

THE ONTARIO CONCRETE PIPE ASSOCIATION



PRECAST BOX & CULVERT GUIDELINE

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1 INTRODUCTION

1.1 Background

This document intends to provide guidance in the specification, design, manufacture, and construction of precast box units for infrastructure sewer and drainage projects within Ontario. The Guideline was created with the efforts and contributions of the Producer Members and Supplier Members of the Ontario Concrete Pipe Association (OCPA).

1.2 Existing Handbook and Drawings

This Guideline is the first of its kind for precast box units, and there is no version of document before this copy.

1.3 Distribution

Copies of this Guideline can be obtained from,

- i) Ontario Concrete Pipe Association
447 Frederick Street, 2nd Floor
Kitchener, Ontario N2H 2P4
Canada

1.4 Revisions

This is the first issued copy of this Guideline, dated August 2016. Please note the publication's date and revision dates as shown in this document's title box.

1.5 Standard Drawings

The drawings in this document are intended to be representative, with standard details and basic information for general understanding purposes only.

2 DEFINITIONS

Apron Wall – A vertical non-structural concrete wall built across the full width of the ends of box culverts and extending below the level of the bottom slab. May also be defined as “Cut-off Wall”

Bearing Capacity – The maximum load that can be applied to a soil at the respective limit state.

Box Culvert – A culvert in the shape of an enclosed rectangle and consisting of a bottom slab, two wall elements and a top slab.

Box Sewer – A sewer in the shape of an enclosed rectangle and consisting of a bottom slab, two wall elements and a top slab.

Box Unit – An enclosed rectangle of precast concrete consisting of a bottom slab, two wall elements, and a top slab; with a determined unit lay length. A box unit can also be comprised of one monolithic unit or two three-sided boxes assembled in clam shell.

Culvert Extension – A portion of a culvert built beyond the limits of a previously existing culvert.

Design Engineer – A licensed professional engineer who has determined the engineering requirements for the precast box culvert or sewer. The Design Engineer will provide the design and detail requirements to manufacture the precast elements.

Distribution Slab – A reinforced concrete slab overlay placed directly on the top slab of a box culvert or box sewer, intended to transfer shear across box units.

Earth Cover – The vertical distance from the top of the top slab of a culvert to the riding surface of the roadway above it.

Gap – A defined distance of separation between parallel lines of adjacent box culverts, that create a multi-cell box culvert layout.

Geotechnical Engineer – A licensed professional engineer designated as a specialist in the soils or geotechnical field.

Haunch – The increase in thickness of a culvert's walls or slabs at the corners.

Header Wall – A vertical concrete wall across the full width of culvert ends and extending upwards from the level of the top slab. May also be defined as “headwall”.

Joint – Precast box units shall have a defined profile of joint at each box end, one spigot joint and one bell joint; each compatible with each other for joining purposes. When box units are laid together, they will make a continuous box with a smooth interior, and free of irregularities in the flow line. The joint profile will be of a geometry to accept a gasket type material for sealing purposes.

Joint Gap – A defined distance of separation between adjacent box units, measured along the joint line.

Length – The length of a culvert is the distance between the ends of the assembled box units, along the longitudinal axis of the culvert.

Lay Length – The lay length is the full length of a single box unit.

Open Profile Culvert – A culvert in the shape of an open rectangle, consisting of two wall elements supported on footings and a top slab. Note, there is no bottom slab.

Project Engineer – The licensed professional engineer on record for the project, working on behalf of the Owner, who has specified the use and layout of a culvert for the project site. The Project Engineer is responsible to approve the proposed precast box units and culvert construction layout, as detailed by the Design Engineer and/or the precast producer.

Retaining Wall – A retaining wall for the purpose of this Guideline is an earth retaining structure consisting of a vertical stem element supported by a horizontal footing element and built of reinforced concrete.

Rise – For box culverts this is the vertical distance measured from the top of the bottom slab to the bottom of the top slab at mid-span. For open profile culverts, this is the vertical distance measured from the bottom of leg to the underside of the top slab at mid-span.

Rigid Frame – A rigid frame is one detailed so that full continuity of bending moment is assured between the wall and slab elements.

Skew Angle – The skew angle is the angle between the centreline of the highway and a line perpendicular to the longitudinal axis of the culvert.

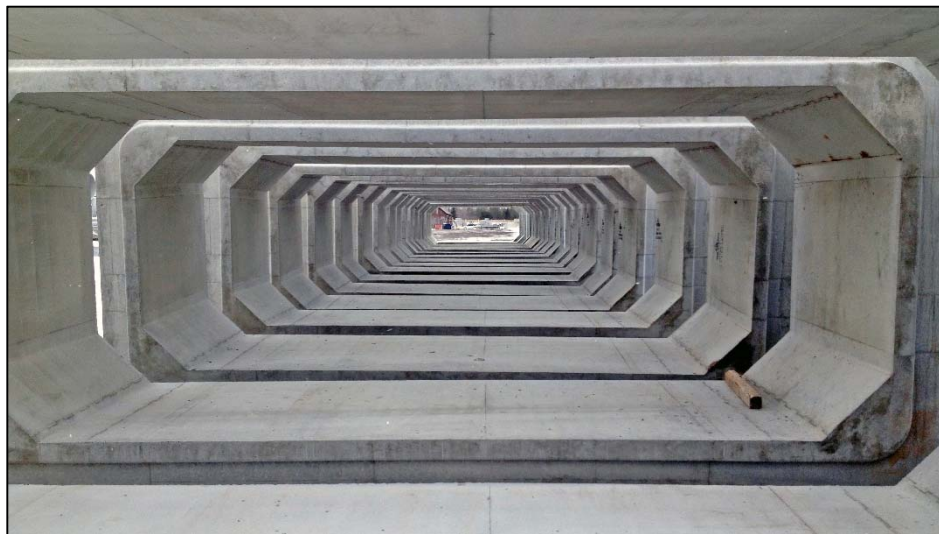
Skewed End Culvert – A skewed end culvert is one with ends not at a right angle to the longitudinal axis of the culvert. Typically, the ends are built at right angles to the longitudinal axis of the culvert.

Span – The span of a culvert is the minimum horizontal distance measured between the inside faces of the box walls.

Standard Culvert – A culvert detailed in accordance with this Guideline.

Structural Engineer – A licensed professional engineer of Ontario specializing in structural design.

Wingwall – A vertical concrete wall positioned at the ends of a culvert and extending upwards to a determined height, so as to provide retention purposes for backfill and soil surrounding the culvert.



3 REFERENCES

The following references have been utilized in this document.

- 1) Concrete Culvert Design and Detailing Manual, MTO Quality and Standards Transportation Engineering Branch Bridge Office.
- 2) CSA A23.1-14, Concrete Materials and Methods of Concrete Construction.
- 3) CSA A23.4-14, Precast Concrete - Materials and Construction.
- 4) CSA S6-14, Canadian Highway Bridge Design Code.
- 5) CSA W186, Welding of Reinforcing Bars in Reinforced Concrete Construction.
- 6) Dayton Superior, Guidelines for Handling Concrete Pipe and Utility Products
- 7) OPSS 422, Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut.
- 8) OPSS 1821, Material Specification for Precast Reinforced Concrete Box Culverts and Box Sewers.
- 9) Plant Prequalification Program, Prequalification Requirements for Precast Concrete Drainage Products, August 2014.
- 10) Precast/Prestressed Concrete Institute, PCI MNL-135 for box culverts.
- 11) Reference for allowable sizes of goods for shipping can be found in the Highway Traffic Act, HTA Regulation 413/05.
- 12) Reference of allowable masses for shipping goods can be found in the Highway Traffic Act, HTA Regulation 413/05.

4 GENERAL INFORMATION

4.1 Introduction

Box culverts provide an alternative to circular concrete pipe intended for the conveyance of storm water, underpasses and natural watercourses. The box geometry provides a larger open area permitting greater flow volumes in an area where hydraulic capacity may be a concern.

With this product's usage in infrastructure and drainage projects, a guideline would serve well to guide specifiers on both the capability and the limitations of the product. This information would be used by specifiers to correctly specify precast box culverts.

The need for this Guideline was realized with the increasing utilization of precast elements. Currently there is only a manual for cast-in-place construction of concrete box culverts.

4.1.1 Scope

This Guideline covers single-cell and multi-cell precast reinforced concrete box units cast monolithically or "clam shell". It includes rigid frame boxes, both four-sided and three-sided units. This document is limited to the intentions of a guideline for reference purposes, and is not a manual for the design purposes of precast box culverts.



Fig. 1: Twin Cell Box Culvert

4.1.2 Design Criteria

Currently, there are nine (9) established standard sizes of precast box in *OPSS 1821, Material Specification for Precast Reinforced Concrete Box Culverts and Box Sewers*. Outside of these nine box sizes, precast producers would be responsible to provide a structural design, stamped by a professional engineer of Ontario.

The design requirements for precast box culverts shall comply with *CSA S6, Canadian Highway Bridge Design Code (CHBDC)*.

For sizing purposes of non-standard precast boxes, industry practice is to utilize varying dimensions of span and rise for the box interior in increments of 300mm. Producers may only be able to provide interior box dimensions in nominal units of 300mm, and this should be considered the minimum dimension in calculations related to hydraulic design.

For manufacturing purposes, hard metric conversions of imperial units are considered equal to nominal units of measure.

4.1.3 Design Considerations

Although precast offers the opportunity for high quality concrete, and efficient onsite construction, there remain some considerations directly related to precast box culverts.

- i) **Constructability** – Design and manufacturing requirements needed to maintain the structural integrity of the precast element for handling during loading, transportation and placement. These include skewed box units, box units with large formed openings, etc.



Fig. 2: Site Considerations for Culvert

- ii) **Shippable Size** – Restrictions of width and limited height on major roads can prevent precast elements to be shipped. Reference to allowable sizes of goods for shipping can be found in the *Highway Traffic Act, HTA Regulation 413/05*.
- iii) **Shippable Mass** – Restrictions on delivery vehicle payloads and lifting equipment limits can prevent precast elements to be handled. Reference to allowable masses for shipping goods can be found in the *Highway Traffic Act, HTA Regulation 413/05*.
- iv) **Foundation & Bedding** – Precast box culverts should be placed on good, undisturbed soil of adequate bearing capacity. A minimum layer of granular bedding material should be used between the precast culvert and bottom of excavation for leveling purposes and to cover any hard points. Site conditions at the location of culvert should be investigated by a geotechnical engineer, providing recommendations for excavation and construction.



Fig. 3: Constructed Foundation for Boxes

For considerations of using this Guideline, the following are not considered here within:

- i) Selection of culvert sizing based on hydrological and hydraulic considerations.
- ii) Selection of design steel areas for reinforcing box unit sizes based on structural design calculations and analysis for dead load and live load.

Bedding and granular backfill requirements.

4.2 Contract Documents

Contract documents include both written specifications and CAD drawings. Revisions to contract documents should be promptly communicated to the necessary party(s).

4.2.1 Contract Specifications

All requirements, as established by the Project Engineer to be pertinent to the design, manufacture, testing and installation of the precast box should be clearly itemized and/or described within the contract specifications.

4.2.2 Contract Drawings

Plan view and elevation of the culvert, showing location and dimensions of all applicable features.

The following minimum information should be provided by the contract drawings for a precast design, if applicable:

- i) Header wall details and skewed ends.
- ii) Apron wall details and dimensions.
- iii) Retaining wall details and dimensions.
- iv) Foundation and soil conditions.

Changes from the Contract Drawings are permitted and may be implemented by the precaster, provided they meet the requirements of this specification, and approval has been received from the Owner.

4.2.3 Shop Drawings

The shop drawings represent the details of precast products to be supplied by the precast producer, as interpreted from the Contract Documents and Drawings.

Shop drawings, including any supporting documentation should be submitted to the Contract Administrator prior to commencement of fabrication of the precast elements. Prior to making a submission, the Design Engineer will affix their seal and signature on the shop drawings verifying that the drawings are consistent with the Contract Documents.

Shop drawings require the review and approval of the Project Engineer to ensure all contract requirements have been correctly detailed for the precast elements.

When other authorities are involved in the approval of the design or construction of a structure, it is advised that submissions be made at least (6) weeks prior to commencement of work and one additional copy of the submission provided for each authority. The requirements of each

authority and the Owner, as stated elsewhere in the Contract Documents, should be satisfied prior to commencement of the Work.

The shop drawings may include the following information but not limited to:

- i) Precast element details.
- ii) Material Specifications, i.e. concrete, reinforcing, etc.
- iii) Reinforcing steel schedules.
- iv) Lifting point locations and Handling requirements.
- v) Details and location of all temporary supports, if applicable.

All other applicable details.

The supporting documents may include the following information:

- i) A letter signed and sealed by an Engineer listing all permitted changes made along with supporting calculations. The letter should state that the changes have not adversely affected the capacity of the precast element.
- ii) Further handling and erection procedures for precast element.
- iii) Details of bracing installed to provide adequate support and stability to the precast element during construction, if applicable.

4.2.4 Professional Engineer Stamp

All shop drawings by the Design Engineer should bear the seal, date and signature of a professional engineer, and a second engineer, if applicable. This Engineer accepts full responsibility for the accuracy of the information contained in these drawings, as it relates to the design, manufacture and supply of the box culvert and precast elements.

Where engineering design changes are made on shop drawings that affect the original design and/or issued shop drawings, those new drawings should be identified as “Revised” and bear the seals, dates and signatures of a professional engineer, and a second engineer, if applicable.

4.3 Precast Culverts

There are many functional forms for which precast culverts can take shape. The typical types are discussed here.

4.3.1 Box Units

Precast box units are three dimensional elements of precast that include an open profile of given span and rise, over a given lay length. Horizontal slabs at the top and bottom are connected with vertical walls, all which outline the open profile of a four-sided structure. Four-sided structures bear on the bottom side for foundation purposes.

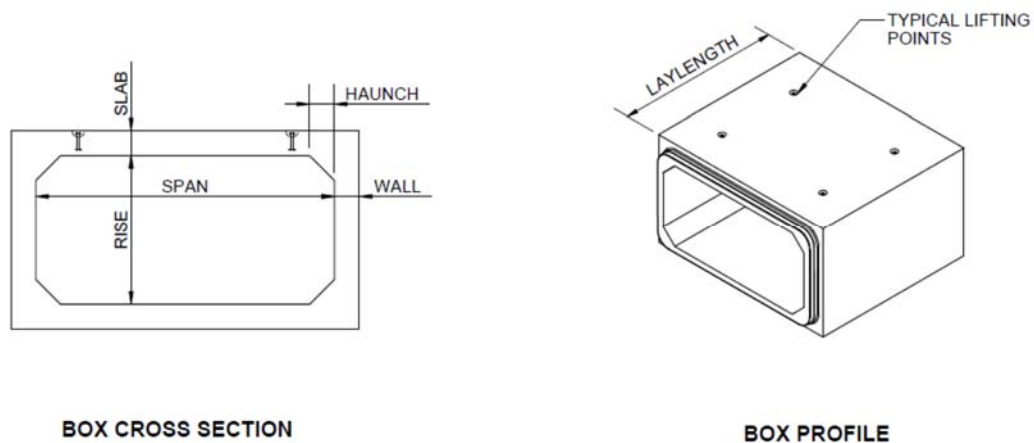


Fig. 4: Box Unit

Sizing for all precast units is based on standard formsets available to the industry, and will be best matched to the original Contract Drawings. Standard dimensions of formsets for vertical rise or horizontal span of the open profile are based on increments of 300mm. Final requirements for wall and slab design will be determined by the Design Engineer based on meeting CHBDC structural requirements. If needed, a Project Engineer or specifier may contact an industry producer for further inquiry.

The specification for industry standard precast box is using OPSS 1821, *Material Specification for Precast Reinforced Concrete Box Culverts*, in which there are nine (9) standard sizes for precast box as shown below. These boxes include approved reinforcing designs as per CHBDC, and complete specifications for manufacture and inspection. The specifier also has the option to reference OPSS 422, *Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut*, which can be used for box installation requirements.

These box sizes are identified as industry standard since most producers in Ontario inventory formwork to match these box sizes. Industry standard boxes give a producer some options such as:

- i) To inventory box units of limited quantity; and
- ii) To readily place formwork into the daily production schedule.

Table 1: OPSS 1821 Standard Box Sizes

SPAN (mm)	RISE (mm)	WALL & SLABS (mm)	DESIGN EARTH COVER (metres)
1800	900	200	maximum 5.5
1800	1200	200	max. 5.5
2400	1200	200	max. 3.6
2400	1500	200	max. 3.6
2400	1800	200	max. 3.6
3000	1500	250	max. 3.6
3000	1800	250	max. 3.6
3000	2100	250	max. 3.6
3000	2400	250	max. 3.6

Table Notes:

1. For earth cover less than 0.6 metres, additional measures are required for box culvert design and construction, such as use of distribution slab over installed box culvert. See Section 4.3.3
2. If industry standard box sizes given in OPSS 1821 do not fit the specified project requirements, producers in Ontario have the capability to build custom formwork to suit large size box units, and/or custom box geometries. See Table 2 below for geometric options in precast box.

Table 2: Precast Box Unit Geometrics

ITEM	STARTING AT (mm)	LARGE BOX (mm)	CUSTOM BOX (mm)	NOTES
Span	900	3600 to 6000	>6000	Limitation of box span is shippable length of truck trailer. Maximum length is 12.50 m, including overhang of 4.65 m
Rise	900	1500 to 3000	>3900	Limitation of box rise is shippable width. Special permits for width start at >2.6 m, and under 4.65 m.
Top/ Btm Slab	200	As required	As required	Limitation is overall shippable mass, or handling mass by producer/site contractor. Maximum height on flatbed trailer is 4.26 m
Walls	200	As required	As required	Limitation is overall shippable mass, or handling mass by producer/site contractor. Maximum overweight may be granted up to 63,500 kg.
<u>Additional Notes:</u>				
<ol style="list-style-type: none"> 1. Dimensions given in table are listed as nominal. Formwork for precast manufacturing can be either the minimal dimension of nominal metric (i.e. 300 mm), or the maximum dimension of imperial conversions (i.e. 12 inches = 305 mm). 2. Span & Rise dimensions are based on 300 mm (305 mm) increments; Wall & Slab dimensions are based on 50 mm (51 mm) increments. 3. For earth cover less than 0.6 metres, additional measures are required for box culvert design and construction, such as use of distribution slab over installed box culvert. See Section 4.3.3 4. Considerations of precast box sizes in the 'Custom Box' size should be done in consultation with a local industry producer(s). 				

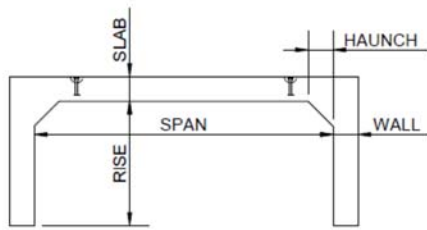
5. Notes pertaining to limited size and/or mass of shippable precast should be referenced with MTO document, *A Guide to Oversize/Overweight Vehicles and Loads in Ontario* ([MTO Vehicle Restrictions](#)). This guide is based on the Ontario Highway Traffic Act (HTA).
6. Special permits by MTO needed for shipping oversize/overweight loads have additional fees, and ample time is required to submit for, and to receive permits.



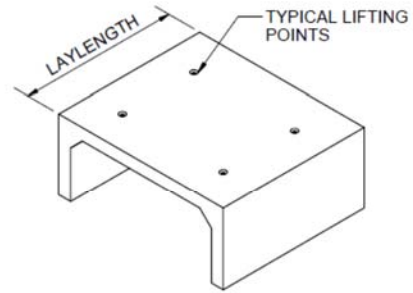
Fig. 5: Check Shippable Limits for Precast Products

4.3.2 Open Profile Units

In addition to four-sided box structures, culverts can also be three-sided which do not include the bottom horizontal slab. Three-sided box precast units or Open Profile precast units require a footing or foundation to support the structure below each vertical leg or wall.



OPEN PROFILE BOX CROSS SECTION



BOX PROFILE

Fig. 6: Open Profile Unit



Fig. 7: Open Profile Box Installed on Footings

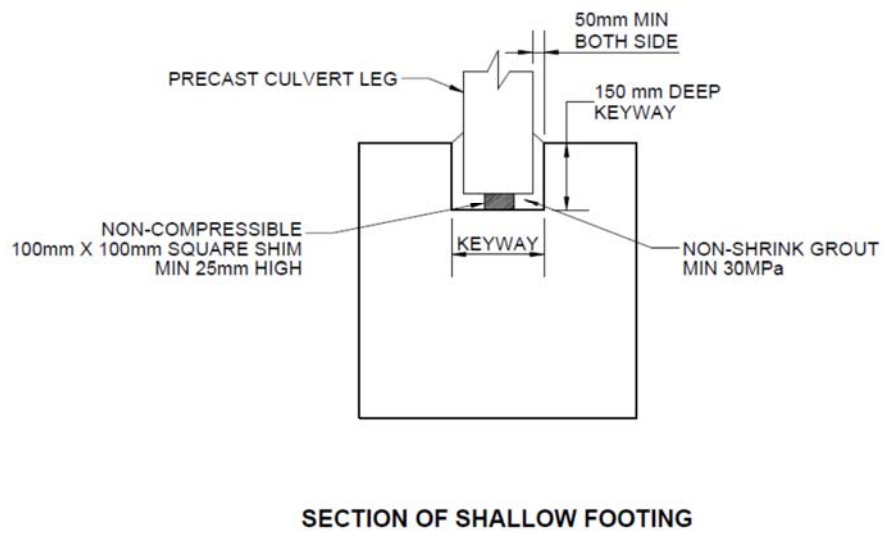
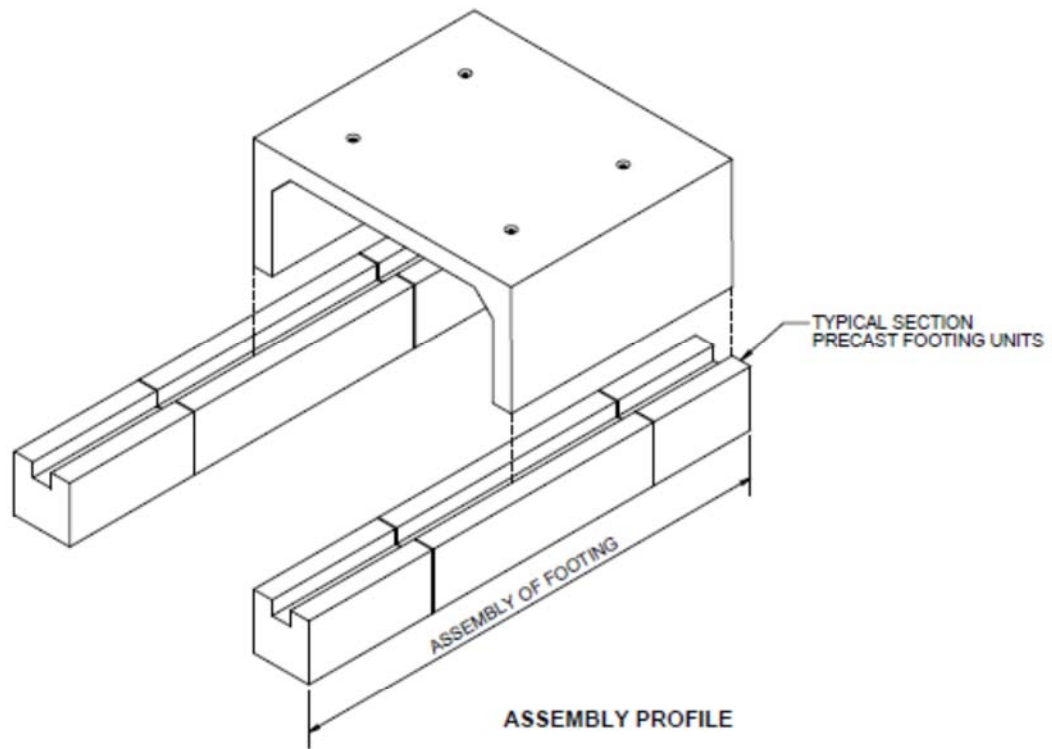


Fig. 8: Precast Footings for Open Profile

4.3.3 Clam Shell Box

A clam shell box can be defined as a two-piece box unit, separated along the vertical wall. The same can be described as two separate, open profile units assembled with an integral joint running along each vertical wall. Installation of a clam shell box begins with the bottom half unit, followed by the top half unit, and hence, enclosing a box shape.

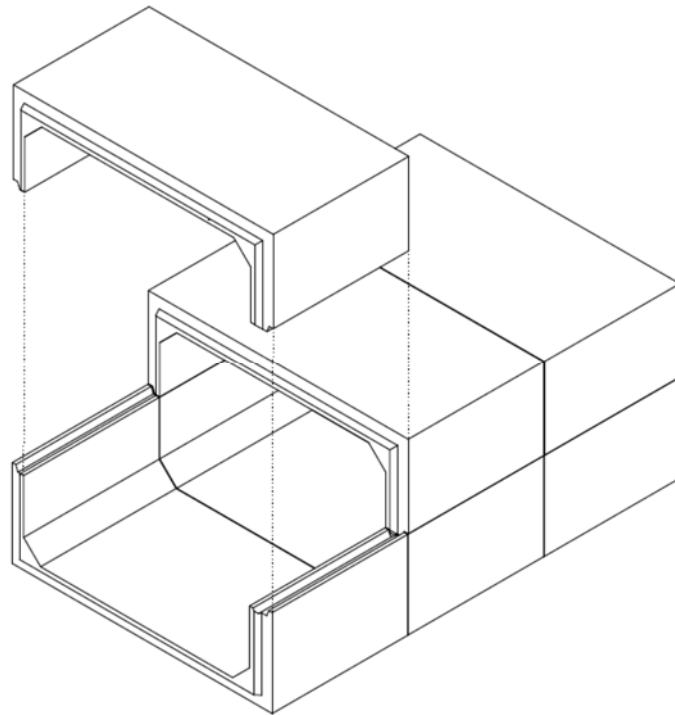


Fig. 9: Clam Shell Box

At times, the required geometry for a box unit may pose challenges on several different fronts, specifically, if the size of proposed box begins to exceed the range of large box. As box units get increasingly large, sections of slab thickness or wall thickness also increase. This cumulative effect to the box unit's outside dimensions and box mass may then exceed the wide-load permits or shippable mass into a jurisdiction or on provincial highways. Exceedingly heavy units of box may have a mass that is not practical for handling at the plant during manufacturing, or on-site during installation.

One other issue which has made the clam shell box beneficial are the on-site rehabilitation works that are needed inside the culvert. An example of this would be the naturalization of the inside culvert bottom using rocks and other means to create a natural habitat to accommodate aquatic life.

4.3.4 Design Earth Cover

Culverts can range in application from zero cover to a maximum earth cover as determined by site requirements and/or by the structural limitations of the box design. Within a culvert's design earth cover, the load influenced on the culvert will be a combination of both dead load and live loads.

4.3.4.1 SHALLOW EARTH COVER

Shallow earth cover for culverts is defined as less than 0.6 metres of earth fill over the top slab of box.

For shallow earth cover applications, a typical design option is the use of a load distribution slab which helps transfer shear across joints of adjacent box units. If site conditions such as limited road elevations do not permit this type of construction detail, alternative construction methods may be suitable. See *CHBDC, Clause 7.8.1.7*. For example, the use of mechanical shear plate connections to transfer shear across joints in place of a load distribution slab.

The Project Engineer should consult with a local producer to determine the optimal design for culverts in shallow earth cover applications.

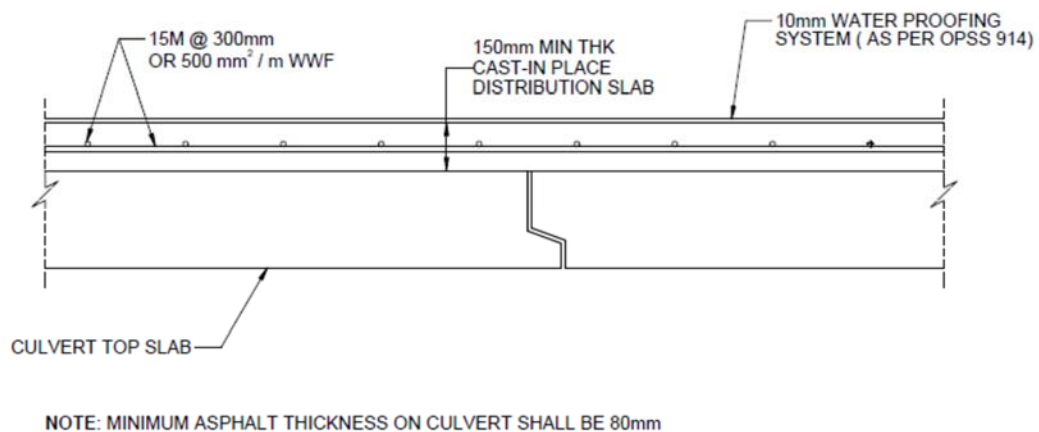
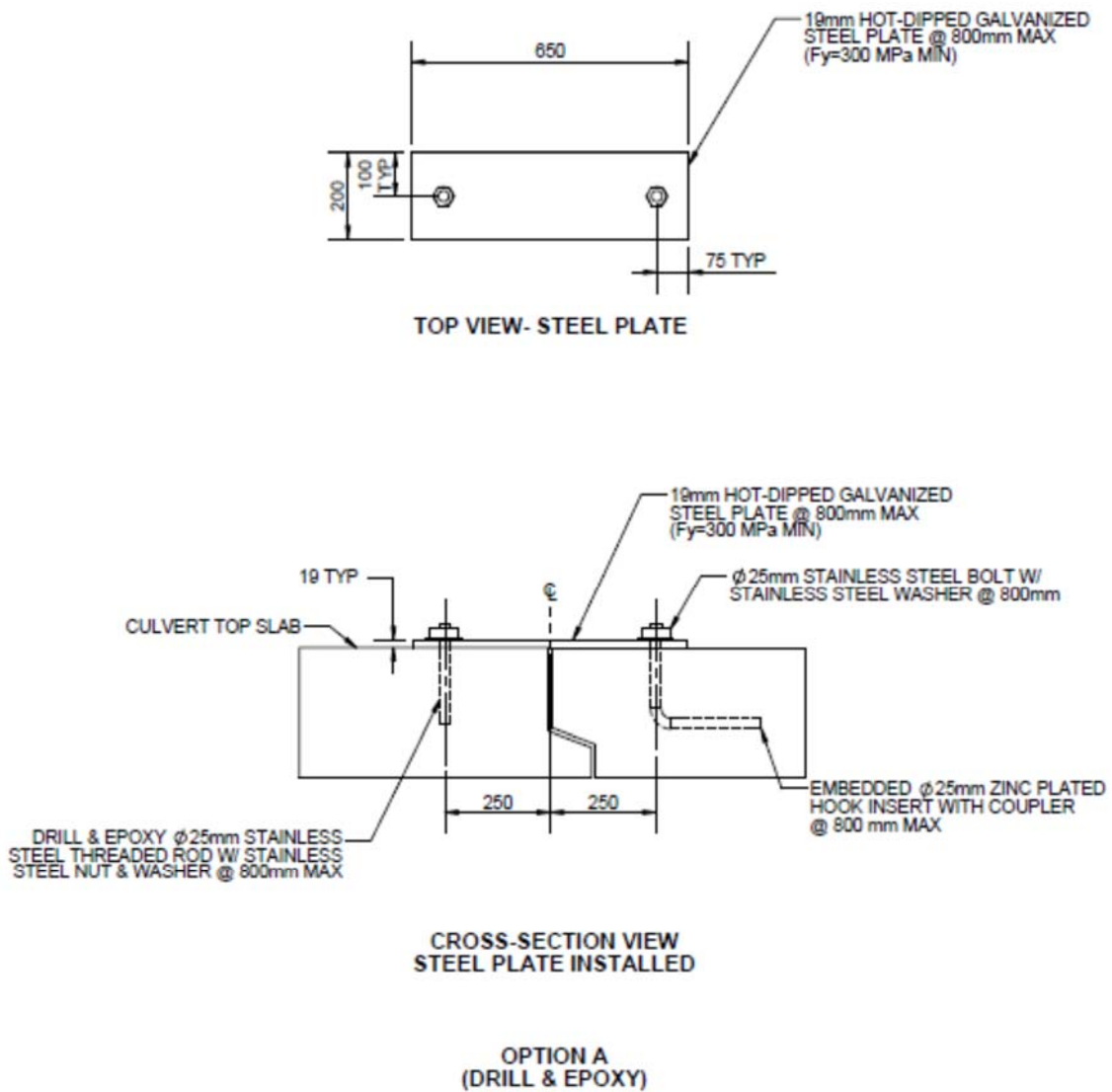
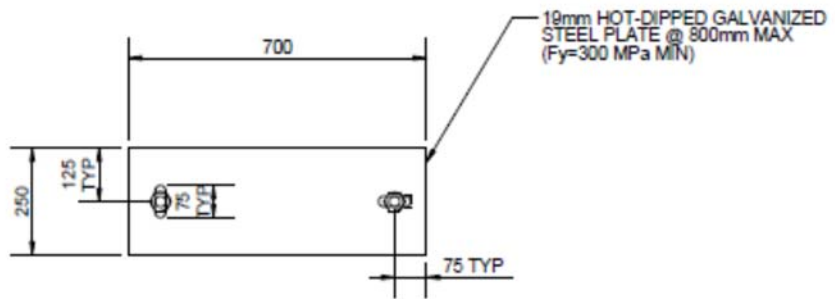


Fig. 10: Distribution Slab

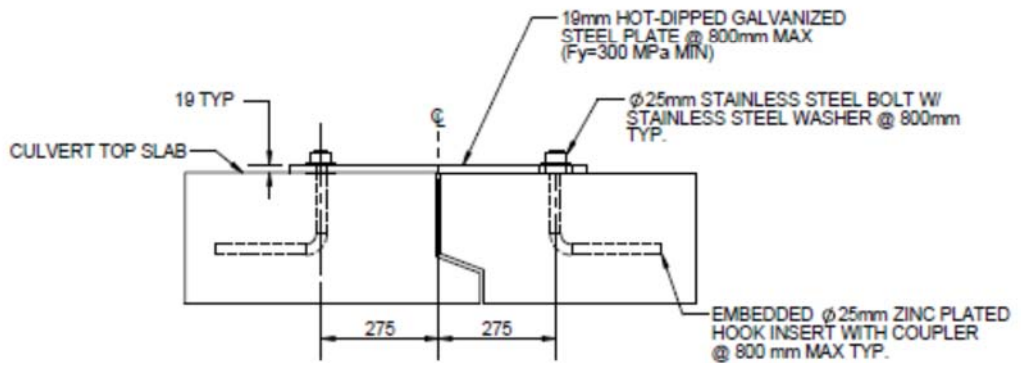


NOTE: ALL DIMENSIONS ARE IN MM UNLESS OTHERWISE

Fig. 11: Shear Connector – Option A



TOP VIEW- STEEL PLATE



CROSS-SECTION VIEW
STEEL PLATE INSTALLED

OPTION B
(CAST-IN INSERTS)

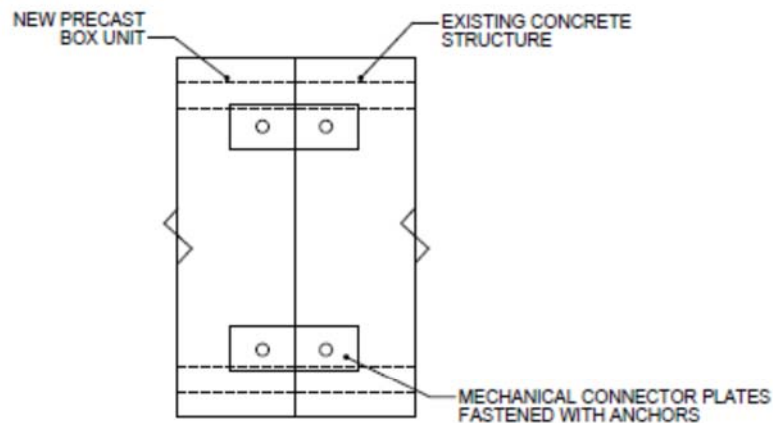
NOTE: ALL DIMENSIONS ARE IN MM UNLESS OTHERWISE

Fig. 12: Shear Connector – Option B

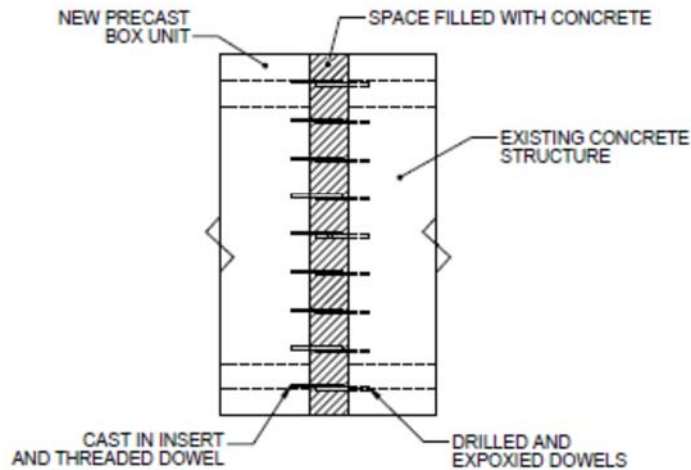
4.3.5 Culvert Extensions

Culvert extensions of existing culverts by using new precast is possible and may be detailed using this Guideline.

Connections between new precast and an existing culvert are made possible by setting dowels and pouring a connecting concrete collar between new and existing. Another method is by using structural connector plates that are anchored in place.



CONNECTOR PLATES



DOWEL CONNECTION

Fig. 13: Existing to New Precast Construction

4.3.6 End Treatments

End treatments for box culverts depend on site conditions and finishing requirements determined by the Project Engineer.

Based on the elevation and side slope of the fill embankment over the culvert, additional culvert elements may be necessary. These include use of headwalls, wingwalls and/or retaining walls that retain the fill embankment when culvert length is limited. If the culvert length is not limited, and the width of right of way and/or the existing watercourse permits unlimited culvert length, culvert elements of headwall or wingwall may not be necessary.

Each box unit is comprised of a bell joint and a spigot joint, complimentary to each other, that allow for joining purposes of adjacent box units. The aesthetic reasons, the Project Engineer may decide to remove the joint profile and create a flush end for the culvert end unit (i.e. smooth face with no joint).

Common practice is to use a full length box unit as the last end unit, instead of shortened box unit. The longer box unit provides greater stability to the end of culverts that can be susceptible to hydraulic effects of flow in and out of the culvert.

4.3.6.1 SKEWED CULVERTS

In some applications, the alignment of culvert is not always perpendicular to centreline of road. In this case, the layout of the culvert will cross the road at an angle that is skewed to the road centreline. This skew alignment is not a concern for the box culvert, unless there is an additional requirement to use the skew angle for the end treatment of the box culvert. In other words, the end face of culvert is to remain perpendicular to the centreline of culvert.

As a rule of thumb, the skew limit for the end treatment of a box unit is a function of the box unit's span. A box unit with shorter spans can accommodate a larger skew angle. As the box span increases, the skew angle decreases. The recommended minimum skew for a box of given span, is to keep the short side length to 1.0 metre.

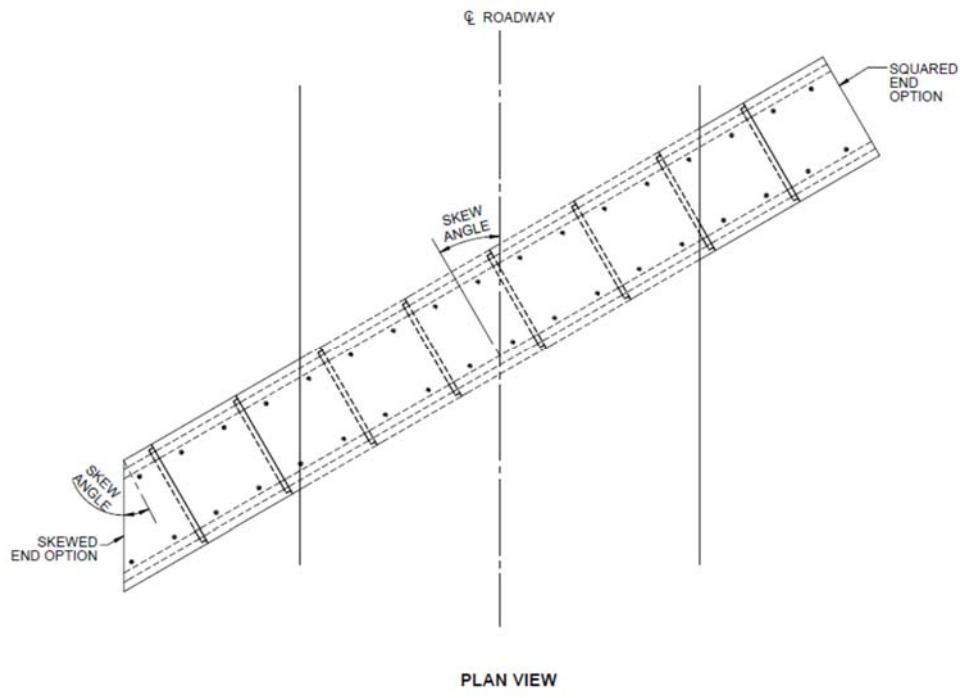
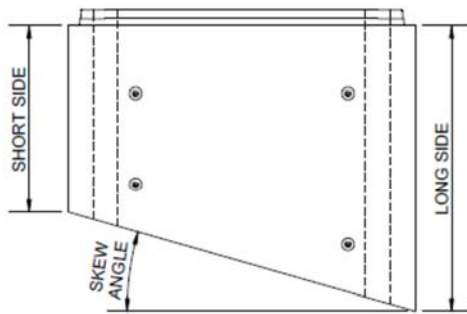


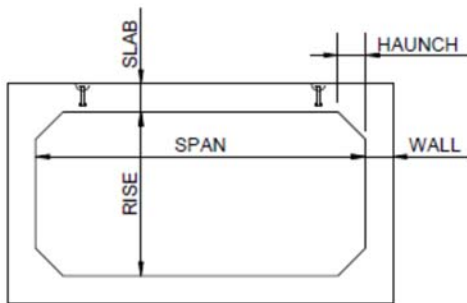
Fig. 14: Skew Culvert Alignment



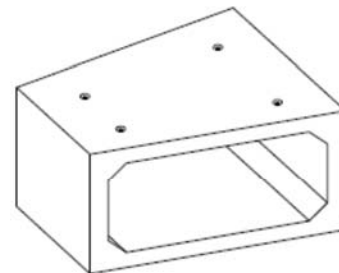
Fig. 15: Skew End Unit for Culvert



PLAN VIEW



BOX CROSS SECTION



BOX PROFILE

Fig. 16: Skewed Box Unit

It is recommended a plan view of the culvert be added to the standard drawings, showing the skew angle and skewed end or ends. In most cases, the ends of a culvert are skewed at the same angle the culvert is skewed to the direction of roadway.

A detail showing reinforcing steel layout at skewed ends should also be added to the standard drawings, with the modified bar spacing and necessary dimensions shown in the appropriate places.

Table 3: Guidelines for Skewed Boxes

4-SIDED BOX SPAN (mm)	SKEW ANGLE (degrees)	3-SIDED BOX SPAN (mm)	SKEW ANGLE (degrees)
900	47	4200	14
1200	40	5400	11
1800	32	6000	10
2100	28	7300	6
2400	25	8500	2
3000	21	9800	1.5
3600	18	10900	1.5
4200	16		
5400	10		
6000	7		
Notes:			
<ol style="list-style-type: none"> 1. Skew angle based on maintaining a short side minimum length >1000 mm, and a maximum unit lay length of 2438 mm. Range for skew angle provided when shortening box unit lay lengths to ensure a maximum 40,000 kg box mass is not exceeded. 2. Span dimensions given in nominal units. 3. For applications of skewed box beyond this table, please contact an industry producer. 			

4.3.7 Use of Culvert Header Walls

Construction options for header walls include cast-in-place or precast.

As precast header walls, physical size and mass are important based on design and/or shipping limitations. For these reasons, the header wall may be cast as a separate precast element to the box unit, known as a “detached” header wall. This stand-alone header wall will be shipped separate of the box unit, and will require assembly to the box unit at the project site.



Fig. 17: Culvert with Precast Header Walls

If the header wall is smaller in size, and not limited by mass or design, the header wall can be cast onto the box unit in a secondary pour while at the plant. This style of header wall is called “attached” or “monolithic”, and is shipped as one unit to the site.

If cast-in-place construction is used, the producer of the precast box unit can provide inserts cast into the top slab of the box unit, ready to accept threaded rebar dowels. The insert & dowel system provides anchorage to the box unit, while also providing the required development length for reinforcing purposes.

Depending on the size of header wall, and/or the lateral force of earth pressure from the road embankment against the header wall, tie backs may be necessary for the box unit supporting the headwall. The tie backs are used to connect the supporting box unit with headwall, to the adjacent box unit(s). Anchoring backwards to the adjacent box unit will resist any lateral force or tipping action due to the soil pressure acting behind the header wall.

An example of tie backs is similar to what is shown in Figure 5 for connector plates.

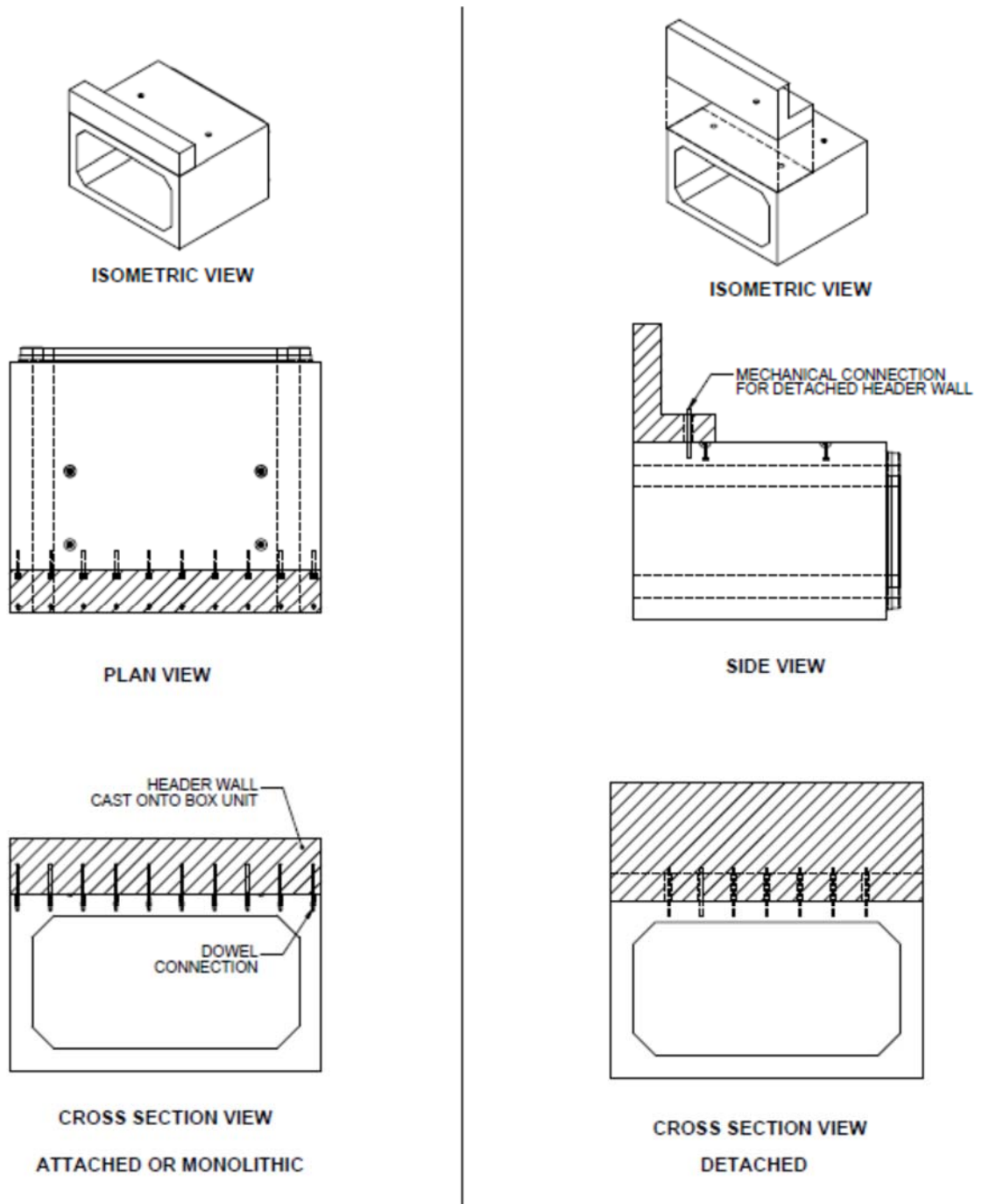


Fig. 18: Typical Header Wall

4.3.8 Use of Culvert Apron Walls

Apron walls can be added at the ends of box culverts using typical details as shown below. The precast box units can be detailed to accept both a precast or cast-in-place option of apron wall. Dowels threaded into inserts, or dowels drilled and epoxied are typical methods used to make the connection of the apron to the box unit.

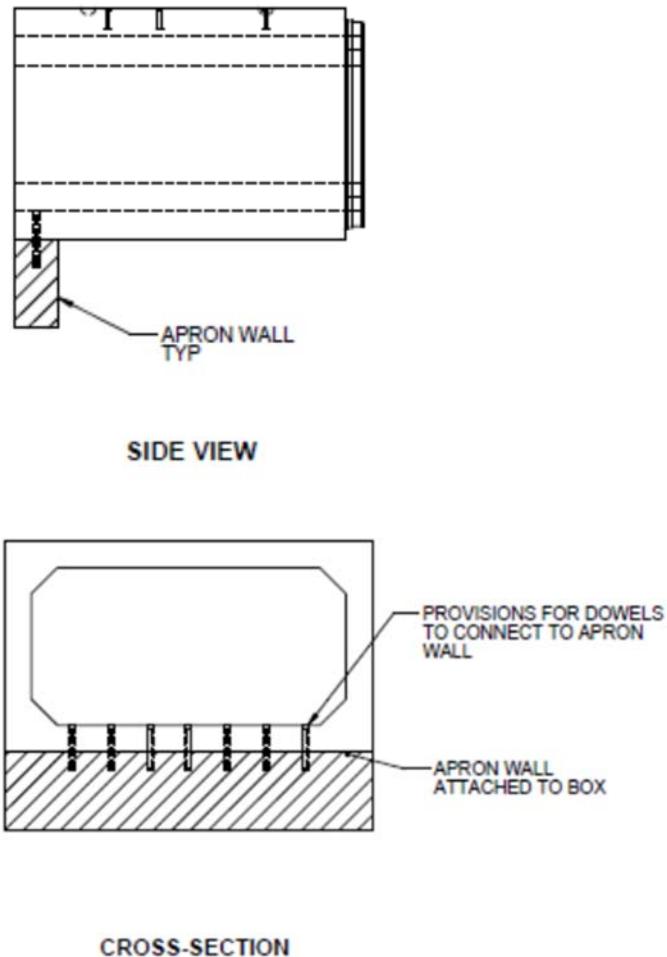


Fig. 19: Typical Apron Wall

4.3.9 Use of Retaining Walls

Retaining walls can be built at the ends of culverts to reduce the total length of culvert, for hydraulic considerations, or for other reasons. Retaining wall construction may include either a precast option for the wall, or a poured-in-place option. Contact the precast producer to

determine if precast is an option for the application, and the necessary connection details, if required

4.3.10 Intersecting Drains, Catch Basins or Manholes

Where drains or other features intersect a culvert, modifications should be made to the structural standard drawings to provide an opening in the wall or top slab of the culvert, and details of the additional steel required to reinforce the perimeter of such openings added by the structural engineer.

A plan view detailing the location, elevation, and dimensions of the opening should be shown.

5 MANUFACTURING & QUALITY ASSURANCE

5.1 Prequalification Requirements

Producers manufacturing box units must possess a current Prequalification Certificate issued under the Plant Prequalification Program, as outlined in the publication, Prequalification Requirements for Precast Concrete Drainage Products.

All box units shall conform to the necessary design and manufacturing standards, as specified by the Design Engineer, and/or outlined in this Guideline.

5.2 Materials

Requirements for raw materials should be specified in the mix design specifications. Raw materials for concrete include water, fine and coarse aggregates, cements and supplementary cementing materials, and admixtures.

The concrete shall be in accordance to CSA A23.4, with a minimum compressive strength stated.

Wet cast concrete is defined as concrete with a slump greater than 20 mm at the time of placing. Dry cast concrete is defined as concrete with a slump equal to or less than 20 mm at the time of placing.

Materials related to reinforcement and cast-in hardware shall be in accordance to CSA A23.4.

Storage of all materials shall be in accordance to CSA A23.4, and/or as per the supplier's recommendations.

5.3 Reinforcement for Precast

Steel reinforcement for precast concrete can be either weldable grade reinforcing steel bars, or pre-manufactured structural wire sheets called Welded Wire Reinforcing (WWR). Each reinforcing type are available in different sizes, shapes or configurations, and each have different material properties such as yield strengths used by the Design Engineer for reinforcing purposes.

If not specified in the box design, use of reinforcing type is the choice of the precast producer, based on availability of reinforcing type, or how the manufacturing process has been established at the plant. Structural concrete design using precast permits different practices used for reinforcing placement than typical poured-in-place. The known quality and accuracy of precast production permits tighter placement of reinforcing within reduced depths of cover.



Fig. 20: Flat WWR Mats



Fig. 21: Bending WWR Mats



Fig. 22: Rebar Bent for Cage Construction

The concrete cover to the WWR shall be 40 mm \pm 5mm, and the cover to reinforcing bars shall be 50 mm \pm 15 mm. Other typical concrete cover and tolerances can be found in Section 8.11 of the CHBDC. At times, special site conditions, environmental exposure, or application of the precast box may determine special requirements as specified by the engineer.

There is a range of useful products like zinc plated cage clips to help ensure proper separation between inside and outside cages, while also maintaining the designated concrete cover to reinforcing. These heavy wire clips snap onto the cage in place. Other products like concrete chairs can be used on the cage's longitudinal ends to ensure reinforcing cage is not resting directly onto the formwork.

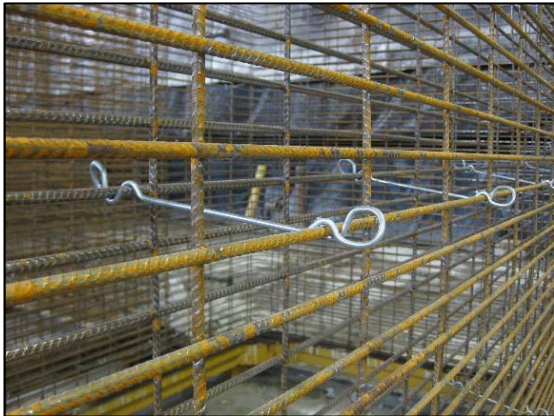


Fig. 23: Cage Clips for Inside/Outside Cages



Fig. 24: WWR Cage Assembled on Pallet



Fig. 25: Chair to Keep Cage Off Pallet

Splices in the perimeter reinforcement can be made by lapping. Reinforcement should not be lapped in tension zones.

Welding of reinforcement is completed in accordance to CSA W186. All welds shall be accepted based on certified performance testing for those welds.



Fig. 26: Fabricated Rebar Cage

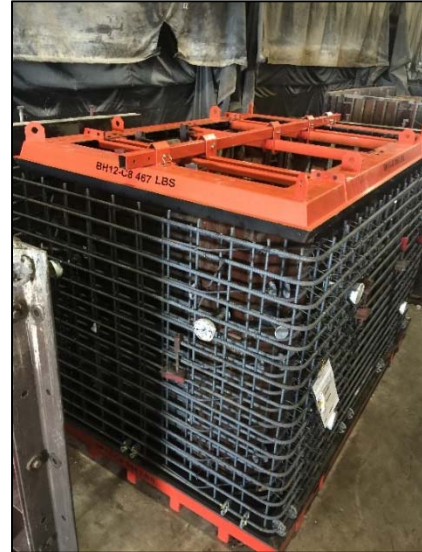


Fig. 27: Rebar Cage on Pallet



Fig. 28: Plastic Wheel Spacer

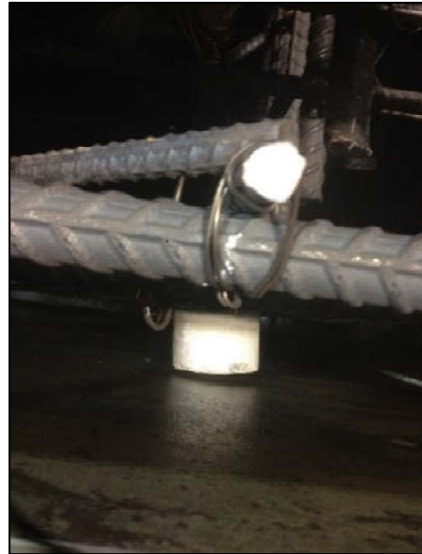


Fig. 29: Concrete Spacer Tied to Cage

5.4 Production

For Wet Cast products, a single formwork set is dedicated to each box unit. Following the allocated curing cycle, the formwork can be removed from the cured product and reused for the next unit of precast.



Fig. 30: Modular Formwork to Assemble



Fig. 31: Wet Cast Form Assembled



Fig. 32: Wet Cast Box Stripped After Curing

By comparison, Dry Cast production permits the pouring of multiple box units from a single set of formwork in a given daily production cycle. After concrete is placed and consolidated inside the formwork, the producer can then remove the formwork from the green concrete product for curing, and return the formwork back to the pour station for the next unit of box. Following the allocated curing cycle, the cured product is now ready for handling.



Fig. 33: Filling Dry Cast Box Form



Fig. 34: Dry Cast Box Stripped from Form



Fig. 35: Dry Cast Box Ready for Curing

Precast producer recommended cast-in lifting anchors will be permitted in each box unit for the purpose of handling and installing.

5.5 Curing

Wet Cast box units are cured by leaving the unit in the form. Dry Cast units are stripped from the form, covered by tarp and cured by steam, or by a curing system whereby temperature and moisture are controlled.



Fig. 36: Temperature & Moisture Control During Steam Curing

Box units shall be cured until a minimum strength of 25 MPa is achieved or for four (4) days, whichever occurs first.

Curing procedures specific to a particular precast plant may be used if the procedures have been shown to produce a finished concrete product that meets or exceeds all of the performance requirements as specified in CSA A23.4, where applicable.

5.6 Quality Control

All quality testing should be done in accordance with the relevant manufacturing standard and/or design requirements, and the Plant Prequalification Program for precast box culverts produced in Ontario.



Fig. 37: Quality Control Programs

Quality control requirements are required for all production runs, considered as continual production provided any interruption is not more than three consecutive days, and there is no change in materials, material proportions, source of materials, production or curing methods, or equipment.

Material testing for concrete, box unit dimensions, and reinforcement checks should be performed for each group of 15 box units or fraction thereof, for each continual production run of a single size.

All precast units shall meet the dimensional tolerance requirements of CSA A23.4. Tolerances for precast units shall be in accordance with the Precast/Prestressed Concrete Institute, *PCI MNL-135* for box culverts – See Appendix B.

Tolerances for product and equipment are to be checked and recorded.

Each box unit can be marked with the necessary product information for identification purposes, including, the Prequalification Stamp as outlined in the publication, *Prequalification Requirements for Precast Concrete Drainage Products*, or similar.

Additional quality control and testing requirements can be referenced in Appendix A.

5.6.1 Quality Records

All results should be retained by the precast producer for a period of two years from the date of manufacture and provided to the Owner upon request.

5.7 Quality Assurance

5.7.1 Acceptance

The latest test results of the precast producer's quality control procedures, specified in the subsection for Quality Control, are to be submitted to the Owner.

The Owner may request submission of samples for testing.

The Owner should be given access to the precast producer's plant, at times and locations determined by the Owner, to perform independent inspection, sampling, and testing.

5.7.2 Rejection

A group of box units represented by failed concrete material testing may be rejected. Individual box units may also be rejected for any of the following:

- a) Inadequate concrete cover to reinforcement.
- b) Defects resulting from incorrect proportioning, mixing, and forming.
- c) Cracks greater than 0.3 mm or full depth cracks.
- d) Honeycombed or open surface texture.
- e) Damaged ends, where such damage would prevent making a satisfactory joint.
- f) Out of tolerance.

6 ADDITIONAL SPECIFICATION REQUIREMENTS

6.1 Details for Standard Drawings

The project consultant should indicate on the project drawings the line and length of box culvert, including the size of box opening and any other finishing details required of the box. Details needed include: choice of skewed ends, apron walls, headwalls, or openings into the box, etc. A profile drawing should be included so that elevations of the box relative to the road elevations can be established. It is also recommended that an alignment drawing be provided.

The precast producer will be required to provide a full set of drawings detailing the precast box culvert that satisfy the culvert specification. Typically, detail and manufacturing drawings are stamped by a professional engineer responsible for the structural design of the precast box units.

6.2 Foundation Investigation

A foundation investigation is generally necessary for culvert design and documentation in the contract for culvert construction purposes. Foundation information such as subsurface conditions, soil strength parameters, settlement limitations, and any dewatering and shoring requirements will be needed. In addition, information will be useful for the contractor to plan his work and as a baseline in the event of any construction disputes. The need and the level of detail required for the foundation investigation is determined by the Project Engineer and should be based on:

- i) The complexity and the importance of the culvert; and
- ii) The data currently available for the foundation material.

If the bearing capacities are exceeded or lateral sliding stability is not assured, then the geotechnical engineer and the structural engineer need to be consulted.

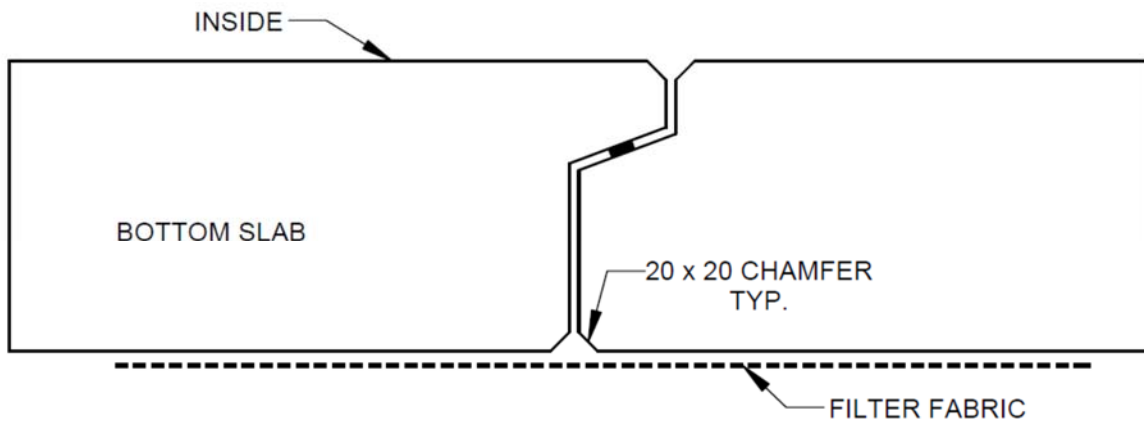
Calculations for general foundation and footing design can be found in the document, MTO's *Concrete Culvert Design and Detailing Manual*.

6.3 Joints

Requirements for joint performance are based on the intended application of the box culvert. The minimum requirement of joints for any buried structure, in this case a box culvert or box sewer, is the prevention of fines from infiltrating through the joints.

In the industry, there are two styles of joint:

- i) Profile Joint – This joint is typical for many linear products and commonly referred to as a “tongue and groove” joint. The common terms used for these joints are “spigot end” and “bell end”. Both ends are compatible allowing the spigot end to be inserted into the matching bell end. The profile joint makes it possible to use different types of jointing materials in order to achieve specific performance requirements.
- ii) Butt Joint – This joint has no profile or inserting ends, only flat ends that butt up to each other.



JOINT IN BOTTOM SLAB

Fig. 38: Tongue & Groove Joint With Jointing Material

6.3.1 Jointing

The precast producer’s recommendations regarding jointing procedures should be closely followed. All of the joints are designed for ease of installation. Ensure joints are clean, with no debris, and not damaged. Align components to ensure jointing materials are not disturbed.

In laying box, it is general practice to face the bell end of the box in the upstream direction. This placing helps prevent bedding material from being forced into the bell during jointing, and enables easier installation of box sections. Minimal removal of the bedding material directly in the bell area of the box can also help to ensure bedding material is dragged into the bell joint during jointing.

Installers of precast boxes have used many methods to install box. Use of a vertical lift and a lateral swing of one box into another box will not typically provide enough lateral force for jointing of boxes. This is especially true when a gasket material is being used within joints.

The same vertical lift can be used with the lateral force of an excavator against the box to push the boxes together. Although this method has good success, it is not recommended for possible damage to the precast, unless steps are taken to protect the equipment contact against the precast. Due to some site conditions, it may not be possible to get any access by heavy equipment to box level (i.e. watercourse).

The method of box installation recommended by the precast producers is to use a box puller. The heavy mechanical equipment is setup inside the first box unit, and uses hydraulic winches to pull the adjacent boxes into position.



Fig. 39: Box Puller Used for Box Unit Installation

It is highly recommended, the methods and equipment needed for good installation practices of precast boxes requires the consultation with the precast producer who is supplying the boxes.

6.3.2 Jointing Materials

Several types of joints and sealant materials can be utilized for boxes to satisfy a wide range of performance requirements.

6.3.2.1 RUBBER COMPOUND

Rubber gaskets for precast box are pre-lubricated gaskets for single offset joints, with one flat side, which is placed on the spigot end. Each joint should be checked to be sure all box sections and joining components are in a homed position. For joints sealed with rubber gaskets, it is important to follow the supplier's installation recommendations to ensure that the gasket is properly positioned, and is under compression.

6.3.2.2 MASTIC

Mastic sealants consist of bitumen or butyl rubber and is usually cold applied. Typically supplied in pre-formed coils, the flexible rope style sealant should be properly sized based on the width of the annular joint space being sealed.

For all gasket types, dirt, dust, and foreign matter must be cleaned from the joint surfaces. Except for pre-lubricated type, the gasket and bell should be coated with a lubricant recommended by the gasket supplier.



Fig. 40: Rubber Gasket for Box

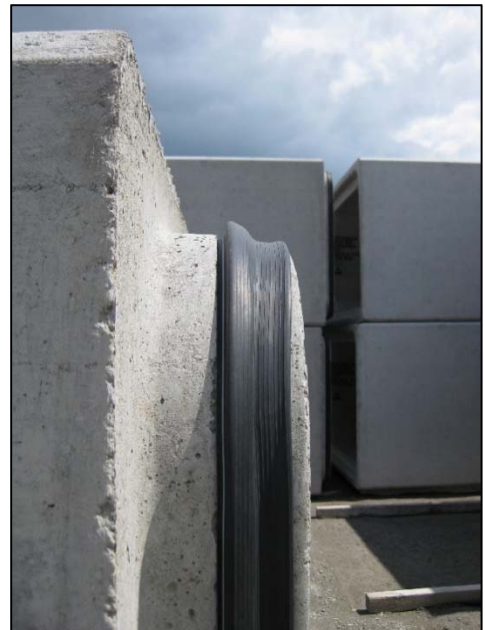


Fig. 41: Rubber Gasket on Spigot End



Fig. 42: Butly Mastic Used for Compressible Joint Filler

6.3.3 Other Joint Treatment Options

Other options exist for addressing joints, but these options are applied to the exterior of the joint.

6.3.3.1 EXTERNAL BANDS

Bands may be used in addition to any jointing material to prevent fine materials from entering the joint; and/or, to prevent infiltration through the joint. To prevent the infiltration of water, the gasket wrap must be of sufficient width to cover the joint, and must be installed with some tension applied, according to the supplier's recommendations. As the joint is backfilled, pressure is applied to the gasket wrap as it is pressed against the structure, providing a seal at the joint.

6.3.3.2 FILTER FABRIC

If the prevention of fines from entering the conveyance system is the primary objective, filter fabric will allow the groundwater to infiltrate through the joint, but stop the fines of backfill material from entering.

If not addressed correctly, loss of fines outside the box would lead to the loss of soil support surrounding the box culvert. Hence, the minimum treatment of the joints for this requirement is achieved by using a filter fabric wrap around the full perimeter of box, centered across the joint.



Fig. 43: Filter Fabric Wrapped Over Joints

6.4 Lifting & Handling

Proprietary lifting systems are used in Ontario for precast box units and other complimentary precast elements. These systems offer a positive lifting connection to the precast, providing added safety and maintaining the structural integrity of the unit.



Fig. 44: Lifting Anchors in Top Slab of Box

For lifting and handling boxes, an appropriate number of lift anchors are located in the face of the top slab to ensure safe and level lifting of the box. This includes all other complimentary precast elements. At times, additional lift anchors may be located in the precast element to assist with handling during production and/or installation of the precast. Additional lifting hardware, such as a spreader beam, may be utilized to ensure angle of cabling between the point of lift and the lift anchor is not compromised. The simple rule is that distance between lifting points should form an equilateral triangle, or the contained angles should be equal.



Fig. 45: Lifting with Spreader Beam



Fig. 46: Lifting with Lifting Straps

6.4.1 Load-Carrying Capacity of Lift Anchors

The maximum safe working load is clearly visible on the head of the anchor for easy recognition of the appropriate hardware and accessories for-use with the lift anchor. However the safe working load of any lift anchor may be drastically reduced due to several factors, such as:

- a) Length of anchor, or embedment depth
- b) Distance to edges, corners or openings
- c) Concrete compressive strength at time of initial lift
- d) Number of lifting points and type of rigging used
- e) Direction of pull (cable or sling angle)
- f) Impact or dynamic loads

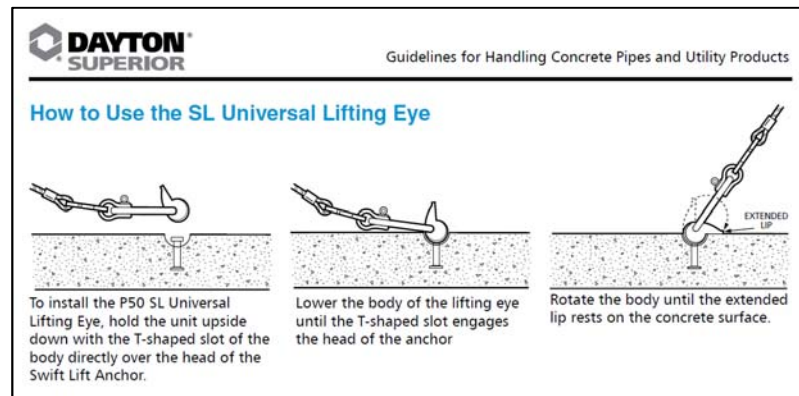


Fig. 47: Proper Use for Lifting Anchors

6.5 Construction of Culvert

Requirements for installation of precast culverts in open cut, including excavation, bedding, backfilling, and cover material can be referenced from *OPSS 422, Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*.



Fig. 48: Backfilling the Culvert



Fig. 49: Backfilling Complete Along Culvert Sides

7 OWNER PURCHASE OF MATERIAL

7.1 Inspection

The quality of materials, the process of manufacture, and the finished box units are subject to inspection by the owner.

7.2 Measurement for Payment

Box units will be measured in metres along the centerline of the invert of the box unit. Payment at the price specified in the purchasing order will be full compensation for the supply and delivery of the box units and jointing devices, to the destination at the times specified.

The cost of all testing, except that performed in the Owner's laboratory will be included in the price.

APPENDIX A – TEMPLATE SPECIFICATION FOR PRECAST BOX

SPECIFICATION FOR PRECAST CONCRETE BOXES

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8.0 CONSTRUCTION

1.0 SCOPE

This specification covers the requirements for materials, design, fabrication and construction of single-cell and multi-cell, four-sided and open bottom precast concrete box culverts; including all associated precast elements complimentary to a box culvert.

2.0 REFERENCE PUBLICATIONS

- .1 Canadian Standards Association (CSA)
 - .1 CSA S6 – Canadian Highway Bridge Design Code

- .2 Ontario Provincial Standards (OPS)
 - .1 OPSS 1821 – Material Specification for Precast Reinforced Concrete Box Culverts and Box Sewers
 - .2 OPSS 422 – Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut

- .3 MTO Structural Manual, Division 1

- .4 Plant Prequalification Program (PPP)
 - .1 Prequalification Requirements for Precast Concrete Drainage Products

3.0 DESIGN AND SUBMISSION REQUIREMENTS

- .1 All box units shall be designed according to CSA S6.

- .2 If applicable, precast reinforced concrete box units shall be according to the requirements of OPSS 1821.

- .3 The precast producer's box unit and culvert Working Drawings shall be submitted to the Owner upon request. All Working Drawings shall bear the seal and signature of an Engineer certifying they are according to the Contract Documents.

- .4 Working Drawings shall include as a minimum,
 - a) Design details
 - b) Fabrication details
 - c) Assembly details
 - d) Lifting details

4.0 MATERIALS

- .1 Normal density concrete in accordance with OPSS 1350 and CSA A23.4
 - .1 Type GU, GUb, HE or HEb cement
 - .2 Minimum compressive strength at 28 Days: 35 MPa

- .2 Wet Cast concrete
 - .1 The air void system of the hardened concrete, when tested according to ASTM C457, shall be as follows:
 - a) Air Content 3.0 % Minimum
 - b) Spacing Factor 0.200 mm Maximum

- .3 Dry Cast concrete,
 - .1 The salt scaling resistance when tested according to laboratory method LS-412 and this specification shall have a mass loss of not more than 0.8 kg/m²

- .4 Self Consolidated Concrete (SCC) will be considered subject to the Ministry's approval. The Contractor's proposal shall be consistent with the Specification for Self-Consolidating Concrete in Precast Products.

- .5 Steel reinforcement shall be according to OPSS 1440.
 - .1 WWF shall achieve minimum 4% elongation at ultimate strength measured over a 100 mm gauge length that includes at least one cross wire.
 - .2 Reinforcing bars shall be weldable grade bar.

- .6 Jointing Material,
 - .1 Jointing material for box units include rubber gaskets, compressible joint sealing compound, or non-shrink cement mortar.

5.0 PRODUCTION

- .1 Precast elements are to be manufactured in a facility,
 - .1 By a precast producer possessing a current Prequalification Certificate, issued under the Plant Prequalification Program as outlined in the publication, Prequalification Requirements for Precast Concrete Drainage Products.

- .2 Placement of Reinforcement,
 - .1 The concrete cover to the WWF shall be 40 mm ± 5 mm, and the cover to reinforcing bars shall be 50 mm ± 15 mm.

.2 The clear distance of the end perimeter reinforcement shall not be less than 35 mm or greater than 50 mm from the ends of the box unit.

.3 Box units reinforced with WWF may be assembled using any combination of single or double layers of the fabric. Box units using reinforcing steel bars shall be assembled with single layers of reinforcement in each face in each direction.

.3 Laps, Welds, and Spacing of Reinforcement,

.1 Welding of steel reinforcement shall be according to CSA W186, performed by a qualified welder working for a company certified by the Canadian Welding Bureau, according to CSA W186.

.2 Splices in the perimeter reinforcement shall be made by lapping. Reinforcement shall not be lapped in tension zones. Sheets of the WWF shall be tack welded at lap locations.

.3 The overlap measured between the outermost longitudinal wires of each WWF sheet, shall not be less than the spacing of the longitudinal wires plus 50 mm or 250 mm, whichever is greater. The centre to centre spacing of the perimeter wires shall not be less than 50 mm or more than 105 mm. The centre to centre spacing of the longitudinal wires shall not be more than 205 mm.

.4 Joints,

.1 The joint design shall consist of a bell or groove on one end of a unit of box and a spigot or tongue on the adjacent end of the joining box, with a smooth interior and free of irregularities, capable of accepting a jointing material.

.5 Curing,

.1 Except for exposed ends, Wet Cast box units shall be cured by leaving the box units in the form or by low pressure steam. Dry Cast box units and the exposed ends of the Wet Cast box units shall be covered and cured by low pressure steam or other system that will maintain a moist atmosphere

.2 Box units shall be cured until a minimum strength of 25 MPa is achieved or for four days, whichever occurs first.

.3 Curing procedures specific to a particular precast plant may be used if the procedures have been shown to produce a finished concrete product that meets or exceeds all of the performance requirements specified in CSA A23.4, where applicable.

.4 Elements containing silica fume shall be moist cured for 7 days.

.5 Curing compounds are not an acceptable method of curing.

.6 Forms,

- .1 The forms used in the production process shall be sufficiently rigid and accurate to maintain the specified box unit dimensions.
- .2 All casting surfaces shall be of smooth, nonporous, and non-staining material. Insulated forms shall not be used.

.7 Handling,

- .1 Lifting hardware will be permitted in each box unit for the purpose of handling and installing.

.8 Markings should be clearly marked on each section of box:

- .1 Size: Span X Rise dimensions
- .2 Specification designation, i.e. OPSS.
- .3 Date of manufacture
- .4 Precast producer's name or trademark
- .5 Plant identification
- .6 Plant Prequalification Program stamp
- .7 Other markings as specified by the owner

6.0 QUALITY ASSURANCE

- .1 Precast concrete box units shall be fabricated by a precast producer possessing a certificate of the Plant Prequalification Program, indicating the plant's conformance to the Prequalification Requirements for Precast Concrete Drainage Products.
- .2 The latest test results of the precast producer's quality control procedures specified in the subsection for Quality Control shall be submitted to the Owner.
- .3 The Owner may request submission of samples for testing.
- .4 The Owner shall be provided access to the precast producer's plant, at times and locations determined by the Owner, to perform independent inspection, sampling, and testing.

7.0 QUALITY CONTROL

- .1 All testing shall be carried out by a person holding certification for either:
 - a) CCIL Certified Concrete Testing Technician; or,
 - b) ACI Concrete Field Testing Technician – Grade 1.

.2 Testing and inspection protocol shall be carried out as outlined in the requirements of the Plant Prequalification Program for precast box units.

.3 Tests with concrete include compressive strength, air void system for Wet Cast concrete, salt scaling for Dry Cast concrete on box units representing a lot size of 1000 m² of box unit floor area or two months of production.

.4 Inspection of box units include box unit dimensions with tolerances for span and rise, slab and wall thickness, length of unit, squareness, straightness of joints, and concrete cover over reinforcement. Refer to Precast/Prestressed Concrete Institute, *PCI MNL-135* for box culverts.

.5 A set of two cylinders shall be made for determining the 28-Day strength of the concrete. The cylinders shall be made, cured, sampled, and tested according to OPSS 1350, except both cylinders shall be either 150 x 300 mm or 100 x 200 mm in size. The testing shall be carried out at a CSA certified laboratory acceptable to the Owner. The compressive strength result shall be the average of a set.

.6 One set of cores shall be obtained from each lot, done according to CSA A23.2-14C. Cores shall not contain steel reinforcement or other embedded material.

8.0 CONSTRUCTION

.1 Installation of box culverts, box sewers and precast elements in open cut shall be in accordance with OPSS 422 and OPSS 902.

.2 The installation contractor is to achieve all construction requirements in the field as detailed on the box supplier's Working Drawings and/or on the design consultant for the precast.

.3 Box units shall be founded on competent in situ soil or a compacted backfill or granular, or as specified in the Contract Documents. All unsuitable material during excavation shall be removed or replaced for the foundation.

.4 The box units shall be installed to make a continuous line forming a box culvert or box sewer. The joint gap between box units shall not exceed 20 mm.

.5 For box culverts placed in parallel lines for multi-cell installations, a 60 ± 10 mm gap or separation, filled with grout between adjacent units, shall be provided.

.6 Unless specified otherwise, a 600mm wide strip of geotextile shall be placed to form a continuous barrier, centred around the exterior of all buried joints. This is to prevent the influx of material from the backfill and/or native soil through the joints.

.7 Transporting, Unloading, Storing and Handling Box

.1 Precast producer's recommendations for transporting, unloading, storing, and handling of pipe shall be followed.

.8 All construction and installation efforts shall be done according to OPSS 404, Occupational Health and Safety Act, and Ontario Regulations 213/91 – Regulations for Construction Projects.

APPENDIX B – PCI MNL-135-00 (excerpt)

Tolerance Manual for Precast and Prestressed Concrete Construction, *Section 10.25.1*

10.25 Box Culvert

a	= Length	- 1/2, +1 in. [-13, +25 mm]
b	= Span:	
	Less than 48 in. [1.2 m]	± 7/16 in. [±10 mm]
	48 in. [1.2 m] to 96 in. [2.4 m]	± 3/4 in. [±19 mm]
	Greater than 96 in. [2.4 m]	± 1 in. [±25 mm]
b ₁	= Thickness* of walls	- 3/16 in., +1 in. [-4.5 mm, +25 mm]
c	= Rise	
	Less than 48 in. [1.2 m]	± 7/16 in. [±10 mm]
	48 in. [1.2 m] to 96 in. [2.4 m]	± 3/4 in. [±19 mm]
	Greater than 96 in. [2.4 m]	± 1 in. [±25 mm]
c ₁	= Slab thickness	- 3/16, +1 in. [-4.5, + 25 mm]
c ₂	= Haunch dimension	± 1/4 in [±6 mm]
e	= Variation in length of opposite surfaces:	
	Per 12 in [0.3 m] of internal span	± 1/8 in. [±3 mm]
	Maximum to 84 in. [2.1 m] span	± 5/8 in. [±15 mm]
	Maximum over 84 in. [2.1 m] span	± 3/4 in. [±19 mm]

* Refer to ASTM C 850 and ASTM C 789 for reinforcement placement tolerances.

Fig. 10.25.1 Box Culvert

