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|  | **ONTARIO** **PROVINCIAL STANDARD SPECIFICATION** | **OPSS.PROV 1821**  **NOVEMBER 2021** |

**MATERIAL SPECIFICATION FOR PRECAST REINFORCED CONCRETE BOX CULVERTS AND BOX SEWERS**

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**1821.01 SCOPE**

This specification covers the requirements for materials, design and fabrication, quality assurance testing and acceptance criteria of single-cell precast reinforced concrete box culverts and box sewers not exceeding 3 m (but including imperial sized spans of 3.048m) in span.

**1821.02 REFERENCES**

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

**Ontario Provincial Standard Specification, Construction:**

OPSS 904 Concrete Structures

OPSS 905 Steel Reinforcement for Concrete

OPSS 909 Prestressed Concrete – Precast Concrete

OPSS 919 Formwork and Falsework

OPSS 932 Crack Repair - Concrete

**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

**MTO Publications**

Structural Manual

MTO Laboratory Testing Manual:

LS-100 Method for Rounding–Off of Test Data and Other Numbers

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**

A23.4-16 Precast Concrete Materials and Construction

S6-19 Canadian Highway Bridge Design Code

W47.1-09 (R2014) Certification of companies for fusion welding of steel

W59-13 Welded steel construction (metal arc welding)

A23.2-9C Compressive Strength of Cylindrical Concrete Specimens\*

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]

**ASTM International**

A153-16a Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A240-20a 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 culvert constructed of precast reinforced concrete box units rectangular in cross- section.

**Distribution Slab** means a reinforced concrete slab on top of the culvert that may be specified when the height of fill is less than 600mm to improve load distribution on a culvert.

**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.

**Element** means an individual precast concrete culvert unit, or a box unit.

**Height of Fill** means the elevation difference, between the top of top slab of a box culvert and the top of pavement or finished grade.

**Joint Annular Space:** means the design clearance between the tapered surface of the bell and spigot ends of adjacent box units.

**Longitudinal Steel:** means steel reinforcement aligned parallel to the longitudinal axis of the precast box unit.

**Lot** consists of all elements of the same span and concrete mix design produced during seven consecutive Days.

**Perimeter Steel:** means steel reinforcement aligned perpendicular to the longitudinal axis of the precast box unit.

**Wet Cast Concrete:** means concrete with a measurable slump at the time of placing, that is generally placed from above, and consolidated by vibration.

# 1821.04 DESIGN AND SUBMISSION REQUIREMENTS

**1821.04.01 Design Requirements**

All box units shall be designed according to CSA S6 and the Structural Manual, Division 1. The manufacturer’s Working Drawings shall be according to Table 2 and the Contract Documents. Where the culvert size or height of fill is not covered in Table 2, the culvert design shall be completed by the Contractor.

Box culverts with a height of fill less than 0.60 m require a distribution slab. When a distribution slab is required it shall cover the entire top of box unit. The distribution slab shall be as specified in the Contract Documents.

**1821.04.02 Submission Requirements**

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

**1821.04.02.01 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 of OPSS 1350.

**1821.04.02.02 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 culvert or box sewer. The results shall demonstrate the concrete meets the requirements of this specification.

For evaluation of the salt scaling resistance of dry cast concrete, the Contractor shall cut and test a set of two specimens for every 1000 square meters of floor area from finished and cured box culvert. The specimens shall be 300 x 300 mm and shall be tested according to LS-412 without further curing.

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.

**1821.04.02.03 Precast Plant Certification Submissions**

The certificate, verifying 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 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.

**1821.04.02.04 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 elements at least 5 Business Days prior to shipping from the precast plant.

The precast report shall contain the following information:

a) List of elements in the shipment, including their ID number, lot number, and description.

b) Mill certificates for the steel reinforcement used in the elements.

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, confirmation of the projected 28-Day compressive strength. If test results are not available at the time of shipping, they may be submitted within four 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 Request to Proceed shall be submitted to the Contract Administrator before the delivery of each shipment of elements to the site.

The elements shall not be delivered to the site until the Contract Administrator has received the Manufacturer’s Certificate of Conformance, the precast report and issued a Notice to Proceed.

**1821.05 MATERIALS**

**1821.05.01 Burlap**

Burlap shall be according to OPSS 1306.

**1821.05.02 Concrete**

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

1. The minimum specified 28-Day compressive strength shall be 35 MPa, unless otherwise specified in the Contract Documents.
2. For wet cast concrete, the minimum specified stripping strength shall be 20 MPa, unless otherwise specified in the Contract Documents.
3. For wet cast concrete, the air void system spacing factor, when tested according to LS-432, shall be 0.200 mm maximum.
4. For dry cast concrete, the salt scaling resistance when tested according LS-412 and this specification shall have a mass loss of not more than 0.8 kg/m².
5. Aggregates shall be according to OPSS 1002.
6. Air-cooled blast furnace slag shall not be used as aggregate.
7. The allowable replacement of Portland cement by ground granulated blast furnace slag in dry cast concrete shall be limited to a maximum of 40% by mass of total cementing materials.

**1821.05.03 Steel Reinforcement**

Steel reinforcement shall conform to OPSS 1440.

# 1821.05.04 Associated Hardware

All associated Hardware shall be in accordance with 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-metalic, or be galvanized according to ASTM A153/A153M, or be stainless steel according to ASTM A240/240M Type 304.

# 1821.05.05 Formwork

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

# 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**

Precast culverts shall be fabricated by a plant certified according to one of the following:

1. Canadian Precast Concrete Quality Assurance (CPCQA) Certification Program, Precast Concrete Drainage Products, or

b) Canadian Standards Association (CSA) Pre-cast 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 Ready Mixed Concrete Association of Ontario (RMCAO).

**1821.07.02 Markings**

As a minimum, the following information shall be embossed using numbers and letters 30 mm wide, 35 mm high and 5 mm deep on an upper top haunch of each element in the following order, readily visible for inspection:

1. Prequalification stamp in accordance with the published requirements of the CPCQA or CSA Certification Program.
2. Name or trademark of the manufacturer.
3. Identification of plant if manufacturer has more than one plant.
4. Date of manufacture (yyyy-mm-dd).

1. Unique Number.
2. Specification designation.
3. MTO Site Number.
4. Minimum and maximum height of fill over box units

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

**1821.07.03 Steel Reinforcement**

The placement of steel reinforcement shall be according to OPSS 905

Under no circumstance shall reinforcement be inserted into plastic concrete.

**1821.07.03.01 Design Tables**

Where culvert size and height of fill are within the limits of Table 2, the box dimensions and reinforcement details shall conform to Table 2. Where the culvert size, or the depth of fill, is not included in Table 2, the Contractor shall be responsible for the design of the culvert.

# 1821.07.02.02 Placement of Reinforcement

The concrete cover shall be according to Table 1.

The clear distance of the end perimeter reinforcement shall be not less than 35 mm nor more than 50 mm from the ends of the box unit. Boxes reinforced with welded wire reinforcement fabric (WWR) may be assembled utilizing any combination of single or double layers of the WWR. Boxes utilizing reinforcing steel bars shall be assembled with single layers of reinforcement in each face in each direction.

The areas of steel reinforcement shall be the steel areas as shown in Table 2. Steel areas greater than those required shall not be cause for rejection.

# 1821.07.04 Laps, Welds, and Spacing of Reinforcement

Splices in the perimeter reinforcement shall be made by lapping and only at locations shown in the contract documents. Sheets of the WWR shall be tack welded at lap locations but shall not be tack welded elsewhere. 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, and longitudinal bars, shall be Class B splices as per CHBDC.

The spacing center to center of the perimeter wires shall not be less than 50 mm nor more than 105 mm. The spacing center to center of the longitudinal wires shall not be more than 205 mm.

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

Welding of reinforcing steel bars shall be according to OPSS 905. The reinforcing steel welding shall be performed by a welder qualified by the CWB working for a company certified in accordance with CSA W186.

# 1821.07.05 Joints

The precast reinforced concrete 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 or box sewer with a smooth interior free of irregularities in the flow line. All joints between elements of the culvert shall be constructed with joint seals.

# 1821.07.06 Production of Concrete

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

**1821.07.06.01 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:

1. 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.
2. 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.
3. For batches of concrete produced at the precast plant, and not delivered by a 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:

1. CCIL Certified Concrete Testing Technician, or
2. ACI Concrete Field Testing Technician, Grade 1, or
3. CSA Standards Concrete Field Testing Technician.

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

**1821.07.06.02 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 as follows:

a) 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 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 °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.

# 1821.07.07.05 Curing

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

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

Dry cast box units and the exposed ends 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.

**1821.07.07.05.01 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 four 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.

**1821.07.07.05.02 Curing with Burlap and Water**

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

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

**1821.07.07.05.03 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 of OPSS 909.

**1821.07.08 Surface Finish**

The surface finish shall be according to the Surface Finish sub-section in OPSS 904.

**1821.07.09 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 one-metre grid on all interior and exterior surfaces of the box unit, including the ends of the unit.

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 installation of the units.

**1821.07.10 Dimensional Tolerances**

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

Elements and culverts shall meet the tolerances specified in the Contract Documents and Table 1 of this specification.

Unless otherwise specified in the Contract Documents, 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 precast concrete box culvert elements.

Cores shall be removed at the plant or on site when the element 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 cores shall be removed from a box unit. The box unit from which the cores are removed shall be randomly selected by the Contract Administrator and the locations of cores shall be determined by the Contract Administrator. The core removal locations shall be repaired according to the Coring clause.

**1821.07.12.03.02 Notification**

A list of elements 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 four 100 mm diameter and 200 mm long cores or, if the panel is less than 200 mm thick, the full depth of the panel such that the core has a length to diameter ratio of at least 1.5. For wet cast concrete, a set of cores shall consist of five 100 mm diameter and 200 mm long cores or, if the panel is less than 200 mm thick, the full depth of the panel such that the core has a length to diameter ratio of at least 1.5.

The element 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 reinforcement or other embedded material. A covermeter capable of detecting the type(s) of reinforcing materials in the element shall be used to establish the location of reinforcement and other embedded material prior to coring.

The contract number, and lot number, and element identification 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 the Form A of the concrete mix design for the precast element. 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.

For concrete elements that require repair, the core holes and slab holes shall be filled, within 3 Days, according to the Filling of Core Holes subsection of 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 element.

**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.

**1821.07.12.05 Management of Excess Material**

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

**1821.08 QUALITY ASSURANCE**

**1821.08.01 Acceptance**

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

Acceptance for compressive strength, air void system parameters, rapid chloride permeability and concrete cover and dimensions of wet cast concrete shall be on a lot basis.

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

The lot size shall be confirmed by the Contract Administrator and remain consistent for the duration of the Contract.

Unacceptable lots shall be deemed rejectable.

The Contract Administrator shall determine the limits of each lot prior to commencing production and shall confirm the specific elements to be included in each lot prior to commencing production of that lot.

**1821.08.02 Acceptance of Concrete Compressive Strength**

Compressive strength shall be determined according to CSA A23.2-14C on moisture conditioned cores.

Three cores shall be tested to determine the acceptability of compressive strength of the lot. Twenty‑eight (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.

Unacceptable lots shall be deemed rejectable.

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

**1821.08.02.01 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 concrete element 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 of this specification. 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 CSA A 23.2-9C on moisture conditioned cores.

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.

**1821.08.03 Acceptance of Air Void System in Hardened Concrete**

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 with 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 Basis of Payment section of OPSS 422.

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

**1821.08.03.01 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.

**1821.08.04** **Acceptance of Rapid Chloride Permeability**

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.

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

For 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 of OPSS 422.

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

For 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.

For concrete containing silica fume, 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 of OPSS 422.

For concrete containing silica fume, 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.

**1821.08.04.01 Referee Testing of Rapid Chloride Permeability**

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.

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.

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.

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

**1821.08.05** **Acceptance of Water, Admixtures, and Cementing Materials**

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

**1821.****08.06 Dimensional Verification and Concrete Cover Measurements**

The Contract Administrator shall carry out measurements on interior and exterior surfaces on at least one element per lot, prior to any waterproofing or backfilling operations, to confirm compliance with the requirements of Table 1. The Contract Administrator shall be notified in writing when the test area is ready for the concrete covermeter survey and dimensional verification.

If an element fails to meet the dimensional or cover tolerances specified in Table 1,

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 elements in the lot are within the tolerances of Table 1.

**1821.08.07 Rejection**

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

1. Inadequate area of reinforcement or cover to reinforcement;
2. Dimensions outside of the tolerances in Table 1;
3. Defects resulting from incorrect proportioning, mixing, and forming;
4. Cracks greater than 0.3 mm, full-depth cracks.
5. Honeycombed or broken surface texture, and;
6. Damaged ends, where such damage would prevent making a satisfactory joint.

**1821.09 MEASUREMENT FOR PAYMENT**

**1821.09.01 Inspection**

The quality of materials, the process of manufacture, and the finished box units shall be subject to inspection by the purchaser.

**1821.09.02 Measurement of Payment**

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

**Table 1 Tolerances**

|  |  |
| --- | --- |
| **Item** | **Tolerances** |
| Span  (Straight-line measurement taken horizontally at the mid-height of element perpendicular to the centre line of the culvert.) | ± 15 mm from design drawings |
| Height | ± 15 mm from design 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 Welded Wire Reinforcement (WWR) and 45 mm ± 10 mm to reinforcing steel bars. |
| Notes:  1. Variations in the lengths of two opposite surfaces of the element. The ends of the element shall be normal to the wall and centreline of the element within the tolerances specified elsewhere in this Table except where special culvert elements, e.g. end walls, toe walls, etc. are specified. | |
|  | |

# TABLE 2 (2.1 to 2.9)

**STEEL REINFORCEMENT AREAS**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 2.1**: 1.8m span by 0.9m rise. 200mm wall thickness. As4=400 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.2:**  1.8m span by 1.2m rise. 200mm wall thickness. As4=400 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.3:**  2.4m span by 1.2m rise. 200mm wall thickness. As4=400. | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.4:**  2.4m span by 1.5m rise. 200mm wall thickness. As4=400 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.5:**  2.4m span by 1.8m rise. 200mm wall thickness. As4=400 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.6:**  3.0m span by 1.5m rise. 250mm wall thickness. As4=500 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.7:**  3.0m span by 1.8m rise. 250mm wall thickness. As4=500 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.8:**  3.0m span by 2.1m rise. 250mm wall thickness. As4=500 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 2.9:**  3.0m span by 2.4m rise. 250mm wall thickness. As4=500 | | | | | | | |
|  | Fill <0.6m | Fill = 0.6m | Fill = 2.0m | Fill = 3.0m | Fill = 4.0m | Fill = 5.0m | Fill = 6.0m |
| 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 TO TABLE 2 (2.1 to 2.9):**

1. All metric or all imperial dimensions may be used for span, height, and wall thickness unless noted elsewhere in the Contract.
2. Specified yield strength of welded WWR Fy = 500 MPa. Reinforcing bar, if used, shall be grade 500W.
3. Area of steel reinforcement given is mm2 per metre length of box unit. In Table 2.1 through Table 2.9,
   * + - As1 shall be the area of steel on of the C-shaped bars on the outside face of the culvert.
       - As2 shall be the area of steel on the bottom face of top slab.
       - As3 shall be the area of steel on the top face of the bottom slab.
       - As4 shall be the area of steel on the inside face of the walls.
       - As5 shall be the area of steel in the longitudinal direction on each face of all slabs and walls.
       - As6 = 525 shall be the longitudinal reinforcement required on the bottom face of the top slab, in lieu of As5, only when Depth of Fill is <0.6m.
       - The extent and details of the reinforcement shall be as shown in the Contract Documents.
4. The area of reinforcement for As1 through As3, shall be determined from Table 2 for height of fill at both edges of pavement and at the crown. The largest 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 culvert size mentioned in their respective in Table 2.1 through Table 2.9
5. As6 is only required for height of fill <0.6m. As6 may be added to the area of As5 of the bottom mat of reinforcement in the top slab or as a second layer of reinforcement on top of the bottom mat of reinforcement in the top slab.
6. Where some reinforcing steel is used instead of fully using WWR, or where reinforcement is comprised of a second layer of reinforcement inside the first layer, the effective area of reinforcement (Ase), calculated as Ase = Asf x ηf + Asi x ηi , shall be greater than the tabulated value of As. Asf is the Area of steel in the layer closest to the face (first layer), Asi is the Area of steel in the interior (second) layer, and ηf and ηi are the efficiency factors obtained from Table 3. The second, interior layer of reinforcement shall be placed against the first layer such that the clear spacing of reinforcing steel in all layers shall permit proper consolidation of the concrete. (For example, if 1000mm2 of reinforcing bar is provided in the face layer of reinforcement, and 2000mm2 of WWR is provided in the interior layer, and the slab is 200mm thick, the effective area of reinforcement shall be 1000 x 96% + 2000 x 83% = 2620mm2, which must be greater than the value from Table 3).

**TABLE 3: STEEL EFFICIENCY FACTORS, ηf and ηi**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **First Layer WWR** | | **First Layer Reinforcement Bar** | |
| **Slab** | **(ηf)** | **(ηi)** | **(ηf)** | **(ηi)** |
| 200 | 100% | 86% | 96% | 83% |
| 250 | 100% | 90% | 97% | 87% |