:
    - the mean of the test deformations multiplied by 1.1, and
    - the highest deformation test.
- If more than four samples are tested, the applicable deformation shall be the mean of the test deformations plus one standard deviation.

REVISIONS: R1 - OFF ROADWAY APPLICATION DUTY AND TEST PAD ADDED. TEST LOADS REVISED. OCT '18 CC

DESIGNED	RECOMMENDED	ACCEPTED	ENGINEER OF RECORD
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DESIGN CRITERIA
PRODUCT AND APPLICATION TEST

ES54 U1-03.01 R 1

Load Test Methods and Procedures

The tests shall comply with ANSI/SCTE 77 Specification for Underground Enclosure Integrity and AASHTO M306 standard Specification for Drainage, Sewer, Utility and Related Casting. The test load shall match the intended application duty and exposure as specified in the table below, and shall be applied at positions to produce the maximum effect on the application.

Application Duty	Test Standard		Test Load		Test Pad WxLxT (mm)
Roadway	AASHTO M306	H25	Vertical	222 kN	229x229
Access Lane	ANSI/SCTE 77	TIER 22	Vertical Lateral	150 kN 57.5 kPa	254x508
	AASHTO M306	H20	Vertical	178 kN	229x229
Off-Roadway	ANSI/SCTE 77	TIER 22	Vertical Lateral	150 kN 57.5 kPa	254x508
	AASHTO M306		Vertical	150 kN	229x229
Sidewalk	ANSI/SCTE 77	TIER 15	Vertical Lateral	100 kN 57.5 kPa	254x254
	AASHTO M306		Vertical	100 kN	229x229
Non-Traffic	ANSI/SCTE 77	TIER 5	Vertical Lateral	33 kN 43 kPa	254x254

REVISIONS: R1 - OFF ROADWAY APPLICATION DUTY AND TEST PAD ADDED. TEST LOADS REVISED. OCT '18 CC

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DESIGN CRITERIA
PRODUCT AND APPLICATION TEST

ES54 U1-03.02 R 1

The latest editions and amendments of the following publications shall apply.

ANCI/SCTE (American National Standard Institute/Society of Cable Telecommunications Engineers)
77 Specification for Underground Enclosure Integrity

BC Hydro Distribution Standards
ES53 Underground Electrical

British Columbia Codes
BC Building Code
BC Electrical Code

Canadian Geotechnical Society
Canadian Foundation Engineering Manual

CSA (Canadian Standards Association)
A23.1/A23.2 Concrete Material and Methods of Concrete Construction/Test Methods and Standard Practices for Concrete
CAN/CSA A23.3, Design of Concrete Structures
A23.4 Precast Concrete – Material and Construction
A23.5-M, Supplementary Cementing Materials
A3000 Cementitious Material Compendium
A176 Masonry Standards
A283 - Qualification Code for Concrete Testing Laboratories
C22.1, Canadian Electrical Code, Part 1
C22.2, Canadian Electrical Code Part 2
C22.3 No 7- Underground Systems
CAN/CSA-O86, Engineering Design in Wood
CAN/CSA S6, Canadian Highway Bridge Design Code
CAN/CSA-S16, Design of Steel Structures
Canadian Foundation Engineering Manual
G30.18 Billet Steel Bars for Concrete Reinforcement
G40.21 Structural Quality Steel
G164 Hot Dip Galvanizing Standard
O80 Wood Design Standard
O15 Wood Utility Poles
S157, Strength Design in Aluminum
S269.1 and S269.3. Concrete Falsework and Formwork Standard

MOTI (British Columbia Ministry of Transportation and Infrastructure)
Supplement to CAN/CSA-S6 Canadian Highway Bridge Design Code

Pad-mounted equipment, such as transformers, switchgear or junction kiosks, is exposed to damage caused by vehicles whenever it is located close to a road, in a parking lot or next to driveways and lanes. One way to prevent damage caused by vehicles is to install the equipment away from such areas. However, this is often not a viable option, due to limited public or private land provided for BC Hydro equipment.

The accepted standard to protect pad-mounted equipment is the installation of bollards or MOTI pre-cast concrete barriers as shown in ES54 U2-02. The detailed design, including the type of the protection and the number of bollards or barriers required, is determined by the Designer.

Grounding construction standards utilize equipotential grounding; therefore all precast or field-cast protective bollards shall be bonded to the BC Hydro equipment ground counterpoise.

Bollards and barriers shall be placed between the pad and the traffic to prevent a vehicle from hitting the pad-mounted equipment. To reduce the risk of hitting the pad-mounted equipment, the barriers should be located in unobtrusive areas.

Roadside Precast Barriers

Pad-mounted equipment placed within 1.5 m of the roadway shall be protected from vehicular traffic by BC Ministry of Transportation and Infrastructure (MOTI) roadside precast barriers or an adequate mechanical barrier system. The roadside barriers shall be designed not only to prevent vehicles from hitting the pad-mounted equipment, but also to comply with the standards of traffic safety engineering and the Authority Having Jurisdiction (AHJ).

The precast barrier shall form a movable segmented system of sufficient length and mass necessary to prevent displacing upon impact, while allowing movements to absorb impact energy. To minimize injury to vehicle occupants, the barrier system approaches are flared to re-direct the vehicle at a low departure angle and reduce the risk of hitting other vehicles. Also, the collision must not result in excessive braking of the vehicle or direct impact on sharp concrete edges.

In the absence of AHJ standards, the barrier design along the roadside shall follow MOTI standards. MOTI standards comply with the Transportation Association of Canada (TAC) guidelines and the American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guides, stipulating approach barrier flares (Xa) and opposing flares (Xo) (Figure 1), depending on road class, traffic volume, clear zone, speed, etc. The minimum shy line offset (a transverse distance measured from the edge of the driving lane to the inside face of the barrier system) shall match or exceed the existing shoulder width.

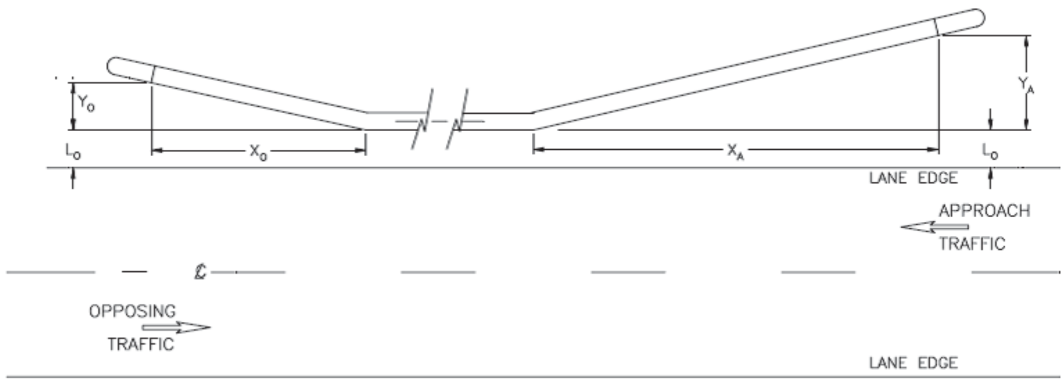

Figure 1: Roadside Barrier - Plan View

At a minimum, the MOTI standard for low volume roads at speeds below 50 km/h requires an approaching flare length (Xa) of 14.7 m, excluding transition and bull-nose pieces.

Application

This standard provides installation instructions for precast and cast-in-place concrete bollards. Bollards or roadside barriers are required when there is a public safety risk of vehicular contact with above ground equipment and to protect BC Hydro equipment from vehicular damage.

Revision Notes

R7 – Reformatted and notes revised. Added table to note 2. Added lifting insert on precast concrete bollard. March 2022, CC

R6 – Roadside barriers moved to U2-03. Updated lifting method. Bollard spacing changed. October 2018, CC

R5 – PVC pipe replaced with grounding and precast bollard option added. December 2016, MK

R4 – Updated text in notes. August 2016, MK

R3 – Title revised, was stanchions. March 2016, MK

R2 – Stock number change. September 2002, MF

R1 – Date unknown

R0 – First issue. February 1982

Items Required

Item	Description	Material No.	Quantity	Supplied By	Installed By
1	Pipe, galv. steel, 100 mm ID or precast bollard	400-0059 9700-2788	As required	BC Hydro	Contractor

Reference Standards

ES54 R1-02	Grounding of Pad-Mounted Equipment on Private Property
ES54 U2-03	Concrete Pad Protection Roadside Barriers
ES54 W1-01	Construction Materials Excavation and Backfill
ES55 B2-3	Clearances for Pad-Mounted and Subsurface Equipment

Notes

1. Bollards are required when above ground equipment is located within parking areas, streets, or roadway right-of-way (ROW).
2. Above ground equipment located in a sidewalk or boulevard 3 m or less from the roadway require bollards. The distance from the curb may be reduced to 1.5 m in dense residential areas when:
   a. Vehicular speed is limited to 50 km/h; and
   b. Rectangular curb is installed and extends 15 m on the approach traffic side. If the rectangular curb does not extend the full length of 15 m, it shall extend to the nearest driveway letdown and bollards shall be installed on the approach traffic side of the transformer.

   This table summarizes when bollards are required for above ground equipment installed in sidewalks or boulevards.

Distance of above ground equipment from curb	Bollards required	
	Rollover (mountable) curb or no curb	Rectangular curb and traffic restricted to 50 km/h
3 m	No	No
1.5 m to 3 m	Yes	No
Less than 1.5 m	Yes	Yes

3. Roadside barriers may be used instead of bollards. See ES54 U2-03.
4. Bollard layout is shown as a guideline. The actual number and placement of bollards may vary depending on the type and location of above ground equipment and site-specific considerations. Designers should specify the number and placement of bollards so a vehicle cannot hit the above ground equipment without first hitting a bollard.
5. Center bollard required only for large above ground equipment (pad width > 2m). If three bollards are installed on one side they should be evenly spaced along the side of the concrete pad.

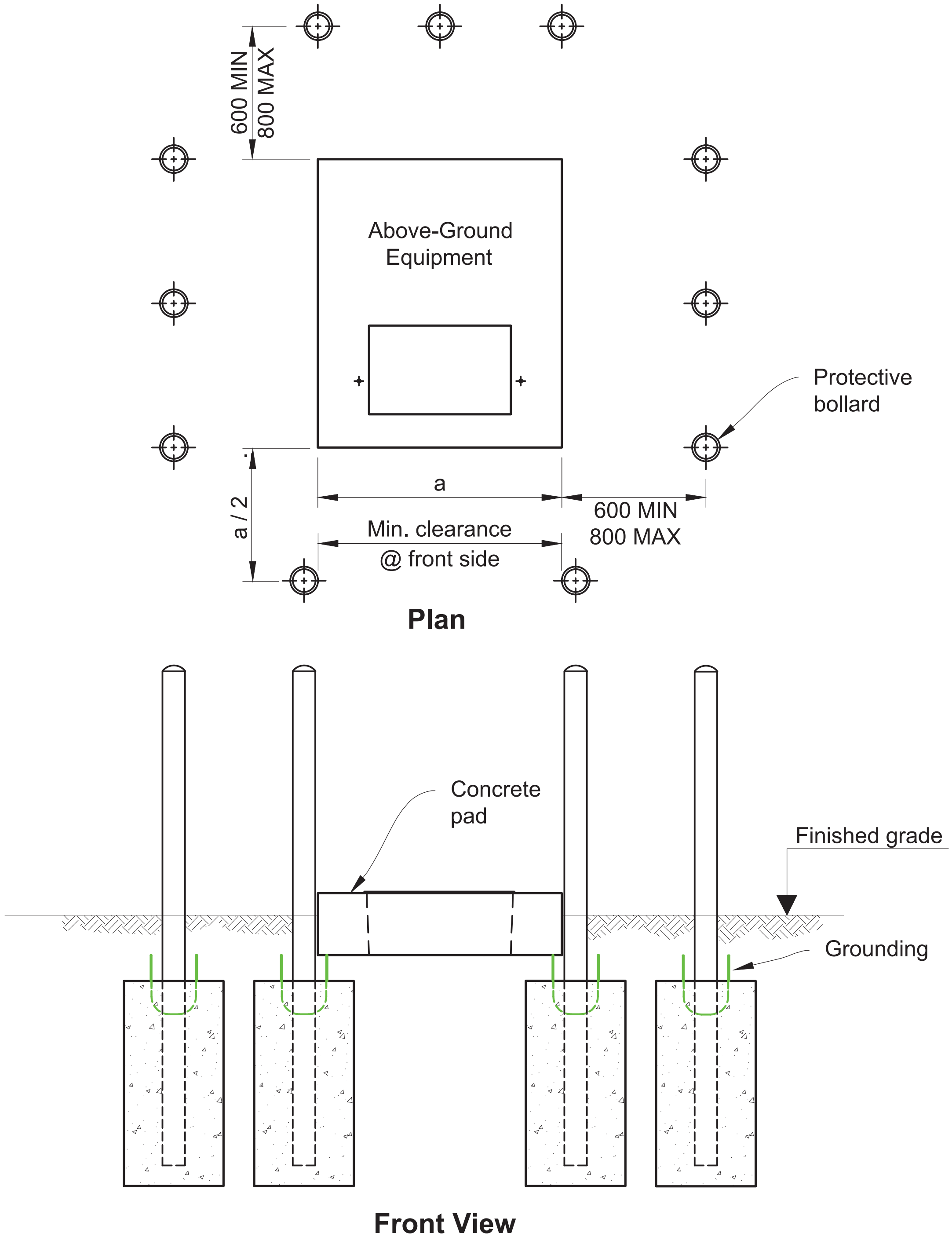

Figure 1 – Typical protective bollard layout

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C. CROWSON	L. STEVANOVIC	F. DENNERT	PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, C. E. CROWSON # 45713, 2022-03-07	CONCRETE PAD PROTECTION BOLLARDS
DISTRIBUTION STANDARDS BC Hydro	ISSUED: MAR 2022 REPLACES: OCT 2018 ORIGINALLY ISSUED: FEB 1982		PAGE 3 OF 5	ES54 U2-02.03 R 7

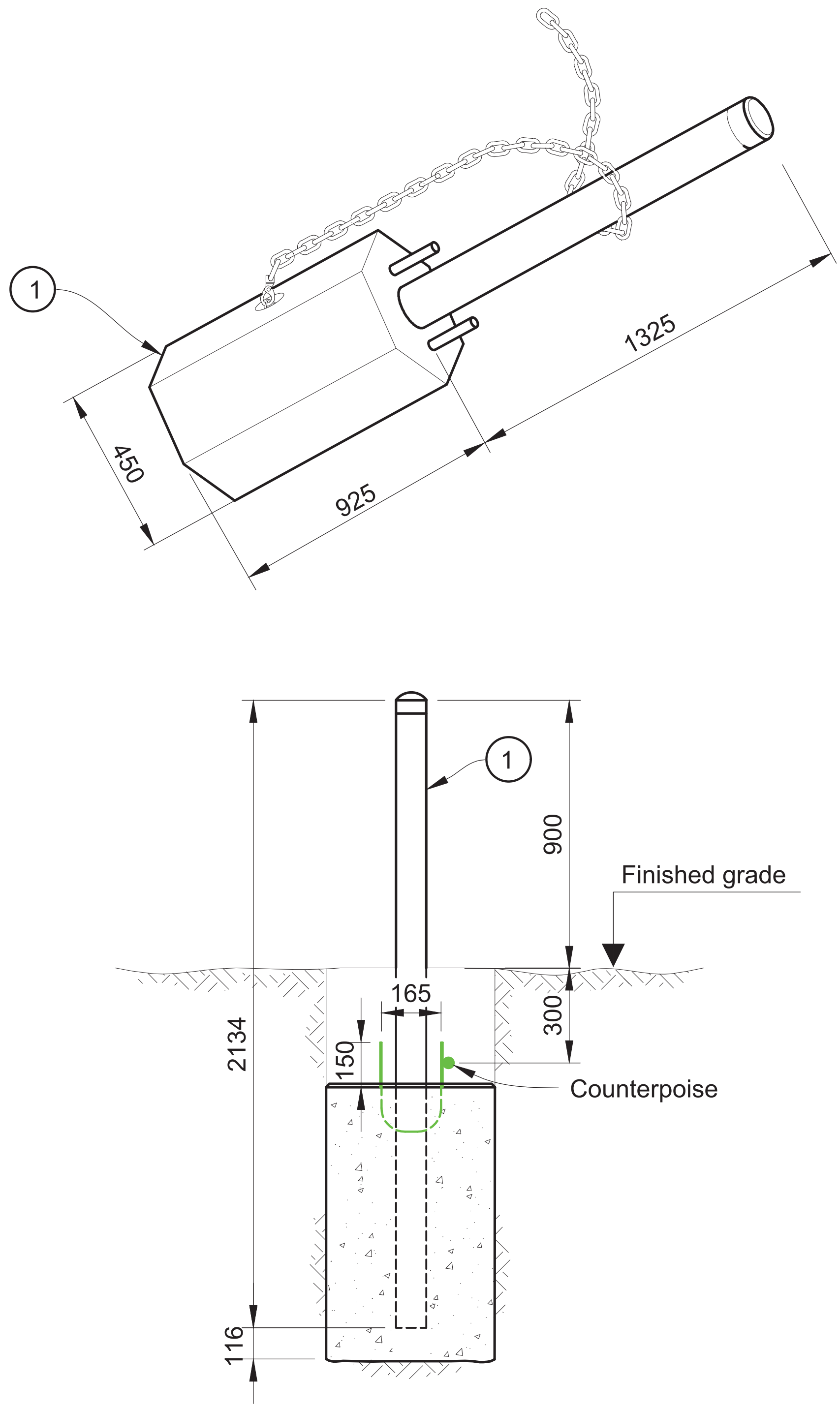

Figure 2 – Protective bollard (precast)

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C. CROWSON	L. STEVANOVIC	F. DENNERT	PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, C. E. CROWSON # 45713, 2022-03-07	CONCRETE PAD PROTECTION BOLLARDS

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R 7

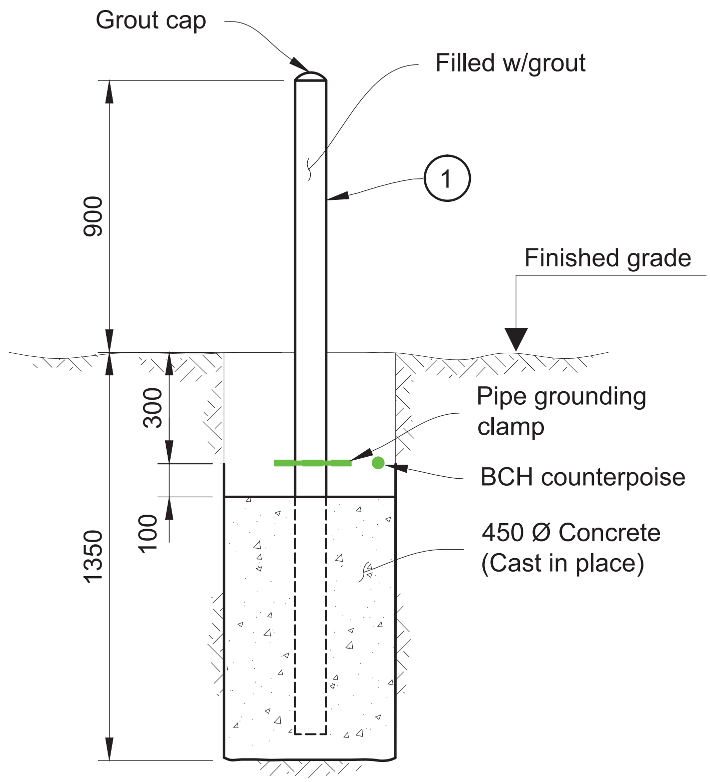

Figure 3 – Protective bollard (cast in place)

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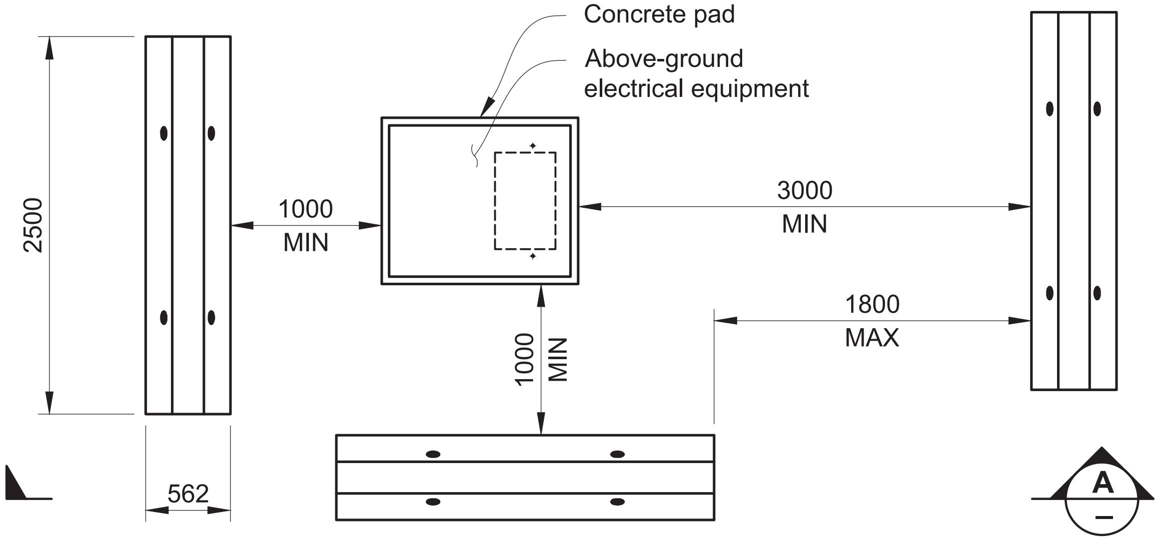
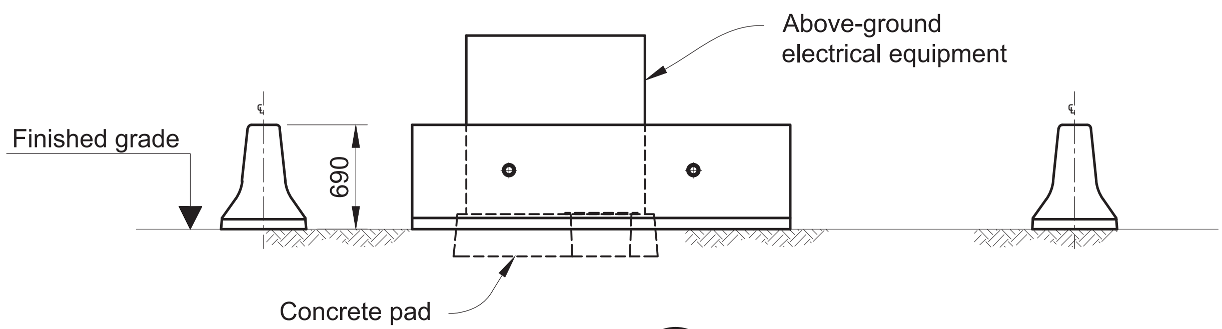
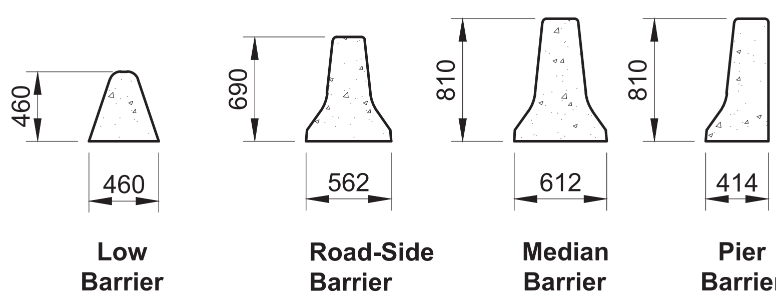
DISTRIBUTION STANDARDS BC Hydro	ISSUED: MAR 2022 REPLACES: OCT 2018 ORIGINALLY ISSUED: FEB 1982		2022-03-07	PAGE 5 OF 5 — ES54 U2-02.05 — R 7



Plan



Section A



Cross-Sections of Precast Barriers

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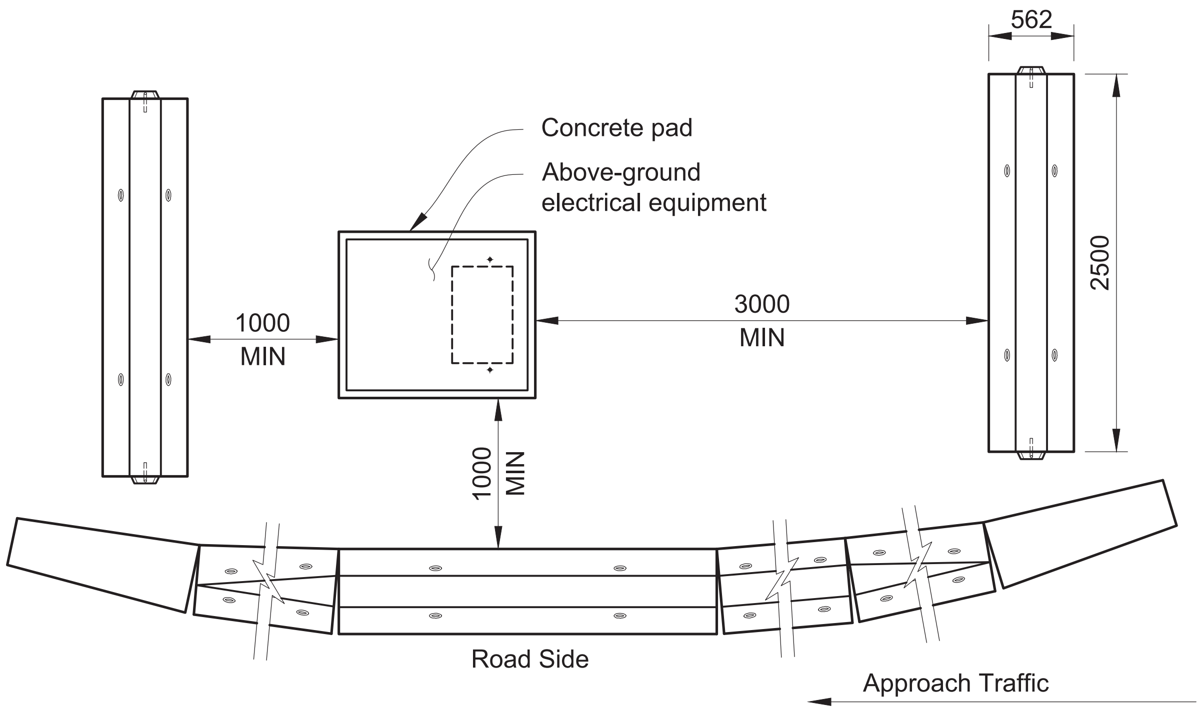
C. CROWSON	L. STEVANOVIC	F. DENNERT	PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, C. E. CROWSON # 45713, 2018-10-30	CONCRETE PAD PROTECTION ROADSIDE BARRIERS
DISTRIBUTION STANDARDS BC Hydro	ISSUED: OCT 2018 REPLACES: N/A ORIGINALLYISSUED: JUL 2018		PAGE 1 OF 3	ES54 U2-03.01 — R 0

REVISIONS:



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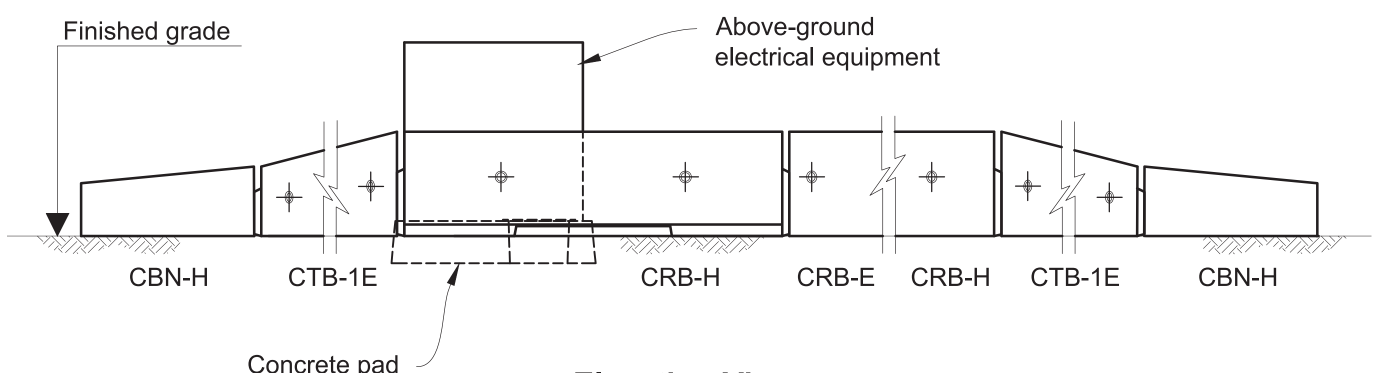

Elevation View

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REVISIONS:

DISTRIBUTION STANDARDS

BC Hydro

ISSUED: OCT 2018
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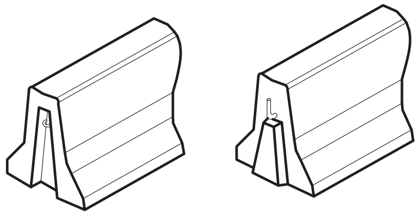
ORIGINALLYISSUED: JUL 2018

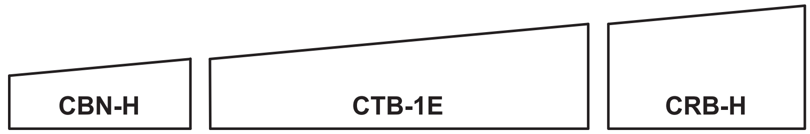
CONCRETE PAD PROTECTION
ROADSIDE BARRIERS

ES54 U2-03.02

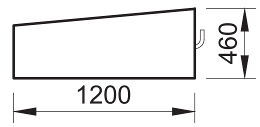
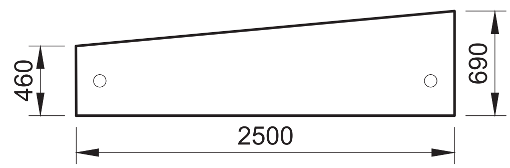
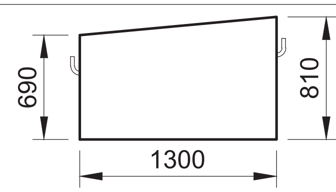
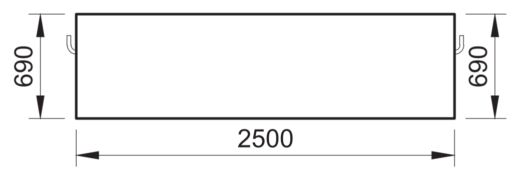
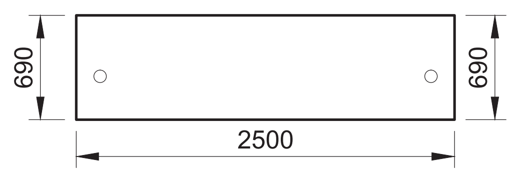
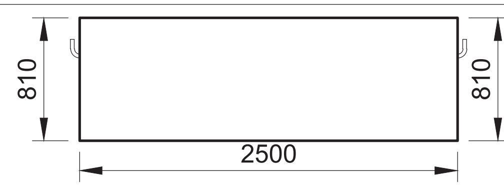
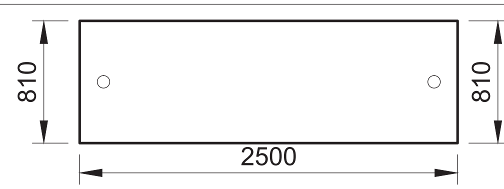
R 0



Eye	Hook



Connection Configuration

Type	Description	Attachment	Illustration
CBN-H	Bull Nose 460mm	Hook	
CTB-1E	Transition 690 mm- 460mm	Eye	
CTB-2H	Transition 810 mm - 690 mm	Hook	
CRB-H	Roadside 690 mm	Hook	
CRB-E	Roadside 690 mm	Eye	
CMB-H	Median 810 mm	Hook	
CMB-E	Median 810 mm	Eye	

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C. CROWSON	L. STEVANOVIC	F. DENNERT	PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA C. E. CROWSON # 45713 2018-10-30	CONCRETE PAD PROTECTION ROADSIDE BARRIERS

REVISIONS:

DISTRIBUTION STANDARDS BC Hydro

ISSUED: OCT 2018
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ORIGINALLYISSUED: JUL 2018

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R 0

Application

This standard describes soil classes and how to identify them. The products included in this standard are designed based on the assumption that soils are class 1 to 5 and are not susceptible to liquefaction. Class 6 to 8 soils susceptible to liquefaction shall be considered a specific site condition and structures installed in such soils shall be designed accordingly.

Revision Notes

Added *Application* and *Revision Notes* sections. Updated soil class descriptions in Table 4. Substantive changes are marked by green vertical revision lines in the left margin. Minor rewording and grammar corrections are not marked. This revision released concurrently with Standards and Equipment Advisory Information Bulletin 2024-051 *Revised Downhaul Guy Alignment and Soil Standards*.

Notes

1. Soil Definition

Soil is the accumulation of mineral particles formed by physical and chemical rock weathering. These particles are transported by glaciers, water, and wind, which can change their size and shape. Soil particles retain the characteristics of the parent rock during the physical weathering. Chemical weathering changes the mineral characteristics of the parent rock. Soil particles can include boulder, gravel, sand, silt, clay, and organic material. Soil particles can be classified into three major groups:

a. Coarse grained soil particles are generally known as cohesionless soil or non-cohesive soil. They are visible to the naked eye. Examples are boulders, gravel, and sand.

b. Fine grained soil particles are generally known as cohesive soil and are not visible to the naked eye. Examples are silt and clay.

c. Organic soil particles contain a high level of natural organics, such as fibrous and amorphous peat or organic silt or clay.

Designed: D. Saadatmand	2025-03-14	Professional of Record Permit to Practice Number 1002449 PROFESSIONAL PROVINCE OF BRITISH COLUMBIA S. H. ABBAS # 33329 ENGINEER 2025-03-14	Soil Identification
Checked: S. Abbas, P. Eng	Syed. Abbas 2025-03-14		
Reviewed: P. Found, P. Eng			DISTRIBUTION STANDARDS BC Hydro — ES54 U3-01 R1
Approved: H. Giesbrecht, P. Eng	H Giesbrecht	Issued: 2025-03-14 Effective: 2025-03-14	

2. Soil Field Identification

Table 1 – Soil identification based on particle size

Soil identification		Particle size	Approximate size
Boulder		>200 mm	Larger than a soccer ball
Cobble		75 mm to 200 mm	Apple to soccer ball
Gravel	Coarse	19 mm to 75 mm	Thumb to apple
	Medium	4.75 mm to 19 mm	Pea to thumb
Sand	Coarse	2 mm to 4.75 mm	Rock salt to pea
	Medium	475 µm to 2 mm	Sugar to rock salt
	Fine	75 µm to 475 µm	Flour to sugar
Silty clay		<75 µm	Flour sized and smaller

The soil standard penetration test (SPT) uses a standardized 51 mm outer diameter split spoon sampler, driven into the soil with a 63.5 kg weight having a free fall of 760 mm. The blows required to drive the split spoon sampler a distance of 300 mm, after an initial penetration of 150 mm, is known as the SPT value.

Table 2 – Soil identification based on cohesionless soil compaction from the SPT

Compactness condition	SPT (blows per 0.3 m)
Very loose	0–4
Loose	4–10
Compact	10–30
Dense	30–50
Very dense	Over 50

Table 3 – Soil identification based on cohesive soil consistency

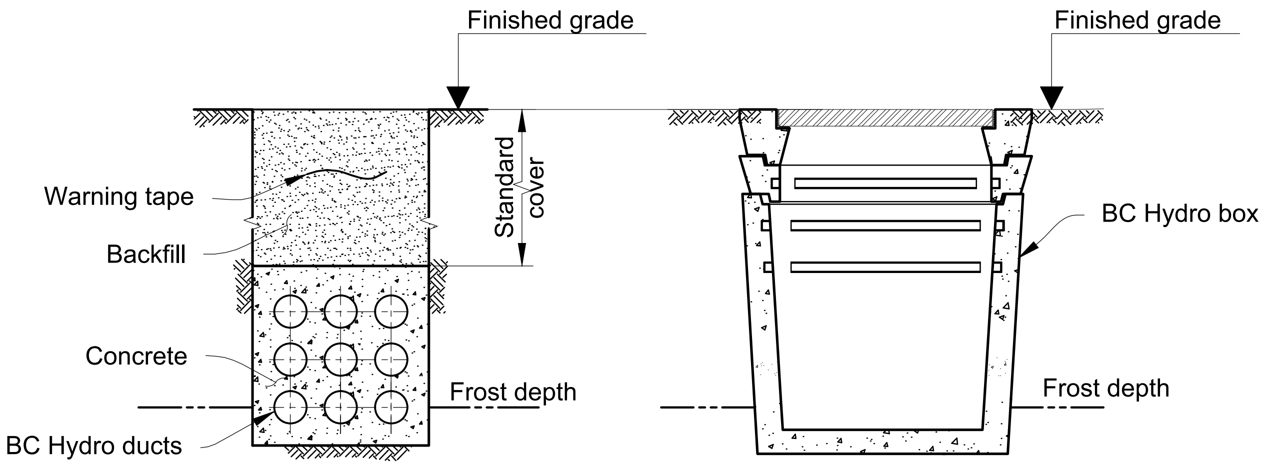
Consistency	Field identification criteria	Undrained shear strength (kPa)	SPT (blows per 0.3 m)
Very soft	Easily penetrated several cm by the fist	<12	<2
Soft	Easily penetrated several cm by the thumb	12–25	2–4
Firm	Can be penetrated several cm by the thumb with moderate effort	25–50	4–8
Stiff	Readily indented by the thumb, but penetrated only with great effort	50–100	8–15
Very stiff	Readily indented by the thumbnail	100–200	15–30
Hard	Indented with difficulty by the thumbnail	>200	>30

3. Soil Classification

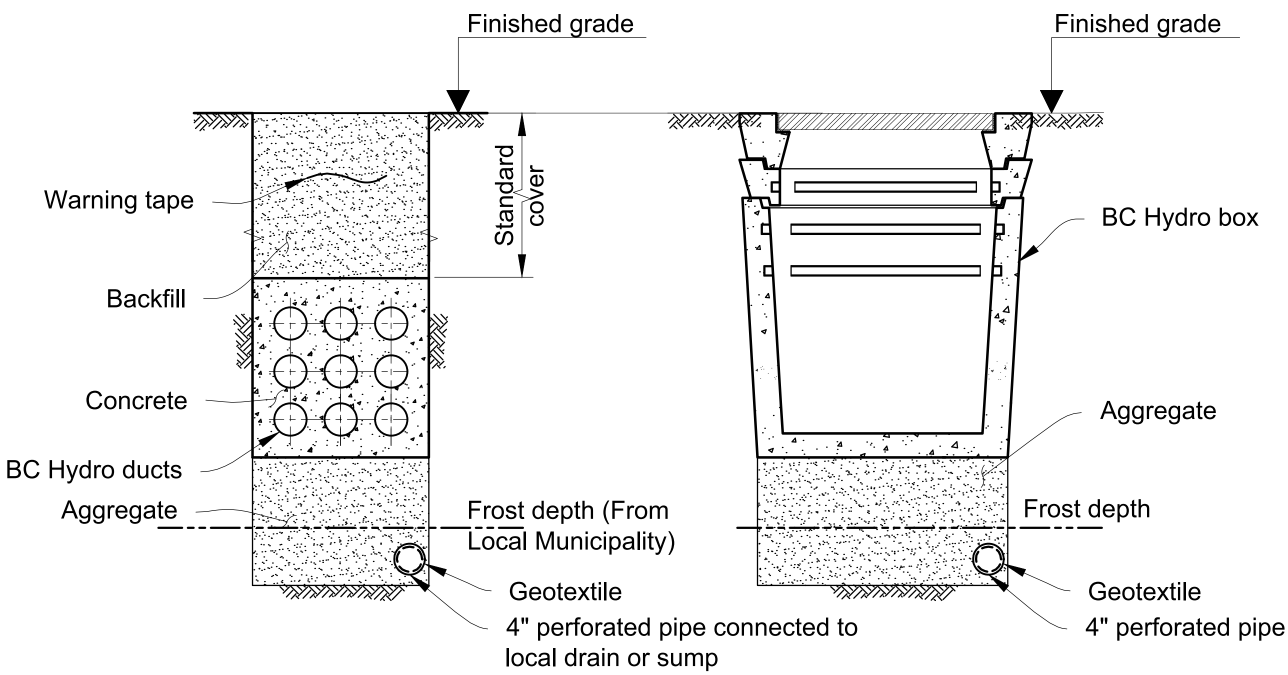
Soil strengths are difficult to measure due to the inhomogeneous nature of native soil. They must be estimated using experience and judgment. This standard recognizes the following soil classes for a preliminary field assessment.

Table 4 – Soil classes

Soil	Class	Description
Rock	1	Solid bedrock with minor to moderate fractures and jointing
Strong soils	2	Laminated rock, slate, sandstone, and undisturbed glacial till (hardpan) that can include materials such as: • Hard to very stiff silt or clay • Very dense sand and gravel
	3	Shale, highly fractured bedrock, stiff silt or clay, dense sand, and gravel
Medium strength soils	4	Compact sand and gravel, stiff to firm silt or clay
	5	Firm silt or clay, loose to compact sand and gravel, compact fine to coarse sand
Soft soils (weak)	6	Soft silt or clay, loose fine to coarse sand
	7	Loose mineral fill, very loose sand and gravel, very soft or sensitive silt or clay
	8	Swamp, marsh, peat, humus, organic silt



A. Frost Depth Above Concrete Base



B. Frost Depth Below Concrete Base

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BC Hydro

ISSUED: MAR 2016
REPLACES: N/A
ORIGINALLYISSUED: MAR 2016

REVISIONS:

SOIL
CONSTRUCTION IN FROSTED GROUND

PAGE 1 OF 2

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R 0

Notes

1. Duct shall be concrete-encased.
2. Concrete encasement shall be constructed as a monolithic pour.
3. Bottom of duct bank shall be placed below the frost depth as per case "A".
4. Alternately, when the duct bank is placed above the frost depth, granular backfill material shall be placed a minimum of 100 mm below the duct bank as per case "B". 4" perforated drain pipe shall be placed below the frost depth at a minimum 2 per cent grade.
5. Refer to local building codes for applicable frost depth conditions and frost depth requirements.
6. Backfill shall comply with Section W1-01.

DESIGNED	RECOMMENDED	ACCEPTED	ENGINEER OF RECORD
Syed. Abbas			PROFESSIONAL PROVINCE OF S. H. ABBAS # 33329 BRITISH COLUMBIA ENGINEER 2017-02-24
S. ABBAS	L. STEVANOVIC	F. DENNERT	

REVISIONS:

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REPLACES: N/A
ORIGINALLYISSUED: MAR 2016

SOIL
CONSTRUCTION IN FROSTED GROUND

ES54 U3-02.02

R 0

Application

This standard guides engineers designing duct banks in unstable ground conditions susceptible to settlement or movement that may adversely impact underground distribution system performance. Duct bank structural design considerations for differential settlements and seismic effects are outlined in this standard. Engineering judgment should be used in determining the applicability of this standard for any specific project based on risk and criticality of the duct bank. Such consideration shall be evaluated in collaboration with the BC Hydro project manager, distribution engineer, and designer to balance cost, risk, and system operability.

External parties performing engineering work are responsible for investigating and identifying alignments and locations that are susceptible to settlement or movement as part of their design scope. Identified locations shall be provided to BC Hydro for their determination of the applicability of this standard for the external party's design.

Underground duct banks are susceptible to ground movements that may result from unstable ground, landslides, slope instability, or seismic induced movement, including liquefaction and lateral spreading. Slope instability and seismic liquefaction commonly produce large ground movements that significantly affect the performance of an underground duct bank. Assessment of potential ground movements and duct bank and soil interaction is critical for performance evaluation and design.

Unstable ground conditions could include, but are not limited to:

- Soft or loose soils;
- Expansive or collapsible soils;
- Non-engineered fill;
- Soils with high-plastic soft clay or organic content, peat; and
- Construction near an unstable slope or ditch, or within a high water table area.

Geotechnical Assessment for Unstable Ground Conditions

A complete site-specific geotechnical assessment shall be performed for unstable ground conditions. The geotechnical assessment shall include relevant geotechnical information and recommendations including, but not limited to, the following:

- Subsoil conditions, soil logs, and slope stability;
- Bearing capacity and predicted total and differential settlement;
- Grain-sized distribution, plasticity, compressibility, and shear strength;
- Frost protection and groundwater issues and control;
- Excavation and backfilling recommendations;
- Seismic site characterization, liquefaction susceptibility, and estimated ground movement; and
- Constructability issues and recommendations.

A professional engineer (P.Eng) shall be retained to provide a site-specific design and construction procedures for construction in the unstable ground conditions. The design and construction procedures shall be submitted for acceptance to BC Hydro and the authority having jurisdiction.

Geotechnical Assessment for Preloading for or Near BC Hydro Plant

For an area being preloaded, the geotechnical site assessment shall include subsoil conditions, design, drawing, preload information, details about installation and monitoring of settlement gauges, piezometer, and information about densification or wick drains, if proposed. The geotechnical report shall specify all effects to, forces upon, and estimated settlement at the BC Hydro plant in the area resulting from the operation. It shall specify proposed monitoring and protection, if required, to ensure the integrity of the BC Hydro plant in the area. The professional of record (POR) shall be responsible for all design and field monitoring services. All proposed and as-built drawings signed and sealed by the POR shall be provided to BC Hydro.

Settlements Design

Unstable soils are not suitable for standard installation of BC Hydro structures and shall be subject to geotechnical investigations and a site-specific design. The design shall account for the effects of long-term settlements and seismic motions including liquefaction, lateral spreading, and fault displacements.

The overall design is an integrated process which includes both geotechnical and structural disciplines in the following functions:

1. Geotechnical investigation, assessment, and recommendations;
2. Structural analysis, modeling, and design; and
3. Final report and duct bank design.

The geotechnical assessment and recommendations should reflect the structural design needs and explore any ground modifications to mitigate settlements, liquefaction, and displacements.

The geotechnical data provides initial input parameters for structural analysis and modeling. The model and analysis may need to be adjusted to accommodate any soil modifications made to the geotechnical design.

Estimated long-term ground settlements and seismic displacements are to be used to design the duct bank.

Soil Settlements Design

The deformed shape of the duct bank in the structural model is developed based on the long-term soil settlement profile of the site. It is achieved by modelling the soil as a series of springs of differing stiffness supporting the duct bank.

If the final estimated soil settlements are not used, the structural analysis shall be modelled in staged construction to address concrete creep and soil settlement history.

Figure 1 shows an example of a structural model. The top figure is the deflected shape of the duct bank after soil settlement has occurred, the bottom figure is the associated moment diagram. The concrete duct bank reinforcement shall be designed to resist the maximum negative and positive bending moments.

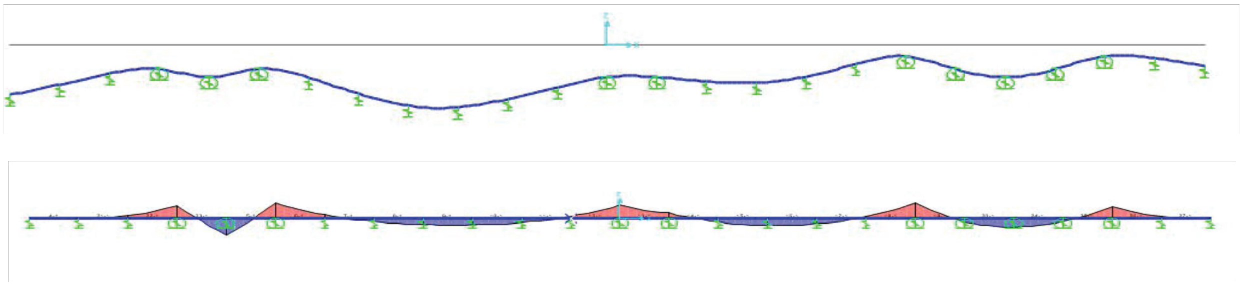


Figure 1. Duct Bank Model Settlement Profile and Moment Diagram

Seismic Design

Seismic design distribution structures are designed for 10% in 50 years probability of seismic reoccurrence (475-year return period). The design is based on performance objectives necessary to maintain life safety, avoid environmental damage, and provide reliable service. Seismic effects to be considered are ground acceleration and displacement. Their intensity depends on magnitude, type, distance, location, and soils. Loose sand, silty clays, and soft saturated granular soils perform poorly while bedrock and stiff soils generally perform better.

The direct effects of seismic ground acceleration on a duct bank are small and can be neglected. Hazards that effect the structural integrity of a buried duct bank are related to ground velocity and displacements. These hazards include fault rupture, liquefaction, lateral spread, slope instability, landslides, buoyancy, and settlements.

Seismic assessment of BC Hydro distribution duct banks installed in unstable soils shall consider the effects of liquefaction and lateral spreading. Liquefaction occurs in saturated non-plastic soils such as silt and sand, when soils lose strength and behave as liquid. Lateral spreading occurs in any unstable soils because of the ground shaking, regardless of liquefaction.

Liquefaction can cause duct bank vertical movements (settlements and buoyancy) and horizontal (lateral) movements. Ground settlements cause stresses in duct banks only in areas of differential settlement such as the boundary between liquefiable soils and improved soil to mitigate liquefaction or a pile supported structure. The design should ensure gradual transition of potential settlements and prevent any shearing effects when a duct bank is crossing such areas.

Buoyancy forces in liquified soil depend on pore water pressure and may vary from unit weight of water at the low side to unit weight of saturated soil at the high side. It is recommended to assess sinking based on low side and flotation based on high buoyancy. BC Hydro precast vaults and boxes are designed against flotation when submersed in ground water where buoyancy forces are based on unit weight of water. They are not designed for liquification induced buoyancy. To prevent floating in liquified soils, the vault should be installed with open floor drains to allow water and saturated soil to flow inside and out.

Lateral spreading occurs in areas close to the ground free face such as slopes, depressions, ridges, and water edges. The ground can move laterally in the range of a few metres depending on the distance to and height of the free face, and seismic hazards such as velocity, acceleration, epicenter location, and type of soil. Duct banks exposed to lateral spread may be subjected to high axial compression loads that can result in buckling of the ducts. Axial loads can be reduced by proper orientation of the duct bank relative to the direction of potential ground movement and by reducing friction at the duct bank and soil interface. The recommended option for reducing friction is to wrap the entire duct bank and surrounding backfill with two layers of geotextile fabric.

The following are recommended mitigation measures for duct banks installed in unstable soils or soils susceptible to liquefaction. If any of these mitigation measures are applied they shall be designed by a professional engineer.

1. Increase duct bank strength:
    a. Design reinforced concrete encased duct bank;
    b. If reinforced concrete is not feasible, design direct buried ducts;
    c. Design gasket joints to allow direct buried duct rotation and elongation; and
    d. Increase direct buried duct wall thickness (schedule 40 or 80).
2. Improve duct bank alignment:
    a. Avoid crossing faults;
    b. Avoid aligning the duct bank perpendicular to ridges and faults; and
    c. Avoid small radius bends.
3. Minimize soil friction on ducts:
    a. Use natural rounded aggregate;
    b. Excavate or backfill trench at 30 to 45 degree slopes; and
    c. Wrap the duct bank with two layers of geotextile to reduce axial loads.
4. Improve duct bank support:
    a. Design duct bank on piles; and
    b. Improve soil to limit liquefaction and lateral spreading effects.

Direct Buried Feeder Duct in Unstable Ground Conditions

When feeder ducts are directly buried, the design shall provide adequate duct-to-vault wall transition to avoid breaking the ducts at the wall connection and shearing the cables. PVC cemented joints are susceptible to cracking and splitting under a cyclic tensile / compression load and shall be installed applying adequate primer and cement according to manufacturers' recommendations.

Pulling twine (rope or wire) can burn through PVC ducts at bends (elbows) during the pulling process. Burning or melting results from frictional heat generated during pulling twine through the PVC duct bends. Fiberglass (RTRC) ducts do not melt. The extent of melting wear depends on bend radius and angle, pulling force, speed, length, and twine type. Steel pulling cable absorbs more heat than polyester rope and reduces frictional heat on contact surfaces. Providing a larger bending radius, smaller angle, lower pulling force and speed, and shorter length will reduce frictional heat and melting effect.

Friction melting should be considered when designing direct buried duct banks. When PVC ducts are encased in concrete, burning will not affect performance. When ducts are direct buried, debris from surrounded backfill may enter the duct through the cut slot and damage the conductor. To prevent burning-through effect, fiberglass (RTRC) elbows shall be used for direct buried feeder ducts.

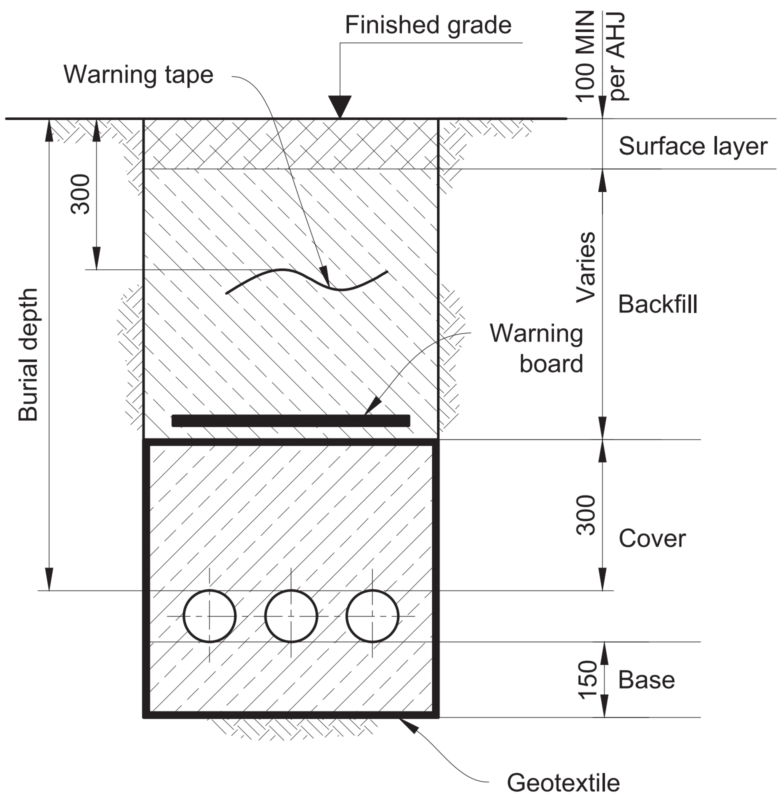
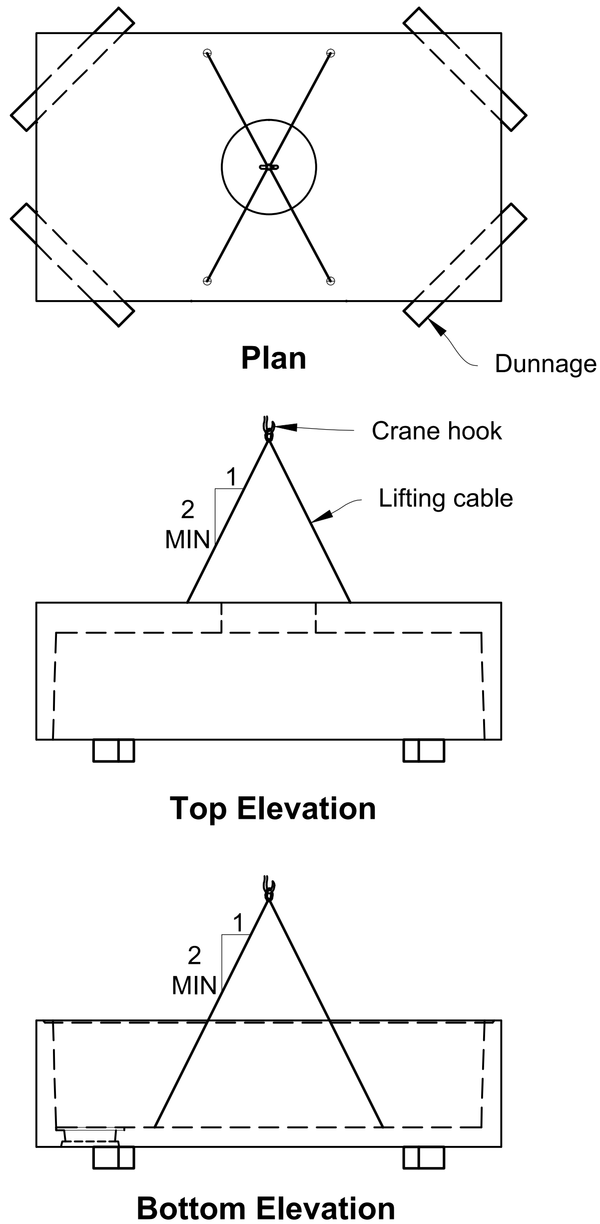


Figure 2. Example of Direct Buried Duct Installation with Geotextile



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S. ABBAS	L. STEVANOVIC	F. DENNERT	S. H. ABBAS # 33329 2017-02-24

DISTRIBUTION STANDARDS
BC Hydro

ISSUED: MAR 2016
REPLACES: N/A
ORIGINALLYISSUED: MAR 2016

LIFTING AND HANDLING VAULT

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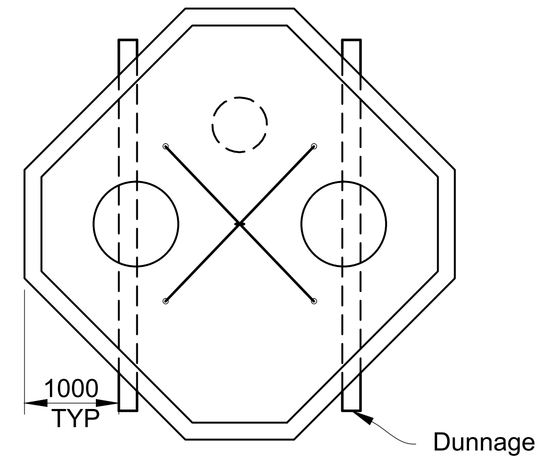
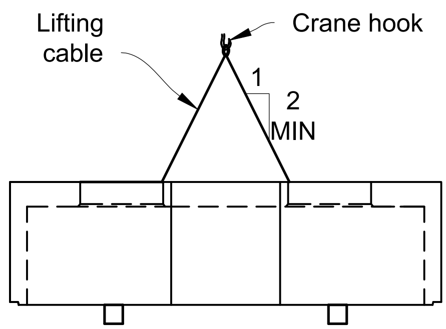
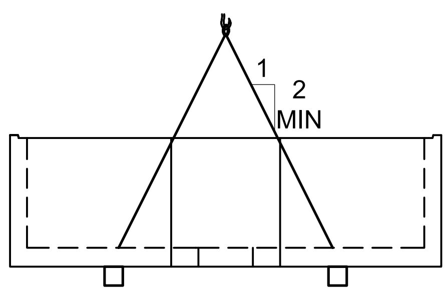


Plan



Top Elevation



Bottom Elevation

DESIGNED	RECOMMENDED	ACCEPTED	ENGINEER OF RECORD
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LIFTING AND HANDLING VAULT

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Abbreviation	Word, Term, Unit of Designation
°C	degrees Celsius
1C	single conductor
2C	two conductor
3C	three conductor
4C	four conductor
1PH	single-phase
3PH	three-phase
A	ampere
AC	alternating current
AGGR	aggregate
AL	aluminum
ANG	angle
APPROX	approximate, approximately
AWG	American wire gauge
BCH	BC Hydro
BLVD	boulevard
BWP	bushing well plug
CCR	concentric round stranding, class B
CL	centre line
CL	current limiting (fuse)
CN	concentric neutral
CPSE	counterpoise
CT	current transformer
CTM	cable transition module
CTS	cable transition splice
C/W	complete with
Cu	copper
CUB	cubicle
D, Δ	delta (connection)
DB	dead break
DC	direct current
DIA	diameter
DWG	drawing
EA	each
EL	elevation (view)
EPDM	ethylene/propylene diene monomer
EPR	ethylene/propylene rubber
F to F	face to face
FCI	faulted circuit indicator
FDR	feeder

Abbreviation	Word, Term, Unit of Designation
FIG	figure
flex.	flexible
FS	far side
FT	feed-through
g	gram
GA	gauge
GALV	galvanize(d)
GND	ground, grounding
GR	grade
HD	hard drawn
HGT	height
HMWPE	high molecular weight polyethylene
HS	heat shrink
HTS	heat shrinkable transition splice
HV	high voltage
Hz	Hertz
ID	inside diameter
IMPD	impedance
INCL	include, inclusive
INCP	insulating cap
JB	junction box
JBAR	junction bar
JK	junction kiosk
kcm	kilo circular mils (previously MCM)
kV	kilovolt
kVA	kilovolt ampere
kVAR	kilovolt amperes reactive
L	litre
LB	load break
LC	longitudinally corrugated (shield)
LF	low frequency
LL	lot line
LPT	low profile transformer
M	mega ($=10^6$)
m	metre
MAX	maximum
MDH	medium hard drawn
MH	manhole
MIN	minimum
NA	not applicable
NO	normally open
No, #	number

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ABBREVIATIONS

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BC Hydro

ISSUED: MAR 2016
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REVISIONS:

Abbreviation	Word, Term, Unit of Designation
NOP	normally open point
NPS	nominal pipe size
NPT	standard taper pipe thread
NS	near side
NTS	not to scale
Ω	Ohm
OC	on centre
OD	outside diameter
OPVC	oil packed varnished cambric (tape)
OSM	oil stop module
Pa (PA)	pascal
PAR	parallel
PB	pull box
PCB	polychlorinated biphenyls
PE	polyethylene
PF	power factor
PH	phase
PH A, A	A phase
PH B, B	B phase
PH C, C	C phase
P/H	pothead
PILC	paper insulated lead covered
PL	plate
PL	property line
PMDFT	padmounted deadfront transformer
PO	purchase order
PVC	polyvinyl chloride
R	radius
RC	reinforced concrete
REQD	required
REV	revision
RFI	radio-frequency interference
RPM	revolutions per minute
RST	reinforcing steel
s	second (time)
SAP	self-amalgamating polymeric (tape)
SD	soft drawn
SHLD	shielded
SI	International System of Units
SIC	separable insulated connector
SOP	standoff plug
SPEC	specification
SPLB	splice box
SRM	Stress Relief Mastic

Abbreviation	Word, Term, Unit of Designation
SST	stainless steel
STD	standard
STL	steel
STRD	stranded
SVCEB	service box
SWGR	switchgear
TEL	telephone
TEMP	temperature
TFR	transformer
TP	terminal pole
TR	trench
TYP	typical
UD	underground distribution (three-phase)
UG	underground
UNC	unified coarse thread
UNF	unified fine thread
URD	underground residential distribution (single-phase)
V	volt
V.A	volt ampere
VOL	volume
W	watt
W.h	watt hour
WP	weatherproof (insulation)
WT	weight
XARM	crossarm
XLPE	cross linked polyethylene
Y	star or wye (connection)
YS	yield strength

Self-Grounding Structures

Traditional ground rods are subject to corrosion and can interfere with, or be damaged by, other utilities sharing congested underground corridors. Instead of using ground rods, Ufer grounds use the rebar in the foundation as a concrete-encased grounding electrode. This turns the structure's foundation into one large ground connection that lasts as long as the structure. Concrete is a better conductor than most soils and encasing a grounding electrode in concrete almost always decreases the resistance to ground. Ufer grounds were developed in the 1940s and are now common in residential and commercial buildings.

Concrete is a good conductor because of its high pH of 11-13, and its ability to absorb and retain moisture. This pH level is due to free ions in the structure, such as K+, Na+, and OH-, which promote the conduction of electricity. These ions leach into the surrounding soil and improve the electrical conductivity there as well. Ground resistance testing is done using the Wenner method. Simply touching the probes of a multi-meter to a wall of concrete does not give meaningful results.

Large fault currents going to ground can cause the concrete to rapidly heat up and vaporize its internal moisture. This could result in explosive cracking near the rebar components. Standards including IEEE-80 and IEEE-142-2007 define the minimum size, length, and type of rebar to be used to prevent such events. "W" type rebar is mandatory, since it is designed to be welded and therefore to handle large voltages and currents. Steel rebar is preferred over copper, which can be degraded by the high pH of the concrete. Any self-grounding structure reaching the surface must also have a counterpoise, to reduce step hazards above ground.

BC Hydro requirements for distribution ground fault currents are for them to withstand 6000 A for 10 cycles at 60 Hz. Table 1 below shows the current capacity per metre of rebar that is buried at least 0.7 metres (2 feet) in well-packed earth. The minimum size is 15M 400W. To find the total current capacity of the structure, add the capacity of each piece of rebar that is 15M 400W or greater. Rebar in the top 30 cm (1 foot) of the structure is not counted as per the depth requirement.

Table 1: Rebar Current Capacity

CSA Bar Designation Number	Current Capacity (Ampere/metre)
15M	285
20M	335
25M	425
35M	570

Example 1: 4212 C1 Double Entry Vault

Calculations are presented in Table 1 where the type (mark #), quantity and length of rebar have been taken from the vault Bill of Materials. Current capacity, C, is found in Table 1. Calculations for the top half must subtract the rebar located in the top 300 mm of the structure, which is not deep enough in the ground to count toward the grounding capacity. Rebar in the knockouts for the ducts does count. This rebar is bent outward and encased by the concrete poured for the duct installation. Adding both halves together, the current capacity from Table 2 is 155 KA. There is also 17.1 metres of 4AWG copper wire in the vault walls that connects all C-channels together. This has a current capacity of 285 A/m bringing the grand total to 160 KA.

Table 2: Vault Example

Bottom Half of Vault

Mark #	Current Capacity (A/m)	Quantity	Unit Length (mm)	Total Length (mm)	Total Current Capacity (A)
Example	C	Q	u	L=Q*u	T=L*C
10M01	0	8	990	7920	0
15M01	285	30	4230	126900	36167
15M02	285	6	3500	21000	5985
15M04	285	12	3630	43560	12415
15M05	285	22	2250	49500	14108
15M08	285	2	4500	9000	2565
15M09	285	8	4440	35520	10123
15M10	285	20	1910	38200	10887
15M12	285	2	2000	4000	1140
15M14	285	4	1160	4640	1322
15ME	285	4	0	0	0
20M01	335	24	1220	29280	9809
				Sub Total	**104520**

Top Half of Vault

Mark #	Current Capacity (A/m)	Quantity	Unit Length (mm)	Total Length (mm)	Total Length in Top 300 mm (mm)	Total Current Capacity (A)
Example	C	Q	u	L=Q*u	S	T=C*(L-S)
10M01	0	4	1350	5400	n/a	0
10M02	0	8	990	7920	n/a	0
15M01	285	24	4230	101520	50760	14467
15M02	285	2	4530	9060	5800	929
15M03	285	9	4470	40230	22320	5104
15M04	285	12	3630	43560	0	12415
15M05	285	16	2250	36000	36000	0
15M06	285	20	1990	39800	20600	5472
15M07	285	8	1050	8400	8400	0
15M12	285	18	600	10800	10800	0
15M13	285	8	3500	28000	22720	1505
15M14	285	4	1160	4640	0	1322
15M15	285	24	1750	42000	42000	0
15M16	285	4	1695	6780	3200	1020
15M17	285	4	1220	4880	0	1391
20M01	335	20	2035	40700	21600	6399
					Sub Total	**50023**