



MATERIAL SPECIFICATION FOR PRECAST REINFORCED CONCRETE BOX CULVERTS WITH SPAN 3m OR LESS

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1821.01	SCOPE

This specification covers the material and fabrication requirements of single-cell precast reinforced concrete box culverts with span 3 m or less (including imperial sized spans of 3.048 m).

1821.02 REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 904	Concrete Structures
OPSS 905	Steel Reinforcement for Concrete
OPSS 909	Prestressed Concrete - Precast Concrete
OPSS 919	Formwork and Falsework

Ontario Provincial Standard Specifications, Material

OPSS 1002	Aggregates - Concrete
OPSS 1302	Water
OPSS 1306	Burlap
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete

Ontario Ministry of Transportation Publications

Structural Manual

MTO Laboratory Testing Manual:

- LS-410 Method of Test for Compressive Strength of Concrete Cores
- LS-412 Method of Test for Scaling Resistance of Concrete Surfaces Exposed to De-icing Chemicals
- LS-432 Method of Test for Microscopical Determination of Air Void System Parameters in Hardened Concrete
- LS-433 Method of Test for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

MTO Forms:

- PH-CC-433A Concrete Mix Design Form A
- PH-CC-701 Request to Proceed
- PH-CC-702 Notice to Proceed

CSA Standards

- A23.2-14C Obtaining and Testing Drilled Cores for Compressive Strength Testing*
* [Part of A23.1-19/A23.2-19 – Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete]
- A23.4-16 Precast Concrete Materials and Construction
- S6-19 Canadian Highway Bridge Design Code
- W47.1-09 (R2019) Certification of companies for fusion welding of steel
- W59-18 Welded steel construction (metal arc welding)
- W186 Welding of Reinforcing Bars Company Certification

ASTM International

- A153/A153M-16a Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A240/A240M-22 Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

1821.03 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Box Culvert means a box culvert constructed of precast reinforced concrete box units rectangular in cross-section, with a span 3 m or less and includes imperial sized spans of 3.048 m.

Box Unit means a single precast reinforced concrete box unit of a box culvert.

Concrete Appurtenances means as defined in OPSS 422.

Dry Cast Concrete means concrete with a slump of 0 mm at the time of placing, that is consolidated in the form using low-frequency high-amplitude vibration.

Height of Fill means the smallest elevation difference, between the top surface of box culvert and the top of pavement or finished grade, from edge of shoulder to edge of shoulder.

Honeycombing means rough and stony concrete surface with voids where the mortar did not fill the spaces between the coarse aggregate particles.

Longitudinal Steel Reinforcement means steel reinforcement aligned parallel to the longitudinal axis of the box unit.

Perimeter Steel Reinforcement means perimeter steel reinforcing bars or perimeter wires reinforcement aligned perpendicular to the longitudinal axis of the box unit.

Wet Cast Concrete means concrete with a measurable slump at the time of placing, that is typically consolidated by vibration.

1821.04 DESIGN AND SUBMISSION REQUIREMENTS

1821.04.01 Design Requirements

All box units shall be designed according to CSA S6, the Structural Manual, Division 1, Table 1 and as specified the Contract Documents.

1821.04.02 Submission Requirements

1821.04.02.01 Working Drawings

The box unit manufacturer's Working Drawings, including supporting documentation, shall be submitted to the Contract Administrator at least 7 Days prior to fabrication of the box units. All Working Drawings shall bear the seal and signature of an Engineer certifying they are as specified in the Contract Documents.

1821.04.02.02 Concrete Mix Designs

The concrete mix shall be designed to provide adequate strength and durability for the intended use and to meet the requirements as specified in the Contract Documents. The concrete mix design shall be submitted according to the Mix Design clause in OPSS 1350.

1821.04.02.03 Salt Scaling Resistance in Dry Cast Concrete

Salt scaling results obtained by the manufacturer shall be submitted to the Contract Administrator within 14 weeks of casting the box unit. Salt scaling results shall be current within 3 months at the time of submission. The results shall demonstrate the concrete meets the requirements of this specification.

For evaluation of the salt scaling resistance of dry cast concrete, a set of two specimens shall be cast and tested a using the same mix design and production procedures as will be used for the work. The specimens shall be 300 x 300 x 75 mm and shall be tested according to LS-412.

The salt scaling resistance test shall be carried out by a laboratory from MTO's list of qualified laboratories for scaling resistance of concrete surfaces. The salt scaling result shall be the average of a set.

1821.04.02.04 Precast Plant Certification Submissions

The certificate, verifying that the precast plant is certified according to the Precast Plant Certification clause, shall be submitted with the concrete mix design submission.

Copies of precast plant certification audit reports of the Canadian Precast Concrete Quality Assurance Program (CPCQA), Canadian Standards Association (CSA), or both as applicable, and related documentation, shall be submitted to the Owner upon request.

If concrete is supplied by a ready-mix concrete supplier, a currently valid certificate of ready mixed concrete production facilities as issued by the Ready Mixed Concrete Association of Ontario (RMCAO), shall be submitted with the concrete mix design submission.

For multi-year Contracts, for all plants supplying the work, documentation verifying that the precast plant, and ready-mix plant(s) if used, continue to hold valid certification shall be submitted annually.

1821.04.02.05 Manufacturer's Certificate of Conformance and Precast Report

A Manufacturer's Certificate of Conformance and a precast report shall be submitted to the Contract Administrator for each shipment of box units at least 5 Business Days prior to shipping from the precast plant.

The precast report shall contain the following information:

- a) List of box units in the shipment, including their ID number, lot number, and description.
- b) Mill certificates for the steel reinforcement used in the box units.
- c) Summary of material test results for plastic concrete. For wet cast concrete, test results for air content, slump, and concrete temperature shall be submitted. For dry cast concrete, test results for concrete temperature shall be submitted.
- d) Covermeter and dimensional check report.
- e) Summary of material test results for hardened concrete: stripping strength (for wet cast concrete only), confirmation of the projected 28-Day compressive strength. If test results are not available at the time of shipping, they may be submitted within 4 Business Days following completion of testing.
- f) Sampling records for compressive strength, air void system (for wet cast), rapid chloride permeability and scaling resistance (for dry cast).

A MTO form PH-CC-701, Request to Proceed shall be submitted to the Contract Administrator before the delivery of each shipment of box units to the Working Area.

The box units shall not be delivered to the Working Area until the Contract Administrator has issued a MTO form PH-CC-702, Notice to Proceed.

1821.05 MATERIALS

1821.05.01 Associated Hardware

All associated hardware shall be according to OPSS 905, except that all exposed and embedded hardware within 35 mm of exposed faces, including spacers and support devices, shall be non-corroding, non-metallic, or be galvanized according to ASTM A153M, or be stainless steel according to ASTM 240M Type 304.

1821.05.02 Burlap

Burlap shall be according to OPSS 1306.

1821.05.03 Concrete

Concrete materials for precast components shall be according to the Materials section in OPSS 1350 with the following additions and amendments:

- a) The minimum specified 28-Day compressive strength shall be 35 MPa, unless otherwise specified in the Contract Documents.
- b) For wet cast concrete, the minimum specified stripping strength shall be 20 MPa, unless otherwise specified in the Contract Documents.

- c) For wet cast concrete, the air void system spacing factor, when tested according to LS-432, shall be 0.200 mm maximum.
- d) For dry cast concrete, the salt scaling resistance when tested according to LS-412 and this specification shall have a mass loss of not more than 0.8 kg/m².
- e) Aggregates shall be according to OPSS 1002.
- f) The allowable proportion of cementing material of ground granulated blast furnace slag in dry cast concrete shall be limited to a maximum of 40% by mass of total cementing materials.

1821.05.04 Formwork

All formwork shall be according to OPSS 919 and CSA A23.4. Formwork shall be fabricated to meet the dimensional tolerances and finishes specified in the Contract Documents. Textile form liners shall not be permitted.

1821.05.05 Steel Reinforcement

Steel reinforcement shall be according to OPSS 1440.

1821.05.06 Water

Water used for curing, including steam curing and pre-soaking of burlap, and water used in proprietary patching materials shall be according to OPSS 1302.

1821.06 EQUIPMENT

1821.06.01 General

Equipment made of aluminum, including tools, shall not come in contact with the plastic concrete.

1821.07 PRODUCTION

1821.07.01 Precast Plant Certification

Box units shall be fabricated by a plant certified according to one of the following:

- a) CPCQA certification program, precast concrete drainage products, or
- b) CSA precast concrete products certification program, group D, drainage products (D1 minimum).

If concrete is supplied by a ready-mix concrete plant, the concrete production facility shall be certified by the RMCAO.

1821.07.02 Markings

As a minimum, the following information shall be lettered with waterproof paint on an upper top haunch of each box unit in the following order, and readily visible for inspection:

- a) Prequalification stamp according to the CPCQA or CSA certification program.
- b) Name or trademark of the manufacturer.

- c) Identification of plant if manufacturer has more than one plant.
- d) Date of manufacture (yyyy-mm-dd).
- e) Unique number.
- f) Specification designation.
- g) MTO site number, when specified in the Contract Documents.
- h) Minimum and maximum height of fill over box units.

In addition, the word "TOP" shall be lettered with waterproof paint on the top surface of each box unit. This requirement shall be waived if the manufacturer installs lift holes in the top slab only.

1821.07.03 Steel Reinforcement

1821.07.03.01 General

The placement of steel reinforcement shall be according to OPSS 905.

Under no circumstance shall reinforcement be inserted into plastic concrete.

1821.07.03.02 Area of Steel Reinforcement

The box unit steel reinforcement area shall be according to Table 1 for the box unit dimensions, wall thickness, and height of fill specified in the Contract Document.

1821.07.03.03 Placement of Steel Reinforcement

The concrete cover shall be according to Table 2.

The clear distance of the end perimeter steel reinforcement shall be not less than 35 mm or greater than 50 mm from the ends of the box unit. Box units may be assembled utilizing any combination of single or double layers of the steel welded wire reinforcement (WWR) or reinforcing steel bars.

The areas of steel reinforcement shall be the steel reinforcement areas as shown in Table 1. Steel reinforcement areas greater than those required shall not be cause for rejection.

1821.07.04 Laps, Welds, and Spacing of Steel Reinforcement

Splices in the perimeter steel reinforcement shall be made by lapping and only at locations specified in the Contract Documents. Sheets of the WWR shall be welded at lap locations using the provisions for non-load-bearing joints according to CSA W186. WWR sheets shall not be welded elsewhere. The welding shall be performed by a welder qualified by the Canadian Welding Bureau (CWB) working for a company certified according to CSA W186. The overlap measured between the outermost longitudinal wires of each WWR sheet shall not be less than the spacing of the longitudinal wires plus 50 mm, or 250 mm, whichever is greater. Lap splices for reinforcing steel bars including longitudinal steel reinforcement, shall be Class B splices according to CSA S6.

The spacing center to center of the perimeter wires shall not be less than 50 mm or greater than 105 mm. The spacing center to center of the longitudinal wires shall not be greater than 205 mm.

Welding of steel hardware shall be according to CSA W59 and shall be performed by a welder qualified by the CWB working for a company certified according to CSA W47.1, Division 1 or 2.

Welding of steel reinforcement shall be according to OPSS 905.

1821.07.05 Joints

The box units shall be produced with bell and spigot ends. The ends shall be of such design that when the boxes are laid together, they will make a continuous box culvert with a smooth interior free of irregularities in the flow line.

1821.07.06 Production of Concrete

1821.07.06.01 General

Production of concrete shall be according to the General, Temperature Control, Mixing Time and Mixing Rate, and Discharge Time subsections in OPSS 1350.

1821.07.06.02 Sampling and Testing of Plastic Concrete for Wet Cast Concrete

For wet cast concrete, sampling and testing of the plastic concrete for slump, air content, and temperature shall be according to OPSS 1350. The results of these tests shall be recorded and submitted in the precast report. The minimum frequency of testing shall be as follows:

- a) For concrete supplied by an external concrete supplier and delivered by a ready-mix truck, once for each of the first three trucks, until satisfactory control is established, and then once every third truck.
- b) For batches of concrete produced at the precast plant and transported by a ready-mix truck, once for each of the first three trucks, until satisfactory control is established, and then once every third truck.
- c) For batches of concrete produced at the precast plant, and not delivered by a ready-mix truck, once for each of the first five batches of concrete, until satisfactory control is established, and then once every fifth batch.

Satisfactory control is established when three or five consecutive tests of concrete, as specified above, are within the specified requirements, without adjustments. If any adjustments are required or conducted, testing shall continue until three or five consecutive tests, as specified above, meet the requirements with no adjustments. Satisfactory control shall be established each Day or when there is a break in production longer than 1.5 hours.

Testing of plastic concrete shall be carried out as close as possible to the location of discharge of concrete into the formwork.

Sampling and testing of slump, air content, and temperature of plastic concrete shall be carried out by a person holding either of the following certifications:

- a) CCIL Certified Concrete Testing Technician;
- b) ACI Concrete Field Testing Technician, Grade 1; or
- c) CSA Standards Concrete Field Testing Technician.

The person shall have a valid original card issued by the certifying agency in their possession at all times.

1821.07.06.03 Testing of Plastic Concrete for Dry Cast Concrete

For dry cast concrete, the concrete shall be tested for temperature. Temperature shall be measured according OPSS 1350. The minimum frequency of testing shall be once for each Day of production.

1821.07.07 Placing of Concrete

1821.07.07.01 General

The method of transporting, placing, and consolidating the concrete shall be such as to prevent segregation.

For wet cast concrete, concrete shall be deposited within 0.5 m of the top of the steel reinforcement and 1.5 m horizontally of its final position.

Concrete shall be placed at a steady rate, such that a monolithic concrete is obtained without the formation of cold joints or pour lines.

1821.07.07.02 Concrete Placing Restrictions

All surfaces against which concrete is to be placed shall be free of standing water.

All debris shall be removed from the area where concrete is to be placed.

Any surface against which concrete is placed, including any existing concrete, steel reinforcement, structural steel, forms, or other surfaces shall be at a minimum temperature of 5.0 °C immediately prior to commencement of placing concrete. The temperature of the formwork, steel reinforcement or any other material against which concrete is to be placed shall not exceed 30.0 °C.

1821.07.07.03 Consolidation

Internal or external vibrators or both shall be used to thoroughly consolidate concrete.

Vibration shall not be used to make the concrete flow or to spread the concrete more than 1.5 m from the point of deposit.

The requirements of this clause do not apply to self-consolidating concrete, where accepted for use by the Owner.

1821.07.07.04 Concrete Finishing

For wet cast concrete, finishing of the concrete surface shall be done immediately following placement.

No material shall be applied to the concrete surface or the finishing tools to aid in the finishing.

1821.07.08 Curing

1821.07.08.01 General

Box units shall be moist cured until a minimum compressive strength of 25 MPa is achieved or for 4 Days, whichever occurs first.

Except for exposed surfaces, wet cast box units may be cured by leaving the box units in the form.

Dry cast box units and the exposed surfaces of the wet cast box units shall be moist cured using one or a combination of the methods in the Moist Curing clause of this specification.

1821.07.08.02 Moist Curing

Moist curing shall be sufficient to keep all surfaces of the concrete in a continuously wet condition, with no dry areas, by applying one or a combination of the following methods:

- a) Curing according to the Curing with Burlap and Water clause.
- b) Curing by means of continuous water application, e.g. mist.
- c) Curing according to the Steam Curing and Other Application of Heat clause.
- d) Curing by means of immersion in water.

Records of moist curing shall be maintained and submitted according to the requirements of this specification.

Formwork shall be removed within 4 Days of concrete placement and the concrete shall be moist cured for the remainder of the minimum curing period and no less than 24 hours.

1821.07.08.03 Curing with Burlap and Water

Curing with burlap and water shall be according to the Curing with Burlap and Water clause in OPSS 909 with the addition of the following:

- a) Burlap shall be held in place without marring the surface of the concrete.

1821.07.08.04 Steam Curing and Other Application of Heat

Steam curing and application of heat, if used, shall be according to the requirements of the Steam Curing and Other Application of Heat section in OPSS 909.

1821.07.09 Surface Finish

The surface finish shall be according to the Surface Finish subsection in OPSS 904.

1821.07.10 Concrete Cover Measurement

The Contractor shall carry out, at the precast facility, a covermeter survey on two box units, selected at random, per group of 15 consecutively produced box units.

Measurement shall be obtained on a 1 metre grid on all interior and exterior surfaces of the box unit, including the ends of the units.

Cover measurements shall be carried out by a method acceptable to the Contract Administrator and shall be reported in writing to the Contract Administrator prior to delivery of the box units.

1821.07.11 Dimensional Tolerances

The Contractor shall carry out dimension measurements on two box units, selected at random, per group of 15 consecutively produced box units.

Box units shall meet the tolerances according to Table 2 and as specified in the Contract Documents.

For dimensional tolerances not specified, the maximum allowable dimensional variation shall be 1:800 or +/- 5mm, whichever is greater.

1821.07.12 Material Sampling for Acceptance Testing

1821.07.12.01 Sampling of Steel Reinforcement

When requested by the Contract Administrator, samples of steel reinforcement shall be provided to the Owner according to OPSS 905.

1821.07.12.02 Sampling of Water, Admixtures and Cementing Materials

When requested by the Contract Administrator, samples of all cementing materials, admixtures, and water shall be obtained for testing by the Owner.

1821.07.12.03 Sampling of Hardened Concrete for Acceptance Testing

1821.07.12.03.01 General

Test specimens shall consist of cores removed from box units.

Cores shall be removed at the plant or on site when the box unit is between 7 to 10 Days of age, and prior to application of any sealer. Cores and slabs shall be removed in the presence of the Contract Administrator or Owner's representative.

The box units and the location of the cores shall be randomly selected by the Contract Administrator.

1821.07.12.03.02 Notification

A list of box units and their identification numbers shall be submitted to the Contract Administrator within 24 hours of the completion of a lot.

1821.07.12.03.03 Coring

One set of cores shall be obtained from each lot for quality assurance testing as directed by the Contract Administrator.

For dry cast concrete, a set of cores shall consist of five 100 mm diameter and 200 mm long cores.

For wet cast concrete, a set of cores shall consist of six 100 mm diameter and 200 mm long cores.

If the box unit is less than 200 mm thick, the full depth of the box unit shall be cored such that the core has a length to diameter ratio of at least 1.5.

The box unit from which the cores and samples are taken shall be clearly labelled and shall be retained until Contract Completion.

Coring shall be carried out according to CSA A23.2-14C. Cores shall not contain steel reinforcement or other embedded material. A covermeter capable of detecting the type(s) of steel reinforcing materials in the box unit shall be used to establish the location of steel reinforcement and other embedded material prior to coring.

The Contract number, lot number, and unique box unit number shall be marked legibly on each core with durable ink. Each core shall be placed in a plastic bag, sealed to prevent loss of moisture and placed into clear polyethylene security bags supplied by the Owner when instructed by the Contract Administrator. The specimens shall be accompanied by a transmittal form and MTO form PH-CC-433A, Concrete Mix Design Form A of the concrete mix design for the box unit. At this point, the Contract Administrator shall take possession of, and assume responsibility for the samples. The Contract Administrator or his representative may apply security seals.

The core holes and lift holes shall be filled, within 3 Days, according to the Filling of Core Holes subsection in OPSS 1350, with concrete or a proprietary patching material from the Owner's pre-qualified products list. Concrete used to patch holes shall have comparable properties to that of the concrete used in the box unit.

1821.07.12.04 Access for Quality Assurance

Unhindered access for inspection and testing of all the work shall be provided to the Contract Administrator or Owner's representative.

Any debris and obstructions shall be removed to allow access for the purposes of covermeter and dimensional measurements or inspection.

1821.07.13 Management of Excess Material

Management of excess material shall be according to the Contract Documents.

1821.08 QUALITY ASSURANCE

1821.08.01 General

The acceptance of box units shall be according to the requirements of this specification.

Acceptance for compressive strength, rapid chloride permeability, concrete cover and dimensional measurements of dry cast concrete shall be on a lot basis.

Lots not meeting the requirements of the Contract Documents shall be deemed rejectable.

1821.08.02 Lot Size

The Contract Administrator shall determine the limits of each lot prior to commencing production and shall confirm the specific box units to be included in each lot prior to commencing production of that lot. A lot generally consists of all the box units of the same span and concrete mix design produced during 7 consecutive Days.

1821.08.03 Acceptance of Concrete Compressive Strength

1821.08.03.01 General

Compressive strength shall be determined according to LS-410.

Three cores shall be tested to determine the acceptability of compressive strength of the lot. 28-Day concrete compressive strength of a lot shall be considered acceptable when the average of the three individual compressive strength cores is equal to or greater than the specified strength and no individual core result is more than 10.0% below the specified 28-Day compressive strength.

Test results shall be forwarded to the Contractor as they become available.

1821.08.03.02 Referee Testing of Compressive Strength

Referee testing of compressive strength may only be invoked by the Contractor within 5 Business Days of receipt of the acceptance test result.

Referee testing of compressive strength shall be carried out on a set of three cores taken by the Contractor from the box unit which the acceptance cores were taken from. The cores shall be removed in the presence of the Contract Administrator. Coring shall be according to the Coring clause. Referee cores shall be obtained within 3 Business Days of invoking referee testing.

The referee laboratory shall be designated by the Owner based on the applicable roster and cores shall be tested according to LS-410.

Referee test results shall be forwarded to the Contractor as they become available.

The confirmation value for confirming the acceptance test result shall be the greater of 10.0% of the specified strength or 10.0% of the strength of the acceptance cores, expressed to one decimal place.

If the difference between the referee test result and the acceptance test result is less than the confirmation value, the acceptance test result is confirmed, and the acceptance test result shall be used in the determination of acceptance of the lot. If the difference between the referee test result and the acceptance test result is greater than the confirmation value, the acceptance test result is not confirmed, and the acceptance test result shall be disregarded and the referee test result shall replace the acceptance test result in the acceptance requirements of this specification.

The cost of referee testing of compressive strength shall be according to OPSS 1350.

1821.08.04 Acceptance of Air Void System in Hardened Concrete

1821.08.04.01 General

For wet cast concrete, one core per lot shall be tested for air void system parameters. Acceptance of air void system shall be based on the result obtained on the core representing the lot.

Testing of air void system shall be according to LS-432. One half of the sample shall be tested to determine the acceptability of the lot. The other half of the sample shall be retained by the Owner for audit purposes.

Test results shall be forwarded to the Contractor as they become available.

For a lot to be considered acceptable, the sample shall have a minimum air content of 3.0% and a spacing factor of 0.200 mm or less. Acceptable lots shall be subject to full payment.

Lots with samples having a spacing factor between 0.200 mm and 0.250 mm shall be considered unacceptable. Unacceptable lots shall be rejected and replaced, except where the Owner permits an unacceptable lot to remain in place. When the Owner permits an unacceptable lot to remain in place it shall be subject to a payment adjustment, calculated according to the Payment Adjustment for Air Void System in Hardened Concrete clause in OPSS 422.

Lots with samples having air content less than 3.0%, a spacing factor more than 0.250 mm or both shall be deemed rejectable.

1821.08.04.02 Referee Testing of Air Void System in Hardened Concrete

Referee testing of air void system in hardened concrete shall be according to OPSS 1350.

The cost of air void system referee testing shall be according to OPSS 1350.

1821.08.05 Acceptance of Rapid Chloride Permeability

1821.08.05.01 General

Acceptance of rapid chloride permeability shall be based on the result obtained on the core representing the lot.

One core per lot shall be tested according to LS-433. Acceptance testing shall be carried out at 28 to 32 Days. Two samples 50 mm long shall be cut from the core representing a lot, tested, and averaged to determine the acceptance of the lot. Another core shall be retained for referee testing.

Test results shall be forwarded to the Contractor as they become available.

1821.08.05.02 Concrete Without Silica Fume

Lots with rapid chloride permeability less than or equal to 2,500 coulombs are considered acceptable. Acceptable lots shall be subject to full payment.

Lots with a rapid chloride permeability result greater than 2,500 coulombs are unacceptable. If the Owner permits the work to remain in place, lots with an average value of rapid chloride permeability exceeding 2,500 coulombs and less than 3,500 coulombs shall be subject to a payment adjustment calculated according to the Basis of Payment section in OPSS 422.

Lots with rapid chloride permeability results exceeding 3,500 coulombs shall be deemed rejectable.

1821.08.05.03 Concrete Containing Silica Fume

Lots with rapid chloride permeability less than or equal to 1,000 coulombs are considered acceptable. Acceptable lots shall be subject to full payment.

Lots with a rapid chloride permeability result greater than 1,000 coulombs are unacceptable. If the Owner permits the work to remain in place, lots with an average value of rapid chloride permeability exceeding 1,000 coulombs and less than 2,000 coulombs shall be subject to a payment adjustment calculated according to the Basis of Payment section in OPSS 422.

Lots with rapid chloride permeability results exceeding 2,000 coulombs shall be deemed rejectable.

Test results shall be forwarded to the Contractor as they become available.

1821.08.05.04 Referee Testing of Rapid Chloride Permeability

1821.08.05.04.01 General

Referee testing of rapid chloride permeability may only be invoked by the Contractor within 5 Business Days of receipt of the acceptance test result.

Referee testing shall be carried out on two 50 mm samples obtained from the reserved core representing the lot for which referee testing was invoked, and the results shall be averaged to obtain the test result for the lot.

Cores shall be tested according to LS-433.

The referee laboratory shall be designated by the Owner based on the applicable roster and cores shall be tested by that laboratory.

Referee test results shall be forwarded to the Contractor as they become available.

The cost of referee testing of rapid chloride permeability for all concrete shall be according to OPSS 1350.

1821.08.05.04.02 Concrete Without Silica Fume

When the referee result is greater than the acceptance test result or no more than 500 coulombs below the acceptance test result, the acceptance test result is then confirmed and shall remain valid. When the referee test result for the lot is more than 500 coulombs below the acceptance test result, the acceptance test result is then not confirmed, and the referee test result shall replace the acceptance test result in the acceptance requirements of this specification.

1821.08.05.04.03 Concrete Containing Silica Fume

When the referee result is greater than the acceptance test result or no more than 300 coulombs below the acceptance test result, the acceptance test result is then confirmed and shall remain valid. When the referee test result for the lot is more than 300 coulombs below the acceptance test result, the acceptance test result is then not confirmed, and the referee test result shall be used for determining acceptability of the lot.

1821.08.06 Acceptance of Water, Admixtures, and Cementing Materials

Acceptance of water, admixtures and cementing materials shall be according to OPSS 1350.

1821.08.07 Dimensional Verification and Concrete Cover Measurements

The Contract Administrator shall carry out measurements on interior and exterior surfaces on at least one box unit per lot to confirm compliance with the requirements of Table 2 and the Contract Documents. The Contract Administrator shall be notified in writing when the test area is ready for the concrete covermeter survey and dimensional verification.

If a box unit fails to meet the dimensional or cover tolerances specified in Table 2 and the Contract Documents:

- a) It shall be deemed rejectable; and
- b) A consultant shall be retained by the Owner, at the Contractor's expense, to verify that all the other box units in the lot are within the tolerances of Table 2 and as specified in the Contract Documents.

1821.08.08 Defects and Deficiencies Causing Rejection

An individual box unit having one or more of the following defects and deficiencies shall be deemed rejectable:

- a) Inadequate area of steel reinforcement or cover to steel reinforcement;
- b) Dimensions outside of the tolerances specified in Table 2 and the Contract Documents;
- c) Defects resulting from incorrect proportioning, mixing, and forming;
- d) Cracks greater than 0.3 mm in width or full-depth cracks;
- e) Honeycombed or broken surface texture; and
- f) Spalls and damaged ends.

TABLE 1 (1.1 to 1.9)
Steel Reinforcement Areas

Table 1.1: 1.8 m span by 0.9 m rise. 200 mm wall thickness. As4=400							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	520	415	400	400	425	510	600
As2	1010	410	400	420	525	635	810
As3	480	425	400	435	540	650	865
As5	300	140	140	140	140	140	140

Table 1.2: 1.8 m span by 1.2 m rise. 200 mm wall thickness. As4=400							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	470	400	400	400	400	465	545
As2	1085	440	400	445	555	670	865
As3	480	460	400	465	575	695	950
As5	300	140	140	140	140	140	140

Table 1.3: 2.4 m span by 1.2 m rise. 200 mm wall thickness. As4=400							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	790	725	545	645	755	920	1085
As2	1350	700	565	715	905	1400	2480
As3	565	730	590	745	930	1560	2750
As5	300	140	140	140	140	140	140

Table 1.4: 2.4 m span by 1.5 m rise. 200 mm wall thickness. As4=400							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	730	685	515	605	705	855	1010
As2	1385	790	630	800	1010	1430	2500
As3	630	825	665	835	1045	1600	2850
As5	300	140	140	140	140	140	140

Table 1.5: 2.4 m span by 1.8 m rise. 200 mm wall thickness. As4=400							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	675	650	490	570	665	800	945
As2	1445	830	660	830	1045	1510	2670
As3	675	875	705	880	1095	1740	3060
As5	300	140	140	140	140	140	140

Table 1.6: 3.0 m span by 1.5 m rise. 250 mm wall thickness. As4=500							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	850	875	660	775	905	1090	1290
As2	1260	835	675	855	1070	1680	2910
As3	620	875	715	895	1110	1910	3310
As5	300	140	140	140	140	140	140

Table 1.7: 3.0 m span by 1.8 m rise. 250 mm wall thickness. As4=500							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	800	835	630	740	855	1035	1215
As2	1290	930	750	945	1185	1685	2950
As3	660	985	800	995	1240	1950	3380
As5	300	140	140	140	140	140	140

Table 1.8: 3.0 m span by 2.1 m rise. 250 mm wall thickness. As4=500							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	750	805	610	710	820	985	1155
As2	1340	970	775	980	1225	1780	3080
As3	700	1035	835	1040	1290	2080	3610
As5	300	140	140	140	140	140	140

Table 1.9: 3.0 m span by 2.4 m rise. 250 mm wall thickness. As4=500							
	Fill <0.6 m	Fill = 0.6 m	Fill = 2.0 m	Fill = 3.0 m	Fill = 4.0 m	Fill = 5.0 m	Fill = 6.0 m
As1	770	740	565	650	750	900	1055
As2	1380	1010	800	1010	1260	1860	3220
As3	745	1080	875	1080	1335	2220	3850
As5	300	140	140	140	140	140	140

Notes Table 1 (1.1 to 1.9):

- a) All metric or all imperial dimensions may be used for span, height, and wall thickness unless specified in the Contract Documents.
- b) Specified yield strength of welded WWR $F_y = 500$ MPa. Reinforcing steel bar, if used, shall be grade 500W.
- c) Area of steel reinforcement given is mm^2 per metre length of box unit. In Table 1.1 through Table 1.9:
 - i. As1 shall be the area of steel of the C-shaped bars on the outside face of the box culvert.
 - ii. As2 shall be the area of steel on the bottom face of top slab.
 - iii. As3 shall be the area of steel on the top face of the bottom slab.
 - iv. As4 shall be the area of steel on the inside face of the walls.
 - v. As5 shall be the area of steel in the longitudinal direction on each face of all slabs and walls.
 - vi. As6 = 525 shall be the longitudinal steel reinforcement required on the bottom face of the top slab, in lieu of As5, only when depth of fill is <0.6 m.
 - vii. The extent and details of the steel reinforcement shall be as specified in the Contract Documents.

- d) The area of steel reinforcement for As1 through As3, shall be determined from Table 1 for height of fill at both edges of pavement and at the crown. The largest steel reinforcement area for each of As1 through As3 shall be used for each one of these points. Interpolation shall be used for values of height of fill between those tabulated. As4 through As6 shall be taken as applicable on each box culvert size mentioned in their respective in Table 1.1 through Table 1.9
- e) As6 is only required for height of fill <0.6 m. As6 may be added to the area of As5 of the bottom mat of steel reinforcement in the top slab or as a second layer of steel reinforcement on top of the bottom mat of steel reinforcement in the top slab.
- f) Where some reinforcing steel bar is used instead of fully using WWR, or where steel reinforcement is comprised of second layer of steel reinforcement, the effective area of steel reinforcement (A_{se}), calculated as $A_{se} = ASL1 \times \eta_f + ASL2 \times \eta_s$, shall be greater than the tabulated value of A_s . ASL1 is the Area of steel in the first layer, ASL2 is the Area of steel in the second layer, and η_f and η_s are the efficiency factors obtained from Table 3. The second layer of steel reinforcement shall be placed against the first layer such that the clear spacing of reinforcing steel bar in all layers shall permit proper consolidation of the concrete. (For example, if 1000 mm² of reinforcing steel bar is provided in the first layer of steel reinforcement, and 2000 mm² of WWR is provided in the second layer, and the slab is 200 mm thick, the effective area of steel reinforcement shall be $1000 \times 88\% + 2000 \times 75\% = 2380 \text{ mm}^2$, which must be greater than the value from Table 3).

**TABLE 2
Tolerances**

Item	Tolerances
Span (Straight-line measurement taken horizontally at the mid-height of box unit perpendicular to the centre line of the culvert.)	± 15 mm from Working Drawings
Height	± 15 mm from Working Drawings
Length	+15/-5 mm
Wall and Slab Thickness	+10 mm, -5 mm
Haunch	± 10 mm
End Squareness or Skew (Note 1)	< 15 mm along its length
Plumbness	1 in 300 maximum
Location of Blockouts	± 15 mm
Location of Inserts	± 10 mm
Concrete Cover	Cover shall be 40 mm, ± 5 mm for WWR and 50 mm ± 15 mm to reinforcing steel bars.
<p>Notes:</p> <p>1. Variations in the lengths of two opposite surfaces of the box unit. The ends of the box unit shall be normal to the wall and centreline of the box unit within the tolerances specified elsewhere in this Table except where concrete appurtenances are specified in the Contract Documents.</p>	

TABLE 3
Steel Reinforcement Efficiency Factors, η_f and η_s

Section Thickness	First Layer WWR		First Layer Reinforcement Bar	
	(η_f)	(η_s)	(η_f)	(η_s)
200	100%	86%	88%	75%
250	100%	90%	91%	82%