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BC Hydro
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Class of Work Specification

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Class of Work Specification for

Duct Crossing of Bridges

Designed / Recommended	Reviewed	Approved
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1.0 General

This specification applies to the design and construction of electrical distribution duct banks crossing a bridge by way of conduits hanging under or passing through a bridge superstructure. The bridge crossing design work shall include the above ground duct bank along the bridge and the underground duct bank to a minimum 6 m length from the abutment back wall or to the nearest pull box or vault at each end of the bridge.

2.0 Definitions

Unless the context requires otherwise, capitalized terms shall have the meanings described in Appendix A. Champion Fiberglass Technical Guide and BC Hydro underground civil standard ES54 W0-04 *Construction Specifications General Definitions*.

3.0 Standards

The following standards apply:

a) BC Hydro ES54 underground civil standards;

b) CAN/CSA-S6-14 *Canadian Highway Bridge Design Code*; and

c) B.C. Ministry of Transportation and Infrastructure supplement to CAN/CSA-S6-14 *Bridge Standards and Procedures Manual Volume 1 Supplement to CHBDC S6-14*.

4.0 Design and Record Drawings

4.1 Design by the Contractor

The contractor shall retain a professional of record (POR) for each engineering discipline. The POR shall be responsible for the design and documented field reviews in accordance with the Engineers and Geoscientists British Columbia (EGBC) *Guide to the Standard for Documented Field Reviews During Implementation or Construction*. The contractor shall complete and submit *Assurance of Professional Design* and *Assurance of Field Review* declaration forms.

4.2 Design Review by Owners Engineer

Design shall be subjected to the BC Hydro owner's engineer review. The contractor shall prepare and submit their design at the conceptual, detailed, and final design stages, and allow a minimum of two weeks for review.

The design review is done on a collegial level by collaboration between the owner's engineer and the POR design engineer. This collaboration should start from the beginning of the project by exchanging and challenging different design approaches and options. The owner's engineer position is to improve the design, addressing more than just the structural design, and ensure it fits BC Hydro standard practices.

The conceptual design shall address various options for the duct bank crossing, including vertical and horizontal alignments, locations of expansion joints and fixed hangers, and any project-specific issues identified by the POR.

Upon final acceptance, the contractor shall submit the signed and sealed issued for construction (IFC) drawings. Any design revisions during construction shall be approved by the POR and submitted to the owner's engineer for review and acceptance. Upon completion of construction, the contractor shall submit record drawings (as-built) and all related letters of assurance to BC Hydro. All engineering content, including design and record drawings, shall be signed and sealed by the POR. All drawings shall be submitted electronically in both PDF and AutoCAD formats.

5.0 Design

This specification is based on Champion Fiberglass Inc. design and components, but any other design and components proposed to BC Hydro will be considered for acceptance.

The design scope shall include access for maintenance at any point along the duct bank alignment at the bridge crossing. The POR shall work with BC Hydro to determine unique access requirements for each bridge crossing.

The design life of the completed works shall be same as the bridge design life.

5.1 Design Loads and Criteria

Deflection of the duct bank at serviceability limit state (SLS) combination 1 shall not exceed 16 mm.

The duct bank shall be designed for the following loads at ultimate limit states (ULS):

a) Electrical conductor self weight of 12.9 kg/m per duct, to be confirmed by BC Hydro;

b) Water inside the ducts;

c) Load effects from pulling the electrical conductor through the duct. Unless specified otherwise, the electrical conductor type is XLPE (cross-linked polyethylene). Pulling loads shall be provided by BC Hydro;

d) Conduit temperature (130°C) from continuous electrical current;

e) An ambient temperature range considering maximum and minimum mean daily temperature as per CSA S6 *Canadian Highway Bridge Design Code* section 3.9.4 *Temperature Effects*. Exposure to sunlight shall be considered for temperature effects;

f) Wind loads to be based on the return period used for the bridge design;

g) Earthquake effects to be based on the return period and performance level used for the bridge design, considering the duct bank as a component of a bridge primary member; and

h) Effects from the bridge structure such as temperature, concrete shrinkage, creep, camber adjustment, and live load deflections.

5.2 Design Drawings

Design drawings shall include the following information, as applicable:

a) Design standards;

b) Design loads and criteria in accordance with section 5.1 Design Loads and Criteria;

c) Any design assumptions;

d) Identification of materials, components, standards, specifications, manufacturer, and model number;

e) Duct bank general alignment shown in plan view, elevation, and typical cross sections, including overhead and underground portions between pull boxes or vaults on each end of the bridge;

f) All dimensions necessary for construction;

g) Detailed profile identifying all components including but not limited to fittings, standard and anchor hangers, and expansion joints;

h) Installation arrangements and sequences;

i) Expansion joints installation chart in reference to the ambient temperature during installation;

j) Sliding connections of expansion joints marked “No Epoxy”; and

k) Details of any structures or attachments required to enable BC Hydro to access, operate, and maintain the BC Hydro plant (for example, aerial maintenance chambers and platforms – see section 8.5 Pulling and Splicing of Conductors).

5.3 Field Review

The field review shall include inspection of expansion joints prior to installation for any defects and limits of expansion and contraction. Sliding portions of the expansion joints shall be marked to clearly indicate they are not epoxy cemented.

6.0 Duct Location and Attachment

The duct bank alignment design includes an overhead portion at the bridge crossing and an underground portion to the pull boxes or vaults at each end of the bridge. The main objective is to keep vertical and horizontal alignments in a straight line as much as practicable.

The following conditions apply:

a) Above ground duct bank shall be aligned both horizontally and vertically with the below ground duct bank along bridge approaches, keeping consistency and uniformity following the bridge alignment;

b) Separation from other utilities shall be maintained as per BC Hydro ES54 H4 duct clearances standards;

c) Duct bank shall be located below the bridge deck within the bridge superstructure, under the cantilevered portion of the bridge deck, and shall not project below the bridge superstructure in profile view, or outside the bridge deck in plan view;

d) Location shall allow heat dissipation. Duct bank shall not be shielded by an object or other utility that may restrict proper ventilation;

e) Duct bank shall be minimum 1.0 m above the 200-year high water level (Q200);

f) Duct bank shall be secured and protected from wood debris in streams and falling objects;

g) Duct bank shall be adequately separated from combustible fluid (liquid or gas) lines;

h) Duct bank and all primary components of the bridge shall be accessible for inspection and maintenance;

i) Duct bank shall not pass through voided decks or box girders unless the voids are accessible for inspection and maintenance;

j) Duct bank shall be connected permanently to the bridge superstructure and follow the roadway horizontal and vertical alignment with a constant offset from the roadway centreline;

k) Couplings shall be provided at all bridge transition joints (i.e. expansion joints) to allow for all possible movements without damage. At transition joints over or near structural bearings designed to be replaced, allowance shall be provided for differential vertical movement when jacking. Allowance shall not be less than 15 mm;

l) Duct openings made through abutment or diaphragm walls shall allow for free transverse duct movement in any direction, but not less than 13 mm; and

m) Minimum 2% longitudinal grade slope shall be provided for drainage.

7.0 Materials

Above ground ducts shall be reinforced thermosetting resin conduit (RTRC), grey in colour, with a minimum nominal wall thickness of 6 mm. For installation in urban areas or where the duct bank is adequately protected and secured, the wall thickness may be reduced to 3 mm. All duct splices shall be joined with epoxy adhesive (referred to as tight lock joints by Champion Fiberglass).

Steel hangers shall not be used in combination with fiberglass duct. All hardware, hangers, and fittings shall be compatible with the duct.

All steel hardware material shall be corrosion resistant unless adequate corrosion protection is accepted by BC Hydro. The type and degree of corrosion protection shall be shown on the drawings.

8.0 Duct System

8.1 General

Unless BC Hydro requests otherwise, duct shall be 5" inside diameter nominal size. The number and configuration of the ducts shall be as per BC Hydro’s

request. A minimum of 50 mm clear spacing shall be maintained between ducts for heat dissipation.

8.2 In-Trench Duct

All underground ductwork included in the design shall comply with BC Hydro ES54 underground civil standards and Class of Work Specification 1323 *Construction of Underground Electrical Distribution Structures by a BC Hydro Customer*.

Duct banks constructed near approaches, abutments, or any area subject to differential settlement, shall be designed and constructed for site specific geotechnical conditions.

8.3 Transition Couplings

Transition couplings shall be used for the transition from PVC to RTRC duct (i.e. Champion Fiberglas 50-DHW27-DBII and 50-DXW27-DBII for transition of 5" fiberglass heavy duty and extra duty ducts to PVC DB2 ducts).

8.4 Duct Bank Expansion Joints

Expansion joints consist of two parts, a sleeve and a short duct with a socket end for connection with the conduit. Each conduct in the duct bank is cut at the expansion joint location to fit the joint, and cut ends are epoxy cemented to the expansion joint. All expansion joints in one section shall be installed in the same orientation. Caution shall be taken to keep the sliding portion of the expansion joints clean.

Selection, design, and installation of expansion joints is critical for duct bank performance and structural integrity. Duct bank expansion joints are designed to accommodate expansion and contraction strains on the duct bank caused by ambient temperature, conductor temperature, and bridge superstructure strains, deflections, and other effects as applicable. Restricting such strains would cause extensive stresses in the conduits leading to failure.

Duct bank expansion joints are located along the bridge span and aligned with the bridge expansion joints or other components designed to allow bridge expansion.

Conduit RTRC material has almost double the thermal expansion coefficient than that of the bridge superstructure material (concrete and steel). Conduits are also exposed to additional temperature dissipated from conductors which adds strains in the conduits proportional to the electrical loads. Expansion joints along the span are designed to compensate for differences in temperature strains between duct bank and bridge superstructure, while the joints aligned and compatible with the bridge expansion joints are designed to allow ducts bank to follow bridge expansion.

8.5 Pulling and Splicing of Conductors

Conductors are typically pulled and spliced in underground vaults located at either side of the bridge. Above ground duct banks with a continuous length over

500 m may need additional pulling and splicing locations within the bridge length, depending on the duct bank configuration and alignment.

8.6 Hangers

The ducts shall be suspended under the bridge by a hanger system. Details of the Champion Fiberglass typical hanger system are shown in Appendix A. Champion Fiberglass Technical Guide.

8.7 Public Protection

The duct bank shall be inaccessible to unauthorized persons. Any enclosure designed to restrict access shall be made of perforated material to allow air circulation and heat dissipation.

9.0 Control of the Work

The contractor shall have complete control of the work and shall effectively direct and supervise the work to ensure conformance with the design. The contractor shall be solely responsible for construction means, methods, techniques, sequences, and procedures, and for coordinating the various parts of the work. The contractor shall maintain the work in a tidy condition and free from the accumulation of waste, debris, and waste products.

The contractor shall provide and maintain competent supervisory personnel and workforce at all times, sufficient to complete the work, and shall disclose knowledge, skills, prior experience, and professional standing or technical or trade certification of any person appointed, employed, or used by the contractor in carrying out any part of the work.

10.0 Warranty

Upon duct bank installation, the contractor shall run a test mandrel in accordance with BC Hydro standard ES54 H0-02 *Duct General Notes*.

The contractor warrants to BC Hydro that:

a) The design is free from deficiencies, including those from errors and omissions;

b) For a period of two years following the completion date, all work is free from defects in materials and workmanship; and

c) The contractor shall, upon notification by BC Hydro, remedy any deficiencies at the contractor's expanse to the satisfaction of BC Hydro.

Appendix A. Champion Fiberglass Technical Guide

The Champion Fiberglass catalogue can be downloaded from their website.

A.1 Expansion and Fixed Joints

The thermal coefficient of the fiberglass ducts is 2.2×10^{-5} 1/ C.

The number of expansion joints required is a function of the crossing length and, in general, the following rule is used:

a) Duct bank lengths less than 15 m do not require an expansion joint;

b) Lengths from 15 m to 61 m require one expansion joint installed mid length; and

c) Lengths greater than 61 m require at least two expansion joints.

When designing longer lengths, place the first two expansion joints at 30 m maximum from each abutment, then space expansion joints equally every 61 m maximum.

Fixed joints are installed at midpoints between two expansion joints. They are provided by installing split anchor rings on either side of the anchor hanger and bonded with epoxy adhesive to the outside of the conduit.

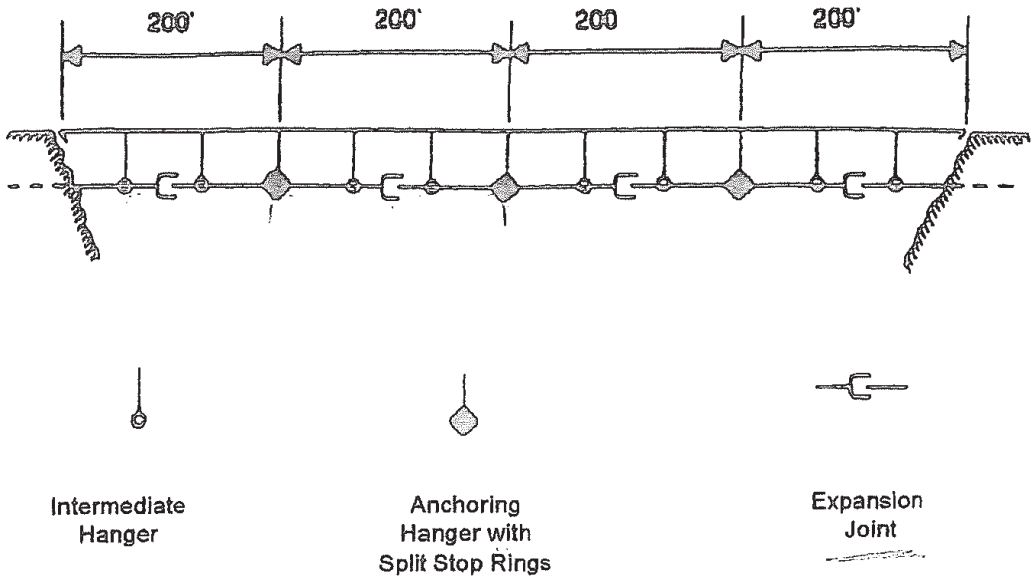

Figure A-1. Sample plan showing arrangement of expansion and fixed joints

A.2 Duct Supports (Hangers)

Hangers are anchored to the bridge superstructure and provide support to the duct bank. Configure the hanger system to allow for a minimum of 50 mm clear spacing between adjacent conduits, both horizontally and vertically. A typical hanger system is made up of a combination of intermediate hangers and anchor hangers.

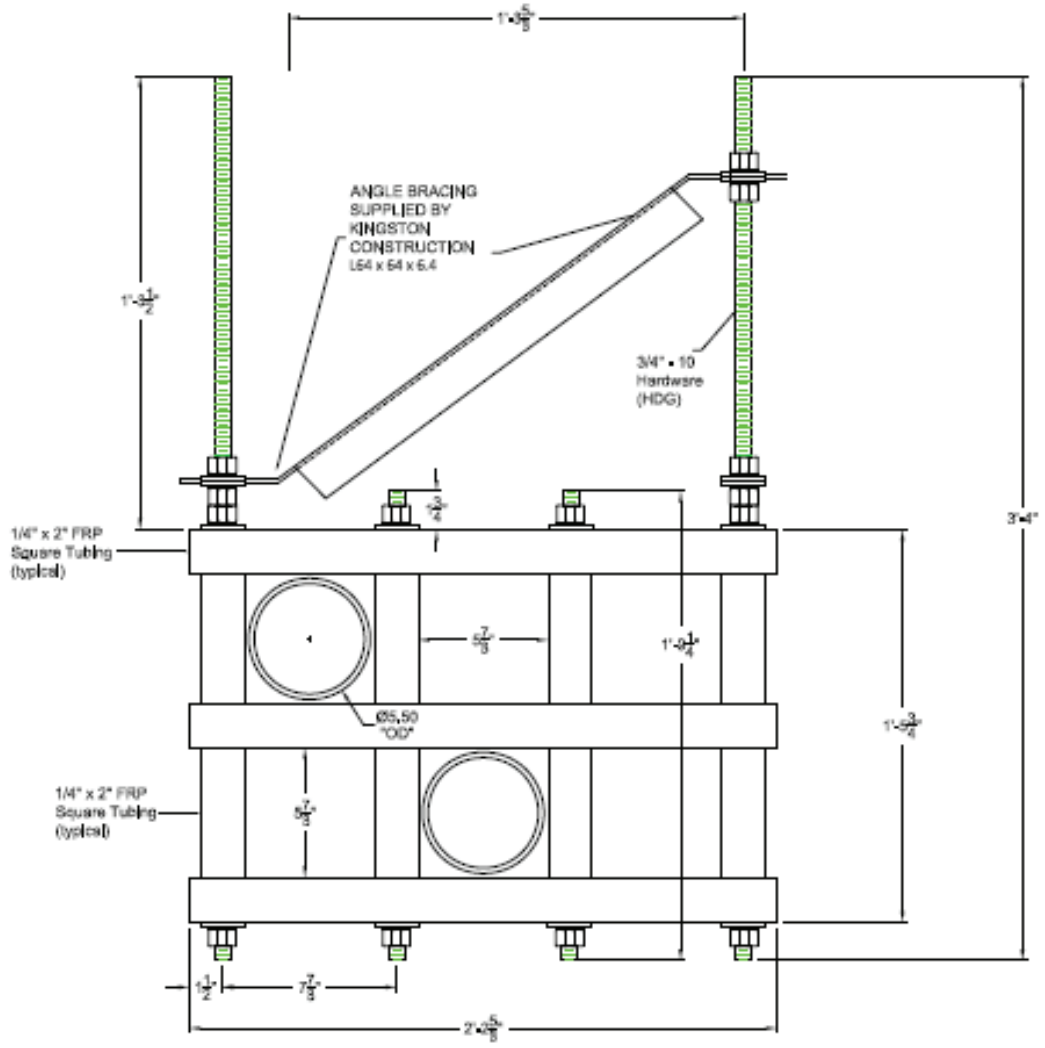

Figure A-2. Typical intermediate hanger design

A.2.1 Location of Supports

The location of supports (i.e. hangers) is determined based on the selected mid-span deflection, given the total cable weight and elastic properties of the conduit. Figure A-3 is a deflection curve that can be used to easily determine support distance between hangars for the most commonly used conduit on BC Hydro crossings. Champion Fiberglass provides deflection graphs for various other diameters and wall thicknesses.

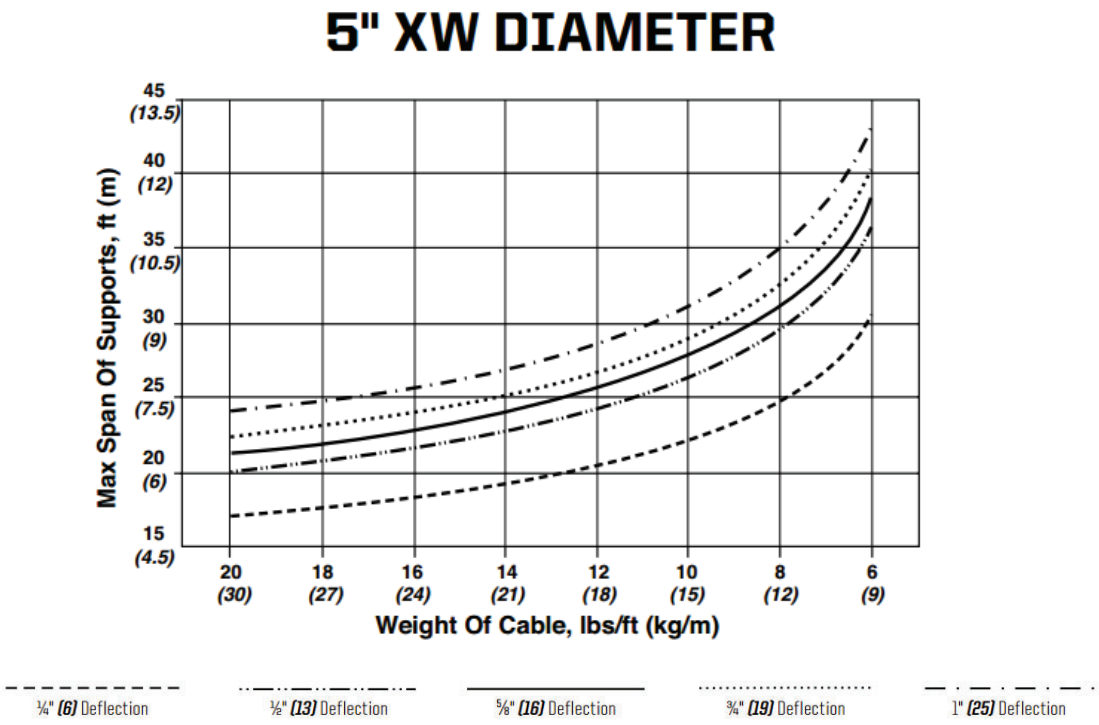

Figure A-3. Example deflection diagram from Champion Fiberglass Technical Guide

A.2.2 Anchor Hangers

Anchor hangers are used to restrict duct longitudinal movements and provide fixed joints in the ducts. They are similar to intermediate hangers but have bracing members attached to support longitudinal forces.

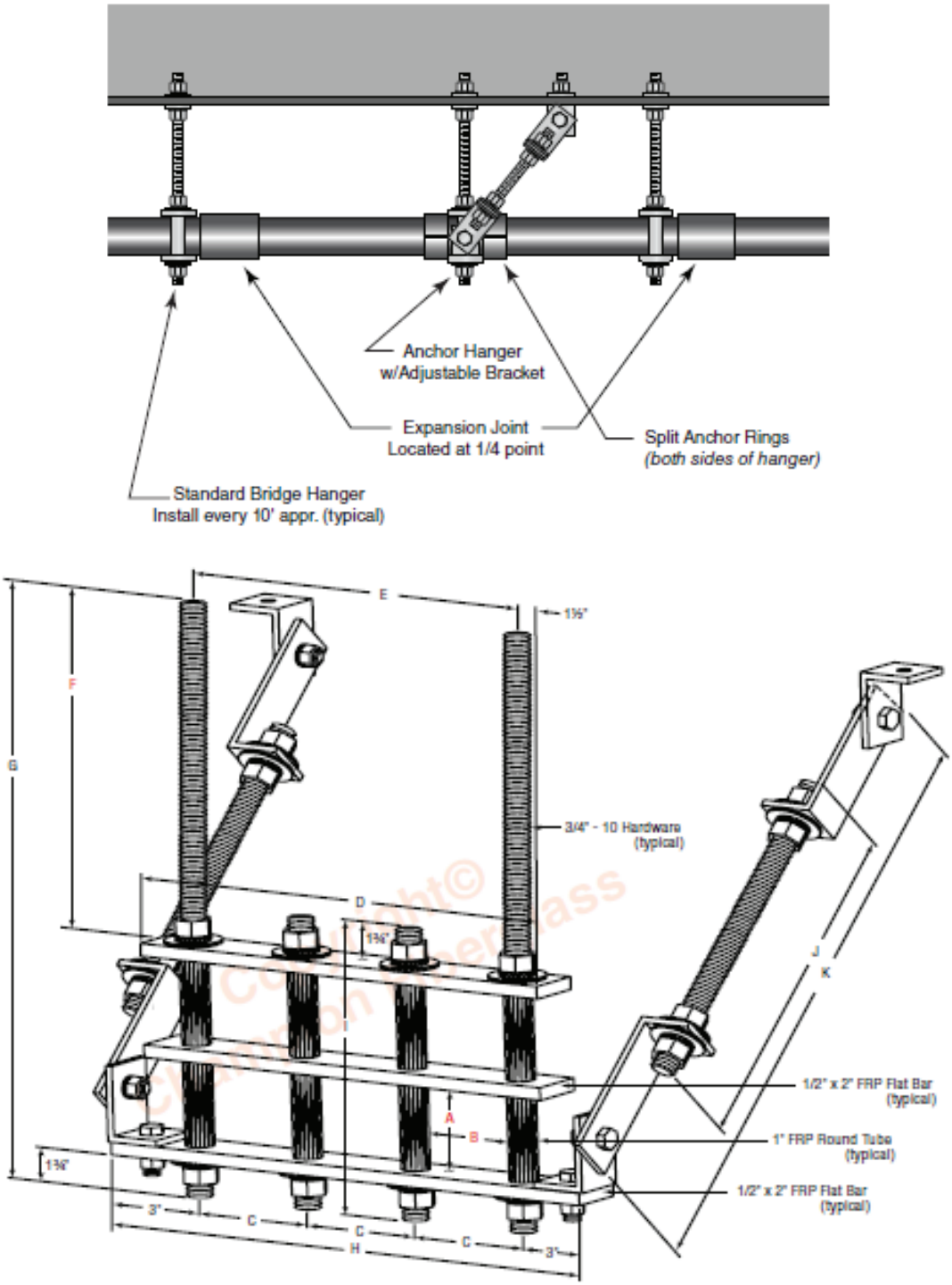

Figure A-4. Champion Fiberglass anchor hangers

Appendix B. Sample Details

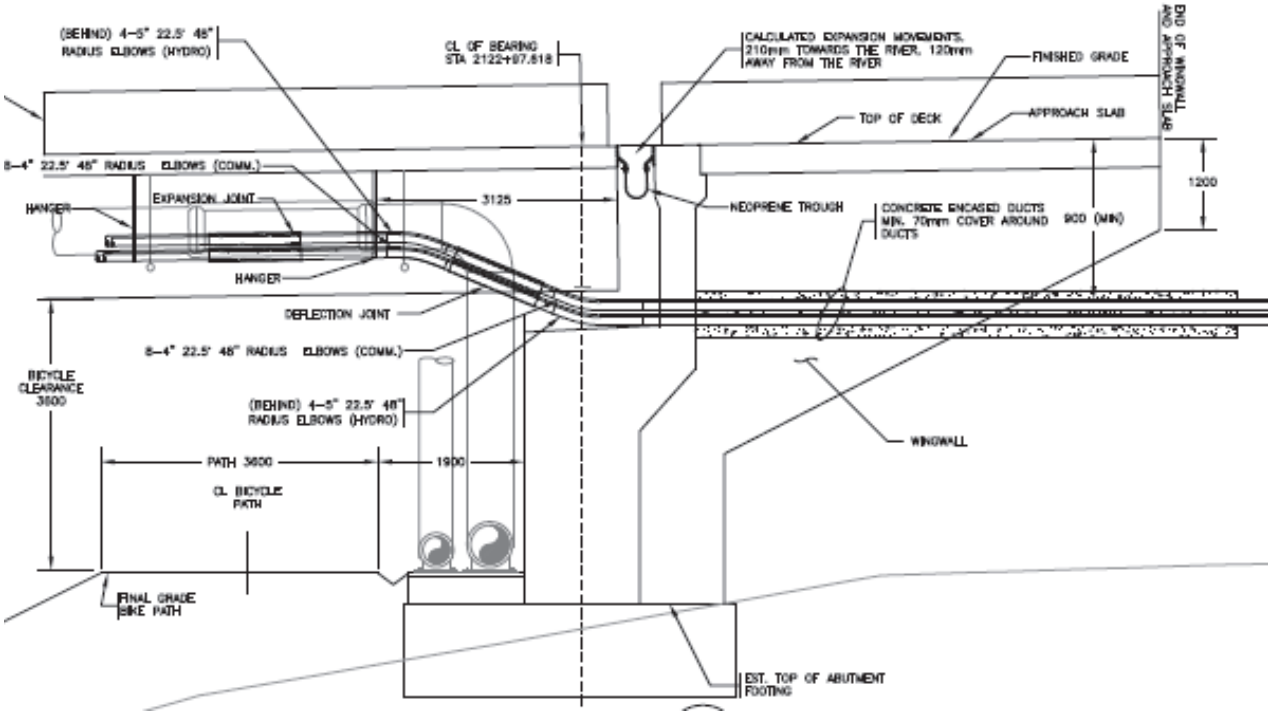

Figure B-1. Sample transition detail at abutment wall