18.1 Construction of CSP and SPCSP Structures - General

The construction of Corrugated Steel Pipe (CSP) and Structural Plate Corrugated Steel Pipe (SPCSP) includes the supply, fabrication, delivery and installation of all culvert and culvert enhancement materials.

18.2 Environmental Constraints

- Fishery concerns
- Code of Practice considerations of instream activities window
- Environmental Construction Operation Plan requirements
- Easement and site access
- Stream flow accommodation – stream diversion
- Siltation prevention measures
- Climatic and ground water conditions
- Seepage control requirements
- Disposal of unsuitable backfill or waste material

18.3 Safety

Refer to the Alberta's Occupational Health and Safety Regulation, General Safety Requirements for specific safety requirements:

- Part 3 Health and Safety Plan
- Part 4 Hazard Assessment, Elimination and Control
- Part 5 Specifications and Certifications
- Part 8 Emergency Preparedness and Response
- Part 11 Fire and Explosion Hazards
- Part 12 Lifting and Handling Loads

- Part 15 Personal Protective Equipment
- Part 16 Powered Mobile Equipment
- Part 27 Excavation, Tunnelling and Trenching
- Traffic Accommodation Strategy

18.4 Bridge Inspector's Record

It is important for the Bridge Inspector to keep an accurate and detailed record, with photographs where possible, to minimize any potential extra claims.

- Record culvert conditions before, during or after fabrication, delivery or installation:
  - CSP or SPCSP Inspection Report,
  - Culvert Installation Inspection Report,
  - Culvert Barrel Measurements, etc.

- All survey information:
  - Profiles and cross-sections,
  - Culvert locations or alignments,
  - Elevations and cambers,
  - Span and rise measurements, etc.

- All quality control test results.

- Sieve analysis for all granular backfill material and for concrete aggregates, as specified

- Record details of discussions and/or instructions conveyed to the Contractor:
  - Minutes of site meetings
  - Work schedules and work methods
  - Any site instructions or stop work orders
  - Extra work orders
  - Progress estimates
  - List of deficiencies, rejections and acceptances, etc.

Prior to excavation, the Bridge Inspector must take a series of levels of the ground surface in the area of the excavation. This survey forms the datum for calculations of the excavated quantities and provides information for future reference, settlements of disputes, etc. Photographs of the original ground of the non-excavated site are required to record conditions prior to the beginning of excavation.

- It is the responsibility of the Contractor to ensure that there are no utilities in the area to be excavated or, if there are utilities that they are accurately located, protected and/or relocated.

- The Bridge Inspector should record the elevations of groundwater, stream water levels and tops of berms and dikes.

- The Bridge Inspector should record the material type excavated. The Bridge Project Engineer shall be notified if soft and yielding material is encountered to review the need for foundation modifications.

- Photographs and records of equipment used for excavation are necessary for reference purposes.

It is important that the Bridge Inspector keep an accurate record of the following backfill items:

- In situation where the backfill is deficient and extra backfill material is anticipated in order to achieve the final gradeline, it is essential to obtain and record before and after cross-sections so that an accurate quantity of the extra backfill material can be calculated for payment purposes.

- The results of density tests need to be accurately recorded in order that rejection or acceptance of a backfill material can be validated.

- All rejected work should be recorded.

- Include the date and any related discussions held with the Contractor, and stated reasons for rejection of any work.

18.5 Supply, Fabrication and Delivery

Supply and Fabrication of CSP and SPCSP are to be in accordance with CSA Standards G401 with additions and exceptions described in Section 18 of the Specifications for Bridge Construction.

- Double zinc coating mass on both sides of pipe shall not less than, 1220 g/m^2 when tested by the triple spot test or 1100 g/m^2 when tested by the single spot test.

- Five copies of the shop drawings for any non-standard materials, (elbows, bottomless arch details, SPCSP bevel end details, horizontal ellipses, etc.) are required to be submitted to the Consultant for review prior to fabrication.

- SPCSP plate arrangement of the bolts in the valley of each longitudinal seam shall be nearer to the visible edge of the plate than the bolts in the crest.

- One set of the assembly drawings must be supplied with the material to the site.

- All pipe supplied shall be clearly marked with the following information at intervals of not more than 3 metres.
  - Manufacturer's name or trade mark
  - Nominal thickness and type of metal
  - Plate/metal coating for non standard coating
  - Specification designation
  - Plant designation code
  - Date of manufacture

18.5.1 CSP Fabrication

- Tables A and B in Section 18 of the Specifications for Bridge illustrate details of sloped end sections for CSP round culverts.

- Lockseams terminating at cut edges shall have 75 mm length of fillet weld (staggered 300 mm apart) run along both sides of the lockseam with the weld area zinc coated in accordance with CSA G401.

- Cut ends shall be made smooth by grinding and zinc coated in accordance with CSA G401.

- All CSP shall have ends recorrugated to provide annular corrugations for couplers.

- Only annular corrugated couplers will be accepted.

18.5.2 SPCSP Fabrication

- Table C in Section 18 of the Specifications for Bridge illustrate details of sloped end sections for SPCSP round culverts.

- SPCSP material shall be unloaded and stockpiled in a neat and orderly manner, in order to facilitate inspection of inventory.

- SPCSP material is to be stored concave down to reduce the occurrence of stain damage on plates which are not going to be assembled immediately.

- All culvert material shall be handled carefully and in such a manner as to prevent bruising, scaling or breaking of the galvanized coating.

18.6 Installation

The installation of CSP and SPCSP includes excavation, bed preparation, pipe assembly, backfill and culvert enhancements.

18.6.1 Excavation

Installation of culverts generally involves "short-term" vertical and/or sloped excavations in order to:

- Divert water around the site.
- Remove soft or yielding material at least 600 mm below the culvert invert so as to provide a firm foundation.
- Remove solid rock material 150 mm to 300 mm below the culvert invert so as to provide for the bedding layer. Place the culvert below average streambed elevation.
- Provide enough space for assembly of the culvert and operation of equipment for placement and compaction of the structural fill.
- Place heavy rock riprap at the ends of the culvert.

(1) Class of Excavation

All excavations below finished gradeline for the installation, removal and/or salvage of culverts, placement of heavy rock riprap, and stream diversions are classified as "channel excavation". The only exception is when solid beds or masses of rocks or boulders exceeding 0.5 cubic metre are encountered, in which case that portion of the excavation is classified as "rock excavation".

(2) Limits of Excavation

In general, the excavation for culvert installation should extend 600 mm below the pipe invert for the entire width of the excavation. The width of the excavation is defined as the pipe width plus 3 m at the invert elevation. The sides of the excavation are generally sloped at one horizontal to one vertical but should be adjusted depending on the depth of excavation, soil type and climatic conditions. The Contractor should also consider extending the excavation limits to include the bedding requirements for rock riprap.

The excavation is to be carried out to the design lines as shown on the drawings. Over excavation for any reason will not be paid for unless recognized and proven as necessary by the Bridge Project Engineer.

In some cases additional excavation may be required to:

- Provide more space for assembly, large excavation equipment, etc.

- Remove soft or yielding material to the specified depth below the pipe invert and/or the specified distance from the side of pipe.

- Stabilize the sides of the excavation by providing benches.

(3) Wet Excavation

In general, vertical banks should be avoided in wet conditions. Some soils will stand at considerable depths vertically while most will slough off to a stable angle or slide into the excavation. Sandy soils will tend to slough during excavation while cemented sands, silty clays and clays will stand up to greater depths.

For excavation in wet areas or excavation at the toe of the slope the following should be considered:

- Minimize the time the excavation has to remain open by proceeding immediately with backfill and culvert assembly.

- Unload the top of the slope as much as possible – remove spoil pile, construction material, etc.

- Do not allow construction equipment to park or travel on the top of the slope – the minimum distance from the top edge should be equal to or greater than the depth of the excavation.

- Use appropriate dewatering and/or drainage scheme.

- Prevent surface runoff from entering the work area.

- Consider using appropriate excavation equipment.

- If possible, excavation below the invert should be done in short sections and backfilled immediately.

- In special circumstances, undertake excavation during freezing conditions.

- Use geotextiles and/or perforated pipe to minimized the depth of excavation.

(4) Excavation Equipment

Sloped or vertical excavation, the type of soil and its moisture content will generally dictate the type of excavation equipment required. The common types of excavation

equipment are excavator, motor scraper, scraper-dozer combination, dragline, and clamshell.

18.6.2 Bedding

The bedding is that portion of the structural fill in contact with the bottom of the pipe and consists of the following layers:

- The 150 mm lift of crushed granular material below the pipe invert, placed in a loose uncompacted state.
- The 600 mm of granular pitrun material below loose crushed material, compacted to a minimum of 95% of Standard Proctor Density at optimum moisture content in 150 mm lifts.

18.6.3 Culvert Assembly

Placing and assembly of the pipe may proceed only after the excavation, foundation and bottom bedding material and shape have been inspected and approved by the Bridge Inspector.

Assembly of CSP sections shall be laid so that the ends are in close contact. Couplers shall be well fitted and evenly tightened all around the pipe. Where required joints shall be sealed using materials supplied by the Contractor.

SPCSP plates shall be correctly assembled as shown on the drawings provided by the pipe supplier and as outlined below:

- Follow manufacturer's instructions,
- Correct lapping of plates,
- Correct torquing of bolts (200 to 340 Nm),
- Maintain shape within 2% of design shape. The Contractor shall supply and install devices to monitor the shape of pipe.
- Correct contact (nesting) between plates.
- Torch cutting of holes or welding on the pipe is not permitted.

18.6.4 Backfill

CSP and SPCSP are flexible structures. Their integrity depends on the properties of the steel and structural fill, and the details of the construction process.

- Structural backfill consists of granular material except at the ends of the pipe when clay seepage cutoffs are specified within a structural fill envelope.
- Material beyond the structural fill envelope is embankment fill.

Granular material has the following favorable characteristics:

- Compaction is easier to control since it is not too sensitive to moisture content and temperatures.
- Higher shear strength is obtained and is not significantly affected by moisture content.
- Higher bearing capacity.
- Low potential for frost action due to its free draining characteristics and large void ratio.
- Can be placed and compacted at 0^{o}C thus allowing more flexibility for installation.
- Generally non-corrosive compared to clayey material.
- Negligible compressibility under high loads when saturated.
- Excellent workability as a construction material.

Compaction

All structural fill, except the 150 mm of granular material immediately below the pipe invert which is placed in a loose uncompacted state, must be compacted to a minimum of 95% Standard Proctor density at optimum moisture content in 150 mm lifts compacted. The structural fill is compacted in order to:

- Increase the soil strength in terms of higher bearing capacity.
- Decrease the compressibility of the soil thereby reducing the settlement.
- Decrease the void ratio which reduces inter-granular movement.

- Increase the passive resistance of the fill and thus reduce horizontal deflections.

- Provide uniform support along the pipe thus enhancing the soil-steel interaction.

- Compaction equipment includes a variety of sizes and shapes of rollers and tampers.

- Method of compaction:
  - Mechanical rollers
  - Hand operated tampers
  - Water jetting

- Field compaction control tests:
  - Nuclear methods
  - Rubber balloon method
  - Sand cone method
  - Rolling pattern

Large diameter SPCSP may require preshaping of the bedding to match the curvature but should terminate 200 mm from the top edge of the bottom plate, to facilitate proper pipe installation in order to:

- Reduce pipe deflection during assembly.

- Minimize rotation during backfill operation.

- Ensure firm contact with bottom surface of the pipe.

Camber is specified when the soil cover is high enough to cause long term differential settlement along the pipe invert. The top surface of the bedding must be constructed on a gradual crest curve with no sudden breaks in the grade. Sharp transitions in the grade will make culvert assembly difficult.

Materials in the haunch areas are considered critical to the integrity of the structure. Ensure that:

- Materials are of high quality and are compacted to 95% of Standard Proctor density at optimum moisture content.

- Material is carefully placed in thin layers and is compacted either using manual labour, manually operated air driven compactors, or water jetting.

- Material fills all corrugations and provides firm contact with the pipe.

18.7 Background on Culvert Enhancements

The following structural enhancements are specially designed additions or special features added to culverts to increase the limits of their structural performance and scope of application:

- End Treatment consists of:
  - Cut-off wall to prevent scouring and undermining of the ends of the culvert.
  - Shoulder or collar continued over the crown of the pipe to provide stiffening and stability and counteract buoyancy or hydraulic uplifts and to provide smooth transition thus decreasing entrance and exit losses with an increase in flow capacity.

- Concrete Headwalls are used for aesthetic reasons or more often as a retaining wall on the upper portion of the culvert to reduce overall longitudinal length.

- Steel Headwalls are used in small culvert where buoyancy and flexibility are not a concern. Since these headwalls are not designed to act as retaining walls the longitudinal length of the pipe cannot be reduced as much as if concrete headwalls were used.

- Fish baffles consisting of Precast Concrete, Cast-In-Place Concrete, Metal or Natural Rock are used to facilitate the passage of fish. Baffles have several effects in addition to provide resting areas for fish, they increases the invert roughness with a resulting boundary envelope of lower velocity which facilitate fish migration and encourages natural sedimentation of the invert.

- Reinforcement Ribs are commonly used in large elliptical culverts to provide additional bending moment capacity and cross-sectional area for the top arch to withstand the increased dead loads from the high cover.

- Thrust Blocks are continuous longitudinal structural stiffeners attached to the culvert along the junction of the side and top arc seams providing additional stiffness along critical seam. They also aid backfill compaction in this otherwise difficult area with a vertical face.

- Attached Concrete Slabs consist of a composite reinforced concrete slab cast onto the top arc portion of low profile horizontal ellipses and open arch flexible steel culvert.

- In the case when the amount of cover over the pipe does not meet the minimum requirements, Unattached Concrete Slabs are used to transfer most of the live loads to the backfill on the sides of the pipe.

- Releasable Joints are used on large horizontal ellipse or arch pipes to promote positive arching and/or permit relative vertical movement of the top and bottom arcs.

The joint between two arcs can be left loose to enable their relative movements and eventually be tightened.

18.8 Checklist

18.8.1 Bridge Inspector's Responsibilities

- Review and be familiar with applicable Specifications, Special Provisions and Drawings.
- Review arrangements of access routes and disposal area.
- Ensure Contractor complies with environmental permit conditions.
- Observe how excavation and insitu material behaves on exposure to weather and water.
- Confirm elevations and dimensions at the bottom of excavation.
- Report unusual seepage condition or unstable foundation condition to the Bridge Project Engineer.
- Keep good records of any excavation extending beyond the required depth.
- Ensure Bridge Project Engineer approves the backfill material.
- Check backfill material frequently to see it is free from topsoil and roots, large lumps and frozen material.
- Be aware as to where granular and non-granular types are required.
- Check that backfill material is being placed to the same elevation on both sides of the culvert in 150 mm lift compacted.
- Ensure Contractor performs density tests as required.
- Ensure Contractor performs concrete tests as required.

18.8.2 Bridge Project Engineer's Responsibilities

- Discuss environmental constraints and anticipated problem areas, traffic accommodation and construction methods with the Contractor and the Bridge Inspector.

- Discuss and approve backfill material, density tests and sieve analysis.
- Review the required shop drawings and provide comments.
- Review and determine the need for over excavation, rock excavation, etc.
- Discuss with the Bridge Inspector any possible “extra work” claim items.
- Ensure Department Contract Administration Procedures are adhered to while processing Extra Work Order.

SECTION 18

CONSTRUCTION OF CSP & SPCSP STRUCTURES

Construction of a CSP culvert

18-1 Structural excavation and removal of the existing bridge structure

18-2 Installation of CSP

18-3 Assembling CSP with fish baffles pre-assembled in the shop

18-4 Bringing backfill up evenly at 150 mm lifts on both sides of the CSP

18-5 Backfill near the top

18-6 Completed upstream end of CSP

SECTION 18

CONSTRUCTION OF CSP & SPCSP STRUCTURES

Construction of a SPCSP culvert

18-7 Removal of the existing culvert and structural excavation

18-10 Assembling SPCSP

18-8 Culvert bed excavation - 0.6 m undercut

18-11 Bringing fill up on both side - Des. 2 Class 40 crushed gravel at barrel sections and clay seal on both ends of SPCSP

18-9 Bedding material – 150 mm lift of loose Des 2 Class 40 crushed gravel on 0.6 m of compacted Des.6 Class 80 pitrun on a layer of woven geotextile filter fabric

18-12 Completing upstream end of SPCSP

SECTION 18

CONSTRUCTION OF CSP & SPCSP STRUCTURES

Construction of an Arch Beam Culvert

18-13 Pre-shaping bed

18-16 Assembling horizontal ellipse SPCSP

18-14 Pre-shaping bed

18-17 Improper way of water jetting material in haunches. Nozzle should be touching the haunch material

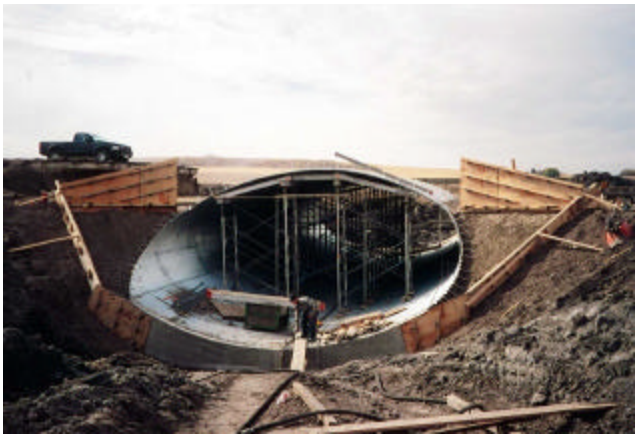
18-15 Pre-shaped bed complete

18-18 Bringing fill up equally on both sides

SECTION 18

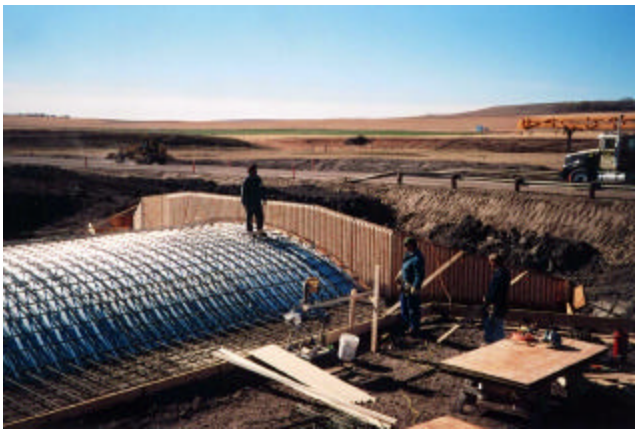
CONSTRUCTION OF CSP & SPCSP STRUCTURES

18-19 Cut-off wall ready for concrete placement



18-20 Shoring in place for concrete placement

18-21 Formwork for concrete slope protection



18-22 Formwork complete for concrete placement

18-23 Night placement of concrete

18-24 Concrete slab complete

SECTION 18

CONSTRUCTION OF CSP & SPCSP STRUCTURES

18-25 Backfill and granular base course completed over culvert

18-28 Downstream end of completed culvert

18-26 Applying tack coat to granular base course surface prior to paving

18-29 Upstream end of completed culvert

18-27 Paving over culvert

18-30 Randomly placed boulders on pitrun bedding. Fish baffles installed on culvert bottom