PERFORMANCE-BASED SPECIFICATION FOR DESIGN AND CONSTRUCTION OF STRUCTURAL CULVERTS

TABLE OF CONTENTS

3271.01 SCOPE

This specification covers the requirements for:

a) The design and construction of new culverts, culvert extensions, and replacement of existing culverts for the following types:
   i. Cast-in-place concrete;
   ii. Precast concrete;
   iii. Structural plate corrugated steel; and
   iv. A hybrid type combining the above.
b) The performance of the culvert during a 10 year warranty period.

3271.02 REFERENCES

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

Design Build Specifications:

DBSP 539 Construction Specification for Temporary Protection Systems
DBSP 903 Construction Specification for Deep Foundations

Ontario Provincial Standard Specifications, Construction:

OPSS 904 Concrete Structures
OPSS 909 Prestressed Concrete – Precast Members

OPSS 911 Coating Structural Steel Systems
OPSS 914 Waterproofing
OPSS 919 Formwork and Falsework
OPSS 928 Structure Rehabilitation – Concrete Removal
OPSS 929 Abrasive Blast Cleaning – Concrete Construction
OPSS 930 Structure Rehabilitation – Concrete Patches and Overlays
OPSS 932 Crack Repair - Concrete

Ontario Provincial Standard Specifications, Material:

OPSS 1002 Aggregates - Concrete
OPSS 1213 Hot Applied Rubberized Asphalt Waterproofing Membrane
OPSS 1215 Protection Board
OPSS 1350 Concrete – Materials and Production
OPSS 1440 Steel Reinforcement for Concrete

Ministry of Transportation, Ontario, Publications:

Aggregate Sources Lists (ASL) - Aggregate Sources List for Structural Concrete Fine and Coarse Aggregates
Covermeter User's Guide for Concrete Cover Survey
Designated Sources for Materials
Embankment Settlement Criteria for Design
Field Guide for the Acceptance of Hot Mix and Bridge Deck Waterproofing
Gravity Pipe Design Guidelines
Guide for Preparing Hydrology Reports for Water Crossings
Highway Drainage Design Standards
Ministry's List of Concrete Patching Materials
Structural Manual

Laboratory Testing Manual:

LS-412 Method of Test for Scaling Resistance of Concrete Surfaces Exposed to Deicing 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
LS-435 Method of Test for Linear Shrinkage of Concrete
LS-445 Method of Test for Compressive Strength of Concrete Cores
LS-601 Method of Test for Materials Finer than 75 µm Sieve in Mineral Aggregates by Washing
LS-604 Method of Test for Relative Density and Absorption of Coarse Aggregate
LS-606 Method of Test for Soundness of Aggregate by Use of Magnesium Sulphate
LS-607 Method of Test for Determination of Percent Crushed Particles in Processed Coarse Aggregate
LS-608 Method of Test for Determination of Percent Flat and Elongated Particles in Coarse Aggregate
LS-609 Procedure for the Petrographic Analysis of Coarse Aggregate
LS-614 Method of Test for Freezing and Thawing of Coarse Aggregate
LS-618 Method of Test for the Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
LS-619 Method of Test for the Resistance of Fine Aggregate to Degradation by Absorption in the Micro-Deval Apparatus

MTO Forms:
PH-CC-736 Notification of Placement of Structural Concrete

ASTM International:

A955/A955M-12el	Standard Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement
E797/E797M-10	Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

CSA Standards:

A23.2-12A*	Relative Density and Absorption of Coarse Aggregate
A23.2-23A*	Method of Test for the Resistance of Fine Aggregate to Degradation by Abrasion in Micro-Deval Apparatus
A23.2-24A*	Method of Test for Resistance of Unconfined Coarse Aggregate to Freezing and Thawing
A23.2-29A*	Method of Test for the Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
A23.2-3C*	Making and Curing Concrete Compression and Flexural Test Specimens
A23.2-9C*	Compressive Strength of Cylindrical Concrete Specimens
A23.2-14C*	Obtaining and Testing Drilled Cores for Compressive Strength Testing
A283-06 (R2011)	Qualification Code for Concrete Testing Laboratories
G30.18-09	Carbon Steel Bars for Concrete Reinforcement
G40.21-04 (R2009)	Structural Quality Steels
G401-14	Corrugated Steel Pipe Products
CAN/CSA-S6-06	Canadian Highway Bridge Design Code (CHBDC)

* [Part of A23.1-14/A23.2-14 - Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete]

International Organization for Standardization/International Electrotechnical Commission

ISO/IEC 17025:1999	General Requirements for the Competence of the Testing and Calibration Laboratories

SSPC Standards:

SSPC-PA2	Procedure for Determining Conformance to Dry Coating Thickness Requirements

Other:

Canadian Foundation Engineer Manual

3271.03 DEFINITIONS

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

Abrasion means wear or disintegration of concrete or steel surfaces resulting from actions such as wearing, grinding, or rubbing away by silt, sand, gravel, rock, and other debris passing over the concrete or steel surface.

Apron means an area of protective material laid on a stream bed to control local scour around a feature requiring protection.

Base Steel Thickness means the steel thickness without a metallic or other protective coating.

Bridge means a structure that is greater than 3 m in span that provides a roadway, carriageway, or walkway for the passage of vehicles or pedestrians or both across an obstruction or gap or facility.

Cold Joint means the interface surface other than at a formed joint that occurs when plastic concrete is placed against concrete that has taken its initial set.

Cold Weather means those conditions when the ambient air temperature is at or below 5ºC. It is also considered to exist when the ambient air temperature is at or is likely to fall below 5ºC within 96 hours after completion of concrete placement. Temperature refers to shade temperature.

Component means a member of a culvert requiring individual design considerations, such as; apron, wingwalls, headwall.

Construction Joint means the surface where two successive placements of concrete meet or where new concrete is placed against old concrete across which it is desirable to achieve bond between the two concrete placements and through which steel reinforcement may be continuous.

Crimping means the local buckling of a culvert wall, usually near areas of higher curvature.

Culvert means structural culvert.

Cusping means the abrupt change in curvature of a culvert wall, typically at a longitudinal seam, leading to a lifting of adjacent plates.

Deep Foundation means a foundation that transfers load to soil or rock through a combination of toe bearing and shaft resistance at a depth exceeding three times the effective pile width below the surface of backfill or original ground level. The minimum depth for a deep foundation is 3 m below the base of the pile cap.

Deleterious Material means material from the recycling stream other than glass, ceramic, reclaimed asphalt pavement, and reclaimed concrete materials that includes but is not limited to the following: wood, clay brick, clay tile, plastic, gypsum, gypsum plaster, and wallboard.

Design Check Engineer: means the Engineer retained by the Contractor to check the design and co-stamp the Issued for Construction Drawings.

Design Engineer means the Engineer retained by the Contractor who has sealed and signed the Issued for Construction Drawings and/or Working Drawings required to complete all or part of the work specified in the Contract.

Design Life means a period of time, specified by the Owner, during which a structure is intended to remain in service.

Dewatering means the measures taken to control groundwater to facilitate construction of the work in the dry.

Disintegration means decomposition of concrete by reduction into small fragments and subsequently into particles.

Earth means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Erosion means wear or disintegration produced by abrasive action of water containing solid particles in suspension.

Falsework means any temporary structural support, including bracing, used to support all or part of the formwork or of the structure during its construction or rehabilitation until it becomes self-supporting.

Formwork means the mould into which the fresh concrete is placed.

Glass Fibre Reinforced Polymer (GFRP) means a fibre-reinforced composite with a polymeric matrix, and continuous fibre reinforcement of glass.

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

Issued for Construction Drawings (IFCD) means design drawings stamped by an Engineer as final documents to construct the Work.

Pile means a relatively slender structural element that is installed, wholly or partially in the ground by driving, drilling, auguring, jetting, or other means.

Piping means the subsurface removal of fines by the movement of water through the ground or embankments.

Protection Board means a durable panel specifically designed to provide an interface protection barrier between the backfill and the waterproofing membrane.

Protection System means the construction necessary to mechanically support existing or proposed work such that its function shall not be affected, or construction necessary to support work such as open excavations during actual construction operations for safety and convenience.

Reinforcing Steel Bars means deformed steel bars made of carbon steel as defined in CAN/CSA G30.18, used for the reinforcement of concrete.

Rock means natural beds or massive fragments of the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered, and includes boulders having a volume of 1 m^3 or greater.

Scour means the removal of stream material and/or bedding material around the culvert inlet or outlet ends, or along the length of the culvert by drainage forces.

Self-Consolidating Concrete (SCC) means a highly flowable yet stable concrete that can spread readily into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation (vibration) and without undergoing segregation or excessive bleeding. It may be designed for high strength and durability in addition to flow characteristics.

Segregation means visible separation of the mortar and coarse aggregate particles in the plastic concrete resulting in concrete that is not uniform in appearance or proportions.

Shallow Foundation means a foundation in which a footing transfers load directly to the soil or rock bearing surface, normally at a depth less than the effective footing width.

Span means the maximum clear opening width of a culvert. For structural plate corrugated steel culverts, the span is the maximum inside horizontal distance between the sidewalls of a culvert cross-section measured between the inside crests of corrugations.

Stainless Steel Reinforcing Bars means deformed stainless steel bars as defined in ASTM A955 used for the reinforcement of concrete.

Steel Reinforcement means all types of steel reinforcement for concrete including reinforcing steel bars, stainless steel reinforcing bars, splice bars, welded steel wire fabric, and prestressing strands and bars.

Structural Culverts means a bridge that is embedded in fill and is used to convey water, pedestrians, vehicles, cyclists, or animals through it. The following criteria apply to structural culverts of any material type:

a) For single cell culverts, the span must be greater than or equal to 3 m; or
b) For multi-cell culverts separated by a structural wall, the cumulative total of the individual spans must be greater than or equal to 3 m with no minimum span requirement for the individual cells. The total span is the total of the spans of the individual cells; or
c) For multi-cell culverts with individual cells separated by fill, the maximum spacing must be 1 times the minimum span of the individual cells and the minimum individual cell span must be 2 m. The total span is the total of the spans of the individual cells; or
d) Has been designated by the Owner as qualifying as a structural culvert.

Structural Plate Corrugated Steel (SPCS) means hot-rolled sheets or plates that are corrugated, curved to radius, custom hot-dip galvanized or has a thermoplastic copolymer coating, assembled, and bolted together to form pipes, arches, pipe-arches, and other shapes.

Structure means any bridge, culvert, tunnel, retaining wall, wharf, deck or guideway, or any part thereof, or other reinforced concrete component designed to carry loads, including high mast pole footings, and sign support footings. For the purpose of this specification, a working slab is not considered a structural component.

Unwatering means separation of the work area from flowing or freestanding water, by means of temporary flow passages, diversions, or dam and pumping, or other means to facilitate construction in the dry.

3271.04 DESIGN AND SUBMISSION REQUIREMENTS

3271.04.01 General

Culverts shall be designed to have a design life of 75 years and provide functionality, durability, ease of maintenance, safety, and pleasant aesthetics. The design shall ensure that the structure will be able to maintain its level of serviceability during its design life. The design including, structural form, materials, and details shall be suitable for the design loads and environmental conditions that will be experienced during the design life of the culvert.

The design shall meet the requirements specified in the Contract Documents, and the following:

a) Canadian Highway Bridge Design Code (CHBDC) CAN/CSA-S6
b) MTO Structural Manual
c) MTO Highway Drainage Design Standards
d) Canadian Foundation Engineering Manual
e) MTO Embankment Settlement Criteria for Design

3271.04.02 Field Investigations

For each culvert, the Contractor shall be responsible to:

a) Determine if additional information is required beyond that provided by the ministry to design and construct the culvert.
b) Determine whether the soil and water parameters provided by the Owner are sufficient and if not, take additional samples.

c) Obtain access to carry out the work.
d) Arrange and perform all field testing and laboratory analysis, surveys and studies, such as foundation investigation, geotechnical investigation, and any other site investigation required in association with the culvert and related work.
e) Verify and account for the condition of all existing culverts, affected by the work, prior to design, for culvert extensions.

3271.04.03 Drainage and Hydrology

For each culvert, the following design functions shall be performed, as a minimum, unless provided by the Owner. If provided by the Owner, the Contractor shall determine whether the information is sufficient and if not, obtain any additional information necessary for the design.

a) Perform a field investigation of the site, watercourses, and associated watershed to assess any existing drainage issues at the crossing locations, upstream, and downstream. This will include stream stability issues and impacts on other structures.
b) Carry out the preconstruction hydrological and hydraulic analysis to establish existing culvert conditions such as but not limited to flow rates, depth and velocities for the required return period, according to the requirements in the MTO Highway Drainage Design Standards.
c) Culverts shall be designed to operate in outlet control with the exception of sites where the culvert must or can only operate in inlet control.
d) Undertake detailed design of the culvert and associated end structures and determine all culvert types, sizing, and lengths including extensions, outlet locations, erosion and sedimentation control at inlets and outlets, invert elevation according to the requirements in the MTO Highway Drainage Design Standards.
e) Design any required permanent erosion control including any stream stabilization works and flow control measures.
f) Design scour protection.
g) Design apron walls, wingwalls, and collars to mitigate effects of water action.
h) Design relief flow, when specified elsewhere in the Contract Documents.
i) Take into consideration the potential for debris, sediment and ice build-up and incorporate mitigation measures in the design.
j) Carry out an assessment of the post construction hydrologic and hydraulic conditions, including but not limited to flow rates, depths and velocity impacts at the culvert site and at all watercourses affected by the culvert design. The impact assessment will be undertaken upstream and downstream until there are no longer any hydraulic impacts evident as a result of the culvert design. This includes but is not limited to identifying:
    i. Existing drainage features;
    ii. The major flow routes;
    iii. Potential flooding areas and proximity of buildings;
    iv. Upstream and downstream structures (such as dams, bridges, and culverts) and non-structural culverts;
    v. The need for fish passage and fish habitat protection;
    vi. Poor crossing locations;
    vii. Scour and bank erosion potential;
    viii. High water marks; and
    ix. Potential problems due to ice and debris.
k) Mitigation measures or culvert alterations shall be designed to eliminate all adverse impacts as determined from the post construction hydrologic and hydraulic impact analysis.

3271.04.04 Foundation Investigation and Design Report

3271.04.04.01 General

The Foundation Investigation and Design Report (FIDR) shall consist of a foundation investigation component and a foundation design component. Recommendations shall be according to the

requirements of the CAN/CSA-S6. The FIDR shall present a subsurface model for culverts and extensions, including, details of subsurface conditions and analysis to justify the recommendations.

The FIDR and the foundation drawings shall be signed and sealed by two Engineers, one of which shall be the principal foundations Engineer, as defined in Registry Appraisal and Qualification System (RAQS), from the foundations engineering firm responsible for the design.

3271.04.04.02 Foundation Investigation Component

The foundation investigation component shall be required, if it is not provided by the Owner, or if the layout is altered. The foundation investigation component shall consist of:

a) Site Description - including topography, vegetation, drainage, existing land use, and structures.
b) Investigation Procedures - including site investigation and lab testing procedures.
c) Description of Subsurface Conditions - including soil, rock and groundwater conditions.
d) Borehole - log sheets, figures, and drawings shall be prepared according to the Owner's standard practice and submitted for all boreholes advanced by the Contractor. The Contractor is responsible for determining whether the borehole information provided by the Owner is sufficient and may take additional boreholes in other locations. Additional boreholes shall be required if the culvert is relocated.
e) Miscellaneous Section - identify the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

3271.04.04.03 Foundation Design Component

The foundation design component of the FIDR shall present a discussion and an analysis of alternatives to justify the recommendations for design. Recommendations shall be according to the requirements specified in the CAN/CSA-S6 and shall address as a minimum the following, if applicable:

a) Foundation drawings consisting of a plan showing the locations of all boreholes, test pits and sounding, various stratigraphical profiles, cross-sections, groundwater levels, recommendations for the design and construction of structure foundations related to earth/rock works.
b) Culvert foundation design (shallow and/or deep foundation), including settlement and footing width assumptions, providing bearing resistance for various settlements (25, 50, 100mm), sliding resistances, axial and lateral capacities, founding elevations, inlet and outlet details including requirements for channelling water (including but not limited to head walls, cut-off, wingwalls, or extended culvert inlets). The analysis shall describe rationale for the recommended design.
c) Design of culvert bedding, backfill, backfill transition, cover, inlet seal, inlet erosion control, outlet cut-off, outlet filter, outlet erosion control, camber.
d) Detour design, including slope geometry, slope stability, settlement, drainage, run-off, erosion protection, wick drains, lightweight fill, and geosynthetic reinforcement.
e) Settlement of cover material and backfill to structure and embankments adjacent to the culvert.
f) Unwatering, dewatering and drainage during and after construction.
g) Flow diversion during construction.
h) Assumptions for earth pressure diagrams and conceptual shoring alternatives.
i) Frost protection.
j) Staged construction.
k) Bedrock excavation, including blasting and vibration monitoring and control.
l) Geosynthetic reinforcement for embankment stability.
m) Retaining walls, and Retained Soil System (RSS).
n) Roadway protection and performance level for protection systems according to DBSP 539.

3271.04.05 Temporary Works – Dewatering, Unwatering, and Protection Systems

Dewatering measures may be required to control groundwater to stabilize the ground and keep the excavation free of water during construction of the culvert, and associated appurtenances. In addition, unwatering measures may also be required to control surface water to permit the work to be carried out in the dry. Temporary work shall also be designed to accommodate any environmental requirements.

The Contractor shall be responsible for the design, and construction of any:

a) Protection systems according to DBSP 539. The protection system shall be assigned an appropriate performance level for design by the design Engineer according to DBSP 539, unless otherwise specified in the Contract Documents.
b) Dewatering and unwatering scheme for the intended purpose. The scheme shall be designed and constructed so as to not be injurious to public health or safety, to property, adjacent elements, to the environment or to any part of the work completed or under construction within and beyond the Contract limits.
c) Temporary measures upstream and downstream of the culvert to prevent the flow of water in and out of the Working Area, and to isolate the Working Area from the watercourse and normal water levels.

Temporary flow diversion systems shall be designed to accommodate storm events with a return period as defined by standard TW-1 (Return Period of Design Storms for Temporary Works) of the MTO Highway Drainage Design Standards.

Dewatering and unwatering effluent shall be discharged into a suitable filtering mechanism. Upon completion of dewatering and unwatering, the streambed and disturbed area shall be returned to the pre-work conditions.

3271.04.06 Culverts

3271.04.06.01 General

Culvert type shall be one of the following listed below, unless otherwise specified in the Contract Documents:

a) Cast-in-place concrete.
b) Precast concrete.
c) Structural plate corrugated steel.
d) A hybrid type combining the above, such as, a concrete footing with a SPCS barrel.

Except for the combination of types a) and b) a culvert shall be the same type throughout its entire length.

Structural components of culverts for which design provisions are not included in the CAN/CSA-S6 such as plastic are prohibited. Fibre reinforced polymer (FRP) type culvert shall be prohibited.

In order to accommodate human entry for inspection during the life of the culvert, a minimum rise of 1.5 m and minimum span of 2 m shall be provided. A single barrel culvert shall be used where the sum of the individual spans is less than 6 m for adjacent multiple cell culverts. When adverse upstream/downstream hydraulic impacts are incurred, other culvert dimensions and/or mitigating measures shall be designed to alleviate the adverse impacts.

The design, supply, and installation of deep foundation units shall be according to DBSP 903.

Bedding and backfill around the culvert shall be specified in the design. For precast concrete and SPCS culverts, the bedding and backfill shall meet the minimum requirements of the culvert manufacturer.

For culvert extensions, there shall be a smooth transition and no gaps. Transitions shall be designed to avoid capture of debris.

The Contractor is responsible for the design of joint treatment and waterproofing system to meet the performance requirements of this specification. Joint treatment is required for all culvert types to prevent leakage and infiltration at the joints, seams, and bolt locations where applicable. A waterproofing system for the protection of the culvert shall be provided as follows:

a) SPCS – waterproofing system shall be designed according to the manufacturer's recommendation for all fill heights.
b) Concrete Culverts
    i. When the fill height is less than or equal to 1 m – a hot applied waterproofing system shall be provided.
    ii. When the fill height is greater than 1 m – a waterproofing system shall be provided at the discretion of the Contractor.

3271.04.06.02 Precast Concrete Culverts

The use of precast concrete culverts shall be prohibited for end sections with skews greater than 45 degrees. Precast culverts shall not be placed directly on top of piles.

3271.04.06.03 SPCS Culverts

SPCS culvert elements shall be designed using either, shallow or deep corrugations, and a suitable protective coating.

The thickness of SPCS and other steel components shall be determined according to CAN/CSA-S6, to ensure the culvert is structurally sound until the end of the design life. The design shall account for environmental conditions that exist at the site or are likely to exist during the design life of the structure, and the anticipated steel material loss during the design life. The MTO Gravity Pipe Design Guidelines and the CAN/CSA-S6 shall be referenced for guidance. Notwithstanding the above requirements, the thickness of the SPCS shall not be less than 5 mm.

The use of SPCS culverts shall be prohibited under the following conditions:

a) Environmental ranges of water, soil, and backfill are outside the limits specified in Table 1.
b) Abrasion level is outside the limits specified in Table 1 when the water is in direct contact with the SPCS.

3271.04.07 Submission Requirements

3271.04.07.01 General

For each culvert, one hard copy and one digital copy (in pdf format) of the following shall be submitted to the Contract Administrator, for information purposes only, 7 Days prior to commencing construction on that culvert:

a) Preconstruction Survey – A condition survey of property and structures shall be submitted where there is rock blasting or potential for property or structures to be affected by the work. The survey shall include the locations and conditions of adjacent properties, buildings, underground structures, wells, Utility services, and structures, such as walls abutting the site.
b) Foundation Investigation and Design Report.
c) Drainage and Hydrology Study and Design Report – including all necessary information concerning the hydrology and hydraulics of the site complete with recommendations and explanations shall be included in the Drainage and Hydrology Study and Design Report. The report shall be according to the MTO Guide for Preparing Hydrology Reports for Water Crossings and shall be stamped by an Engineer. Preconstruction, post construction, and mitigated post construction culvert performance curves shall be included in the report.

d) Provisions to maintain stream flow during construction according to environmental requirements, including temporary passages, diversions.
e) Durability Analysis – For SPCS culverts, a durability analysis providing the estimated material loss over the service life, calculated according to the methodology described for non-structural culverts in the MTO Gravity Pipe Design Guidelines.
f) Detailed issued for construction drawings, including construction staging for the work, and structural design calculations. All the drawings shall have a design Engineer and a design checking Engineer's seal and signature on them.
g) Excavation limits and details.
h) Backfill – including type of backfill to be used, pH, resistivity, chlorides and sulphate range of the backfill, organic content of backfill, method of installation, backfill sequence, spreading and compaction details.
i) Waterproofing System – including type of waterproofing system to be used, surface preparation, and method of installation.

3271.04.07.02 Issued for Construction Drawings

3271.04.07.02.01 General

One hard copy and one electronic copy of the IFCD and supporting documentation shall be submitted to the Contract Administrator at least 7 Days prior to the commencement of the work stated below, for information purposes. A design Engineer and design checking Engineer's seal and signature shall be affixed on the IFCD verifying that the details and procedures are consistent with the IFCD and the Contract Documents.

A sealed and signed copy of these drawings shall be at the site before and during the operation.

When other authorities are involved in the approval of the design or construction of a highway structure, submissions shall be made at least 5 weeks prior to commencement of work and one additional copy of the submission shall be provided for each authority. The requirements, as stated elsewhere in the Contract Documents, of each authority and the Owner, shall be satisfied prior to commencement of the work.

When culverts are designed with both concrete and SPCS, the IFCD shall meet the requirements of both the "Structural Plate Corrugated Steel Culvert" and the "Concrete Culvert" clauses of this specification.

3271.04.07.02.02 Structural Plate Corrugated Steel Culvert

The IFCD shall include the following:

a) Full detail dimensions and sizes of all component parts of the structure. These dimensions shall make allowance for changes in shape due to camber, and any other effects that cause finished dimensions to differ from initial dimensions.
b) Elevation, plan, and section view of culvert and any associated components.
c) Corrugation profile, wall thickness, protective coating.
d) Water and soil test results (pH, resistivity, chlorides, sulfate, hardness), and abrasion level.
e) Plate layout: flat outside view, plate lap and assembly detail, cross-section detail of all plate laps, and plate assembly guidelines.
f) Anchor bolt layout and details.
g) Transportation and storage of components.
h) Installation Instructions:
    i. Assembly of structure.
    ii. Joint requirements between SPCS and between existing and new culvert where applicable.
    iii. Bolts – size, type, torque requirements, and installation requirements.
    iv. Dimensional check of structure during assembly and backfilling operation.
i) Existing culvert (for extensions).

j) Any other details required to complete the fabrication and erection of the culvert according to the design.
k) All necessary specifications for the materials to be used.
l) Manufacturer's recommendation for:
    i. Bedding and Backfill – type of material to be used, material chemistry, sequence and method of installation.
    ii. Waterproofing System – type of waterproofing system to be used, and requirements for material, surface preparation, installation, and testing to determine acceptability.
    iii. Joint treatment between culvert units, at construction joints, seams, bolts, and between existing and new culverts.
m) All other applicable details.

3271.04.07.02.03 Concrete Culvert

The IFCD shall include the following information:

a) Full detail dimensions and sizes of all component parts of the structure.
b) Elevation, plan, and section view of culvert and any associated components.
c) Water and soil test results (pH, resistivity, chlorides, sulfate, hardness), and abrasion level.
d) Existing culvert (for extensions).
e) 28 Day compressive strength of the concrete.
f) Post-tensioning, prestressing, and jacking forces as required by the design, if applicable.
g) Steel Reinforcement –
    i. Quantity, bar size, grade, mark number, location, and spacing.
    ii. Location and spacing for all steel reinforcement.
    iii. When a metric to imperial bar size substitution is made, the placing drawings shall include the quantity, bar size, grade, location and spacing of both the metric and the substitute imperial bar.
    iv. Steel Reinforcement Schedules - The schedule shall include at least: quantity, bar size, grade, reinforcing steel bars, stainless steel reinforcing bars, type if applicable, length and bending dimensions. When bar marks are shown on the IFCD, they shall be used in the schedule.
    v. Steel reinforcement shall be detailed according to the CAN/CSA-S6 and the MTO Structural Manual.
    vi. Mechanical Connector Details – The connection details shall contain the following information:
        – The type or series identification of the connector.
        – The grade and size of the reinforcement to be joined by the connector.
        – A copy of the manufacturer's catalogue giving complete data on the connector material and installation procedures.
        – Location of splices, including type of splice.
h) Transportation, handling and storage of precast concrete if applicable.
i) Installation procedures for precast concrete.
j) Waterproofing System – type of waterproofing system to be used, surface preparation, and method of installation.
k) Joint treatment between culvert units, at construction joints, and between existing and new culverts.
l) Bedding and Backfill – type of material to be used, material chemistry, sequence and method of installation.
m) All other applicable details.

3271.05 MATERIAL

3271.05.01 General

Unless otherwise specified herein, the Contractor shall be solely responsible for selecting all materials, including sources, types, properties, and all other requirements for materials that are used.

3271.05.02 Bolts and Associated Metal Fasteners

Bolts, and associated metal fasteners for SPCS shall meet, as a minimum, the requirements of CSA G401.

Bolts and fasteners shall have a demonstrated ability to provide appropriate corrosion resistance.

3271.05.03 Concrete

3271.05.03.01 General

The Contractor shall design the concrete mix to provide strength and durability for the intended use, site conditions, exposure conditions, and to meet the performance requirements of this specification and the requirements of the Contract Documents. All concrete components of the culvert shall be reinforced.

The Contractor shall identify the target slump, and air values for all plastic concrete. Plastic air content and slump shall meet the requirements of OPSS 1350. The concrete temperature at the point of discharge into the work shall be at or between 10 and 28ºC.

When SCC is proposed to be used, SCC shall be according to the requirements of the current ministry Special Provision for SCC.

A copy of the Special Provisions can be obtained from the Materials Engineering and Research Office, Concrete Section.

3271.05.03.02 Admixtures

Air entraining, chemical, and superplasticizing admixtures shall be selected from the Ministry's DSM list.

3271.05.03.03 Aggregates

Fine and coarse aggregates shall be selected from sources listed on the current Ministry of Transportation regional Aggregate Sources List for Structural Concrete Fine and Course Aggregates or from sources meeting the equivalent requirements as determined by the Owner. Irrespective of this requirement, the warranty provisions of the Contract Documents shall apply.

Fine aggregate shall be according to the following physical property requirements specified in Table 2 of OPSS 1002:

a) LS-619/CSA A23.2-23A: Micro-Deval Abrasion Loss, % maximum.

When coarse aggregate contains more than 15% passing the 4.75 mm sieve, material finer than 4.75 mm shall also meet the physical property requirements shown in Table 2 of OPSS 1002.

Coarse aggregates shall consist of a minimum of 60% crushed particles when tested according to LS-607 and shall have 1.00% by mass maximum passing the 75 µm sieve when tested according to LS-601. The nominal maximum aggregate size shall be 19.0 mm.

In addition, coarse aggregate shall be according to the following physical property requirements specified in Table 5 of OPSS 1002:

a) LS-604/CSA A23.2-12A: Absorption, % maximum.
b) LS-608: Flat and Elongated Particles, % maximum.

c) LS-609: Petrographic Number, Concrete, maximum.
d) LS-614/CSA A23.2-24A: Unconfined Freeze-Thaw, % maximum loss. (Note: the Owner shall waive the requirements of LS-614, Unconfined Freeze-Thaw, provided the Contractor has submitted a written request that the coarse aggregate meet the alternative physical property requirement for LS-606, Magnesium Sulphate Soundness Loss, maximum).
e) LS-618/ CSA A23.2-29A: Micro-Deval Abrasion Loss, % maximum.

Aggregates that produce excessive expansion or cracking of concrete through reactions other than alkali aggregate reactions shall not be used in concrete. The total content of lime (CaO), periclase (MgO) and glass in the aggregate shall be less than 0.001% by mass. The content of gypsum and anhydrite shall be less than 1.0% by mass.

3271.05.03.04 Cementing Materials

Cement and supplementary cementing materials shall be selected from the Ministry's DSM list.

Ground granulated blast furnace slag (slag) or fly ash or both may be used in the form of a commercially preblended cement or may be added at the ready-mix plant/batching plant to replace a portion of the cement. The amount of slag, fly ash or both shall be restricted to 25% of the mass of the total cementing material unless the mix design has been prequalified for MTO use.

Silica fume may be used, and if used it shall be in the form of a commercially preblended cement. Where silica fume is used, the requirements of OPSS 904 for high performance concrete including fog misting and curing, and the requirements of this specification for concrete containing silica fume, shall be followed.

The Contractor may propose the use of silica fume in a form other than commercially preblended cement, and the approval of the Owner shall be required prior to use of such silica fume in the work, based on demonstration to the satisfaction of the Owner that:

a) The silica fume will be uniformly distributed throughout the concrete, with no clumps; and
b) The specified permeability of the concrete in place is achieved.

For prequalified mixes, replacement of cement by slag shall be a maximum of 35%, replacement by fly ash shall be a maximum of 25% and replacement by a combination of slag and fly ash shall be a maximum of 35% (with fly ash not to exceed 25%), by mass of total cementing materials. A list of prequalified mix designs and their suppliers will be maintained by MTO Materials Engineering and Research Office, Concrete Section. Prequalification shall be valid for a period of 24 months, provided the materials, their sources and proportions remain unchanged.

Prequalification shall be based on successful completion of laboratory testing to demonstrate the scaling resistance of the mix design, with a maximum allowable loss of 0.8 kg/m2 when tested according to LS-412. Samples for prequalification testing shall be from concrete of the same mix design proposed for use in the work, using materials from the same sources in the same proportions. The testing shall be done by a laboratory with prior experience in the performance of LS-412 test for qualification of aggregates for MTO use, who is on the list of qualified laboratories maintained by MTO Materials Engineering and Research Office, Concrete Section. Suppliers seeking to prequalify mixes shall contact this office to initiate the process.

3271.05.03.05 Water

Water used for production and curing shall be potable.

3271.05.04 Proprietary Patching Materials

Proprietary patching material, if used, shall be from the Ministry's List of Concrete Patching Materials.

3271.05.05 Steel Reinforcement

Steel reinforcement shall be according to OPSS 1440. Reinforcing steel bars and stainless steel reinforcing bars shall be selected from the Ministry's DSM list and reinforcing steel bars shall be Grade 400W. When welded steel wire fabric is used, it shall be Grade 450, 500 or 550.

Mechanical connectors shall be according to OPSS 1440. All procedures and equipment for mechanical connections shall be according to the manufacturer's recommendations.

Only hardware including spacers and support devices approved by the Owner shall be used with steel reinforcement. All supports or support systems shall be capable of withstanding the loads to be placed on them. Except for tie wire, all embedded hardware within 50 mm of exposed faces shall be coated with an acceptable material or be of an acceptable non-metallic material.

Tie wire shall be annealed ferrous wire 2.6 mm in diameter. Tie wire used to tie stainless steel reinforcing bars to stainless steel reinforcing bars, reinforcing steel bars and shear studs, shall be Type 316 LN, or Type 316 L, stainless steel wire, 1.2 or 1.6 mm in diameter.

Bar chairs for supporting stainless steel reinforcing bars shall be non-metallic. Concrete chairs shall not be used to support stainless steel reinforcing bars.

If dowels are used, they shall be according to the requirements of the most current ministry Special Provision.

When GFRP is proposed to be used, it shall be subject to Owner approval prior to use. Where accepted for use, GFRP shall be according to the requirements of the most current ministry Special Provision, "Glass Fibre Reinforced Polymer Reinforcing Bar". A copy of the Special Provision can be obtained from the Bridge Office.

3271.05.06 Structural Plate Corrugated Steel

SPCS and protective coatings shall be according to CSA G401. Protective coatings shall be either galvanizing, or thermoplastic copolymer coating.

When thermoplastic copolymer coating is used, it shall be an organic barrier coating applied to the SPCS in a controlled environment after fabrication.

As of July 1, 2015, all SPCS used on the Contract shall be supplied from a manufacturer that produces the SPCS according to CSA G401 and shall be certified by a certification body recognized by the Owner and have a valid certificate from the Corrugated Steel Pipe Institute (CSPI). The certification body shall be an independent 3rd party agency accredited by the Standards Council of Canada that has the qualifications, skills, and expertise required to confirm that a culvert manufacturer produces culverts to the quality and requirements of an accepted standard and that has the mandate to certify the culvert produced. Certified SPCS shall be marked according to CSA G401, along with the logo of the certification body and CSPI stamp.

3271.05.07 Structural Steel

Structural steel used for ancillary components (i.e. headwalls, wingwalls, cut-off walls) shall be according to CSA G40.21.

3271.05.08 Waterproofing Systems – Concrete Culverts

Hot applied rubberized asphalt waterproofing membrane and protection board shall be selected from the Ministry's DSM list. An alternative waterproofing system may be proposed to be used subject to the Owner's approval.

3271.05.09 Prohibited Materials

The following materials are prohibited:

a) In concrete culverts:
   i. Steel slag aggregate, glass aggregate.
   ii. Admixtures – Calcium chloride, sodium chloride, or other chlorides, or any admixtures containing chloride ion (by mass of cement) greater than 0.01 percent, air detraining, water-proofing, admixtures added for the purpose of extending concrete discharge time beyond that specified (such as retarding, hydration stabilizing, workability retaining or other).
   iii. Recycled concrete as aggregate without the advance agreement of the Owner.
   iv. Organic impurities, clay lumps, aluminum, gypsum plaster, sulphates, wood or other cellulose materials.
   v. Mineral fillers in concrete, except for SCC.
b) Spray foam.
c) Steel stay-in-place forms.

In addition, materials containing contaminants that may discharge into the environment and that could have an adverse effect on the natural environment shall not be used.

3271.07 CONSTRUCTION

3271.07.01 General

The Contractor shall be responsible for:

a) Obtaining appropriate approvals and permits required for the work.
b) Removing and disposing of any existing culverts to be replaced.
c) Removing and disposing of bedding and backfill, granulars and hot mix unless suitable for reuse. Portions not designated for removal shall be left undisturbed and undamaged.
d) Constructing the culvert according to the IFCD, and Contract Documents.
e) Installing a waterproofing system.
f) Carrying out any remedial work necessary to meet the performance requirements of this specification.
g) Backfilling all excavations.
h) Reinstating pavement structure above the culvert as required by the Contract Documents.
i) Reinstating slopes and vegetative cover.
j) Carrying out the required work with due regard for environmental, traffic control and safety concerns.
k) Obtaining samples of materials upon request by the Contract Administrator.

3271.07.02 Foundations

The Contractor shall ensure that the integrity of the founding soil or rock, on which the footing, working slab, or granular pad is to rest, is protected from exposure to weather to avoid disturbance and degradation.

Deep foundation work shall be according to DBSP 903.

3271.07.03 Protection Systems

Protection systems shall be installed where the stability, safety, or function of an existing structure, roadway, railway, or other facility can be impaired by an excavation or temporary slope. The protection

system may be required to retain the sidewalls of an excavation in order to permit safe execution of the work.

The design, materials, construction, maintenance, monitoring and removal of a temporary protection system shall be according to DBSP 539 and the requirements of the Contract Documents.

Dewatering and unwatering shall be carried out as required to facilitate the installation of the protection system according to DBSP 539 and requirements of the Contract Documents.

3271.07.04 Bedding

Bedding shall be used to level out any irregularities in the trench bottom and ensure uniform support under the full width and length of the culvert.

3271.07.05 Culverts – Concrete

3271.07.05.01 General

Use of mobile mixers is not permitted.

Cementing materials shall not be added by bags or sacks or from a remote storage facility.
Frozen aggregate shall not be added to the concrete. When ice is used it shall be completely melted by the time concrete mixing is completed.

3271.07.05.02 Concrete Batching Plant – Cast-In Place Concrete Culverts

Concrete shall be produced at a batching plant. A valid Certificate of Ready Mixed Concrete Production Facilities as issued by the Ready Mixed Concrete Association of Ontario (RMCAO) is required for any plant being used. The batching plant and equipment shall be certified by the RMCAO prior to producing concrete for the work and shall meet the requirements for certification throughout the production of concrete.

3271.07.05.03 Precast Concrete Plant Certification

Precast concrete culverts shall be fabricated by a manufacturer certified by the Canadian Standards Association (CSA) under the category precast concrete products – structural, or by the Canadian Precast/Prestressed Concrete Institute (CPCI) under the appropriate category of certification. Where precast plant is supplied with concrete from external concrete production facility, the facility shall be certified by RMCAO.

3271.07.05.04 Formwork and Falsework

Formwork and falsework shall be according to OPSS 919.

3271.07.05.05 Steel Reinforcement Placement

Steel reinforcement shall be placed according to the IFCD, and within the tolerances specified in the MTO Structural Manual, to ensure the specified concrete cover is met. When internal form ties are used, concrete cover to any metal left upon removal of the forms shall be 20 mm minimum.

3271.07.05.06 Concrete Placement

Prior to concrete placement, any new or existing concrete surfaces against which new concrete is to be placed shall be prepared according to subsection, " Preparation for Concrete Placement" of OPSS 904 to ensure a full bond.

No concrete shall be placed until the Design Builder's Engineer has signed the MTO form PH-CC-736, verifying that all the required information has been received and conditions are acceptable.

The method of transporting, placing, and consolidating the concrete shall be such as to meet the performance requirements in this specification.

Plastic concrete shall be protected from contact with rain or snow.

The temperature of formwork, steel reinforcement or any other material which the concrete is to be placed against shall be within a minimum of 5°C and a maximum of 30°C.

Concrete shall be transported to the site by means of agitating or mixing equipment. Discharge of the concrete shall be completed within 1.5 hours after introduction of the mixing water to the cement and aggregates, except when the air temperature exceeds 28°C and the concrete temperature exceeds 25°C, the concrete shall be discharged within 1 hour after the introduction of the mixing water.

When concrete is to be dropped more than 1.5 m, fully enclosed vertical drop chutes extending to the point of deposit shall be used. Drop chutes are not required for placing concrete in steel tube piles of 0.6 m diameter or less.

All exterior corners on concrete work and the edges of the soffit shall have a chamfer that has a vertical and horizontal dimension of 20 mm.

3271.07.05.07 Curing and Protection

3271.07.05.07.01 General

The concrete shall be protected to ensure the concrete temperature is within the specified limits for the duration of the curing and protection period.

The protection shall not be removed until the average concrete temperature is within 10°C of the ambient air temperature.

3271.07.05.07.02 Cast-In-Place Concrete

Curing for cast-in-place concrete shall be according to subsection, "Curing" of OPSS 904.

3271.07.05.07.03 Precast Concrete

Curing for precast concrete shall be according to subsection, "Curing and Protection" of OPSS 909.

3271.07.05.08 Control of Concrete Temperature

The concrete, and air temperature during the curing and protection period for cast-in-place and precast concrete culverts, shall be monitored and recorded. All necessary action shall be taken to maintain the temperature within the range specified in Table 4 of this specification. Thermocouples and dataloggers shall be used to measure and record temperatures.

Thermocouple wires shall be installed prior to placing concrete in the following locations:

a) A minimum of three sets of thermocouples shall be installed for each culvert and each staged construction in the following locations:
    i. Mid-span of the culvert.
    ii. 0.5 m from each end of the culvert.

A set consists of two thermocouples; one at the mid-depth and one at the surface. Thermocouples used to monitor the surface concrete temperature shall be imbedded in the concrete within 5 mm of the surface. Thermocouples for monitoring air temperature shall measure air temperature adjacent to the culvert.

Recording of concrete and air temperatures shall begin at the start of placement. Thermocouples and associated instrumentation shall have an accuracy of ± 1.5 °C. The temperatures shall be recorded automatically at time intervals not exceeding 1 hour until the end of the curing and protection period. The dataloggers shall display the temperature and be left in place until the end of the monitoring period.

The Contract Administrator and the Owner shall be provided access to verify temperature readings.

The datalogger temperature records and temperature difference shall be forwarded to the Contract Administrator at the end of the temperature monitoring period.

3271.07.05.09 Early Loading of Concrete

Full design loads shall not be applied to the structure until the specified 28-Day compressive strength has been attained. Early loading of a structural component or culvert is permitted unless expressly stated otherwise by the Designer, subject to the following conditions,:

a) Prior to any early loading, the Contractor shall demonstrate that the concrete has reached a compressive strength of 20 MPa.
b) Subsequent placement of SPCS, reinforcement, formwork, falsework, and concrete on a footing, pile or any part of the culvert shall not be carried out until at least 24 hours after concrete placement and the concrete has reached a compressive strength of 20 MPa.
c) Early loading of concrete is not permitted where cold weather protection is required.
d) Full curing is to be maintained at all times during the curing period.

The Contractor shall be responsible for making, curing, transportation and testing of cylinders for verification of early strength prior to loading any concrete. Casting and testing of concrete cylinders shall be in accordance with CSA A23.2-3C and 9C, respectively. Testing shall be carried out at a laboratory certified by CCIL according to CSA A283 as a concrete testing laboratory which can demonstrate successful participation in the MTO Correlation Program. Results shall be forwarded to the Contract Administrator as they become available.

3271.07.05.10 Surface Finish

Concrete surfaces shall not be treated with cement slurry or paste.

Care shall be taken to select material, including proprietary patching materials, where it is used for remedial work or patching core holes, to achieve uniformity of colour and appearance.

3271.07.05.11 Cracks in Concrete Surfaces

The Contractor shall inspect all concrete during construction and identify and document:

a) Any cracks including their location, width, and density.
b) Any areas requiring repair or rejection/replacement.

A copy of the crack survey shall be forwarded to the Contract Administrator prior to any remedial work. The inspection of the surface to be waterproofed shall be carried out after completion of curing and before application of tack coat for waterproofing. For all other areas of concrete, the inspection shall be carried out in a timely manner but no later than one month following completion of curing. The Contractor shall not proceed with waterproofing until all repairs have been completed and permission to waterproof has been given by the Design Builder's Engineer, and the Contract Administrator has had the opportunity to

carry out the milestone inspection. The Contractor shall continue to inspect and monitor the cracks up to the date of Completion of the Work.

The Contractor shall identify any areas requiring repair or rejection/replacement.

Areas which can be repaired by crack injection shall be repaired according to OPSS 932. Where concrete removal is required, the removals shall be according to OPSS 928 and preparation of concrete shall be according to OPSS 930. Upon completion of repairs of a component, the Contractor shall provide a report to the Contract Administrator detailing the repair treatment.

Irrespective of the requirements in Table 5 and 9 , where deficiencies are severe or so extensive that they would be expected to adversely affect the structure performance or long term durability of the structure, a repair proposal shall be submitted under the signature of an Engineer, to the Contract Administrator, for acceptance, prior to proceeding with the repairs. The repair report shall include a copy of the accepted repair proposal as well as the details of the repair treatment.

3271.07.05.12 Material Sampling and Testing for Concrete Acceptance

3271.07.05.12.01 Concrete Plastic Slump, Air Content and Temperature

Field sampling and testing of plastic concrete shall be performed by a person holding either of the following certifications:

a) CCIL – Certified Concrete Testing Technician; or
b) ACI Concrete Field Testing Technician – Grade 1.

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

3271.07.05.12.02 Obtaining Concrete Samples for Acceptance Testing

The Contractor shall be responsible for:

a) Removing cores for determination of compressive strength, air void system parameters (AVS), and rapid chloride permeability (RCP);
b) Making and curing of specimens for determination of linear shrinkage; and
c) Transportation of all specimens to the Regional Quality Assurance laboratory for testing by the Owner.

Concrete shall be sampled and tested on a lot basis. A lot shall consist of no more than 400 m^2 of floor area of a concrete culvert. Where a culvert has no floor, the area of the upper surface shall be used. Separate lots shall be used for each culvert and each construction stage of a culvert.

The test results will be forwarded to the Contractor as they become available.

3271.07.05.12.03 Compressive Strength, Air Void System Parameters, and Rapid Chloride Permeability

The Contractor shall remove five cores from each lot, 100 mm diameter and 200 mm long, for testing by the Owner; three for 28 Day compressive strength, one for AVS, and one for RCP. Coring shall be according to CSA A23.2-14C. Each core shall be removed at a random location within the lot, as specified by the Contract Administrator.

All cores shall be removed when the concrete is between 7 to 10 Days of age and cores from the top slab shall be removed prior to application of waterproofing membrane. Steel reinforcement and other

embedded material shall be avoided while coring. A covermeter shall be used to establish steel reinforcement location prior to coring.

The Contract number, component identification, and lot number shall be marked legibly on each core with durable ink. Each core shall be placed in a plastic bag and sealed to prevent loss of moisture, before they are placed in security bags.

The cores shall be protected from extremes in temperature and loss of moisture from the time they are removed until they are delivered, to the Regional Quality Assurance Laboratory. Cores shall be delivered to the Regional Quality Assurance laboratory within 24 hours of coring. The cores shall be accompanied with a transmittal form and Form A of the concrete mix design for the component.

Testing shall be according to Table 4.

Referee testing shall be according to OPSS 1350 with the following exception:

a) Referee sampling for compressive strength will be based on cores.
b) Referee cores for compressive strength and RCP will be extracted only when referee testing is invoked.

3271.07.05.12.04 Linear Shrinkage

3271.07.05.12.04.01 General

The Contractor shall make one set of three specimens from each lot as directed by the Contract Administrator for determination of linear shrinkage. Linear shrinkage specimens shall be moulded, and cured on site for cast-in place concrete and at the precasters facility for precast concrete according to LS-435.

The specimens shall be transported between 20 and 23 hours of age to the Regional Quality Assurance laboratory in an environment which maintains a temperature of 15 to 25ºC and a relative humidity of not less than 95%. Linear shrinkage shall be tested according to LS-435.

3271.07.05.12.04.02 Referee Testing

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

For referee testing the Contractor shall make a new set of three specimens from concrete placed on the Contract of the same mix design and method of placement for which referee testing was invoked. The specimens shall be moulded, cured, delivered, and tested according to this specification. The referee laboratory will be designated by the Owner based on the applicable roster. Referee test results will be forwarded to the Contractor as they become available.

When the referee result is greater than the acceptance test result or no more than 0.01% below the acceptance test result, then the acceptance test result is confirmed and shall remain valid. When the referee test result for the lot is more than 0.01% below the acceptance test result, the acceptance test result is not confirmed, and the referee test result shall replace the acceptance test result in the acceptance requirements of this specification.

3271.07.05.12.04.03 Referee Testing Cost

The cost of referee testing shall be as specified elsewhere in the Contract Documents.

When the referee result confirms the acceptance test result, the Contractor shall be responsible for the cost of linear shrinkage referee testing. When the referee result does not confirm the acceptance test result, the Owner shall bear the cost.

3271.07.05.12.05 Filling of Core Holes

Each core hole shall be filled immediately after coring with a proprietary patching material. The patching material shall be comparable to the surrounding concrete in terms of strength, permeability, and appearance. The patching material shall be mixed, handled, and cured according to the manufacturer's instructions. The patch shall be finished flush with the surface of the surrounding concrete.

3271.07.06 SPCS Culverts

Transportation, handling, and storage of the SPCS shall be according to the manufacturer's recommendations. Culverts shall be installed according to CSA G401, IFCD, and the Contract Documents.

3271.07.07 Joint Treatment

Joints, including seams, shall be constructed and treated to prevent leakage and infiltration.

3271.07.08 Waterproofing Systems

3271.07.08.01 General

Waterproofing shall not proceed until the milestone inspections and any associated remedial work have been completed.

3271.07.08.02 Concrete Culverts

The top surface of the concrete culvert shall receive a waterproofing system and protection board when the fill height is equal to or less than 1 m. The waterproofing system shall extend continuously down the vertical face of the outside walls for a depth of 300 mm for box culverts, to footing level for arch culverts, and to the mid-depth for circular and elliptical culverts. For precast culverts that include a topping slab, the top of the cast-in-place reinforced concrete slab shall receive the waterproofing system.

Prior to the placement of the waterproofing system, the surface of the concrete shall be completely clean to expose sound, laitance-free concrete. All dirt and debris shall be removed from the concrete surface. The waterproofing system shall be installed according to the manufacturer's recommendations by a firm certified by the manufacturer of the product and applied within the specified temperature range.

3271.07.08.03 SPCS Culverts

Waterproofing systems shall be installed according to the manufacturer's instructions.

3271.07.09 Backfill

All backfill material, placement, and compaction procedures shall be according to CAN/CSA-S6,and recommendations of the culvert manufacturer(s) , and be consistent with the design methodology.

Backfill material shall be free from frozen material, lumps, cinders, ashes, refuse, vegetable or organic matter, rocks and boulders over 150 mm in any dimension, and contaminants or other deleterious material.

For concrete culverts, backfill shall not be placed until the concrete has been demonstrated to have reached a compressive strength of 20 MPa, unless otherwise specified by the Designer.

3271.07.10 Remedial Work

Where work does not meet the performance requirements of this specification, remedial work shall be carried out according to Tables 2-10, at the Contractor's expense. The remedial work shall be completed according to current ministry specifications and Special Provisions.

Where a non-conformance is identified, a detailed proposal for the remedial work shall be submitted to the Contract Administrator for acceptance within 10 Working Days of identification of non-conformance during construction or 20 Working Days within the warranty period.

The proposal shall include as a minimum:

a) An explanation of the cause and extent of the non-conformance;
b) Photographs of all defects;
c) Proposed remedial actions;
d) Identify limits of repair or replacement;
e) Methodology details including materials;
f) Installation techniques;
g) List of specifications and Special Provisions used; and
h) Timeframe to complete remedial work.

Notwithstanding the above requirements, any safety related concern as a result of any non-conformance shall be addressed by the Contractor immediately. This will include temporary measures prior to final repairs.

The Contractor shall not proceed with repairs until the proposal has been accepted by the Contract Administrator in writing. The Contractor shall implement preventative measures prior to continuing with the associated activity and shall not proceed with any subsequent activity that would prevent or impede corrective action.

Notwithstanding the ministry's acceptance of the repair or replacement proposals, the Contractor is responsible for meeting the performance requirements of the Contract throughout the duration of the warranty period.

3271.07.11 Submission Requirements, During the Work

3271.07.11.01 Certificate of Compliance – SPCS Culverts

A copy of the certificate of compliance from the manufacturer shall be submitted to the Contract Administrator prior to installing the culvert. The manufacturer's certificate of compliance shall be issued by the certification body confirming that the manufacturer produces certified SPCS according to CSA G401 and holds a valid CSPI certificate.

3271.07.11.02 Mill Certificates

One hard copy and one electronic copy of the mill certificates shall be submitted for each heat prior to shipment of reinforcing steel bars, stainless steel reinforcing bars, splice bars, stainless steel splice bars, structural steel, bolts, SPCS and protection systems designed by the Contractor where the yield strength specified on the IFCD is greater than 250 MPa.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificates verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the

name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

If the material cannot be identified by mill test certificates, coupons shall be taken and tested according to the requirements stated above and these test certificates shall be made available.

3271.07.11.03 Concrete Mix Design

The concrete mix design shall be submitted according to the requirements of the "Mix Design" clause of OPSS 1350 with the following exceptions:

a) The mix shall not be placed until the Design Builder's Engineer provides written confirmation to the Owner that the concrete mix design submission meets the Contract requirements.
b) Prior to the placement of concrete of a given mix design, the Contractor shall ensure that for each Form A submitted, a corresponding Form B is accurately completed by the concrete supplier and submitted directly to the Head, Concrete Section (concretemixdesign@ontario.ca) and Regional Head of Quality Assurance.
c) For precast concrete plants, documentation verifying certification of the concrete production facility by the Ready-Mixed Concrete Association of Ontario shall be submitted when concrete is supplied by an external concrete supplier.

If precast concrete culverts are used, the precast concrete manufacturer's certificate verifying compliance with the certification requirements of the Canadian Standards Association (CSA) or the Canadian Precast/Prestressed Concrete Institute (CPCI) shall be submitted to the Contract Administrator as part of the concrete mix design submission.

3271.07.11.04 Delivery Tickets

Delivery tickets shall be according to OPSS 1350 and shall be made available to the Contract Administrator upon request.

3271.07.11.05 Plastic Concrete Test Results

At the end of each week, a summary shall be submitted to the Contract Administrator which includes, for each load of concrete delivered:

a) Air contents.
b) Slumps before and after any additions.
c) Concrete temperature.
d) All adjustments made to the load.
e) Identify of all rejected material.

3271.07.11.06 Concrete Temperature Records

All datalogger concrete temperature records shall be forwarded to the Contract Administrator at the end of the temperature monitoring period.

3271.07.11.07 Interim Inspection – Precast Culvert

A letter from the Quality Verification Engineer giving the Contractor permission to proceed with the Work shall be submitted to the Contract Administrator prior to shipping the precast culvert. The letter shall state that the QVE has conducted an interim inspection and verified that the fabrication of the precast culvert and required testing have been carried out in general conformance with the sealed and signed IFCD, supporting documents, and Contract Documents.

3271.07.11.08 Certificate of Conformance – All Culvert Types

A completed Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the work. The Quality Verification Engineer's seal and signature shall be affixed on the completed Certificate of Conformance confirming that the work has been carried out in general conformance with the IFCD, Contract Documents, and meets the performance requirements of Tables 2-7. Certificate of Conformance shall be submitted for the following:

a) Formwork and falsework for which Working Drawings are submitted, if applicable.
b) Culvert – upon completion of each culvert installation and prior to backfilling.

3271.08 QUALITY ASSURANCE

3271.08.01 Milestone Inspections

3271.08.01.01 General

The Contractor shall notify the Contract Administrator, in writing, 3 Days prior to reaching each milestone, in order for the Contract Administrator to complete inspections and verify performance requirements of Tables 2 to 7. The Contractor shall clear all debris and obstructions, provide unhindered access and notify the Contract Administrator in writing that the culvert is ready for each milestone inspection.

The Contract Administrator shall be provided 3 Working Days to perform each milestone inspection prior to commencement of the next successive operation. Subsequent work shall not proceed until the Design Builder's Engineer has given permission in writing, and the Owner has had the opportunity to carry out the milestone inspection.

3271.08.01.02 Concrete Culvert – Cast-In-Place

Milestone inspections for cast-in-place concrete culverts are as follows:

a) At the completion of excavation.
b) Prior to concrete placement and after installation of steel reinforcement.
c) After concrete has been cured, any remedial work completed, submission of Certificate of Conformance for the concrete culvert, and prior to waterproofing.
d) After waterproofing and prior to backfilling.

3271.08.01.03 Concrete Culvert – Precast

Milestone inspections for precast concrete culverts are as follows:

a) At the completion of excavation.
b) After culvert has been installed, remedial work completed, and prior to waterproofing.
c) Prior to concrete placement of topping slab, where applicable, and after installation of steel reinforcement.
d) After topping slab has cured, where applicable, remedial work completed, and Certificate of Conformance for the precast culvert has been submitted.
e) After waterproofing and prior to backfilling.

3271.08.01.04 SPCS Culverts

Milestone inspections for SPCS culverts are as follows:

a) At the completion of excavation.

b) After culvert has been installed, remedial work completed, submission of Certificate of Conformance for the SPCS culvert, and prior to waterproofing and backfilling.
c) After waterproofing has been completed.

3271.08.02 Concrete Covermeter Survey for Concrete Culverts

The Contract Administrator will carry out a concrete covermeter survey on interior and exterior surfaces prior to waterproofing and/or backfilling. The Contractor shall clear all debris and obstructions, provide unhindered access and notify the Contract Administrator in writing when the test area is ready for the concrete covermeter survey.

The Contractor shall allow the Contract Administrator a time period of 3 Business Days to complete the survey from the time the notice is received by the Contract Administrator. The time period to carry out the survey shall be extended if inclement weather or the ambient air temperatures below 5ºC fall within that time period.

3271.08.03 Dowels

If dowels are used, acceptance shall be according to the visual acceptance criteria and pull testing criteria specified elsewhere in the ministry's Special Provision.

3271.08.04 Performance Requirements

The culverts shall meet or exceed all performance requirements identified in Tables 2 to 10 during construction and throughout the duration of the 10 year warranty period.

The Contractor shall review and assess the work throughout construction and shall immediately identify and notify the Contract Administrator of any non-conformance. Notwithstanding Contractor assessment, the Contract Administrator shall determine whether the acceptance criteria are met based on the assessment during construction and throughout the warranty period.

Additional data collection may be carried out by the ministry where there is evidence of or potential for non-conformance. The additional data collection may include review of the Contractor's records, plans, and actions taken, or conducting field and/or laboratory testing.

The Contract Administrator shall share performance assessments with the Contractor.

Table 1: Recommended Environmental Range for SPCS Culvert Options in Ontario

Steel Type	Hot Dipped Galvanized (> 5 mm)	Thermoplastic Copolymer Coating
pH (Water)	5.8 to 9.8	4.0 to 9.0
Resistivity of Water (ohm-cm)	2,000 < R < 8,000	>750
Chlorides (ppm)	<250	NA[1]
Sulfates (ppm)	<600	NA[1]
Hardness (ppm)	>80 $CaCO_3$	NA[1]
Abrasion[2]	Level 1 or 2	Level 1, 2 or 3

Note:

1. Resistivity is relative to Total Dissolved Solids (TDS) and therefore may indicate the presence of chlorides, sulphates, calcium and other soluble ions.
2. Abrasion Levels:
   - Level 1: Non-Abrasive – very low velocity and no bedload. Anticipated Flow Velocity – NA.
   - Level 2: Low Abrasion – Minor bedloads of sand and gravel. Anticipated Flow Velocity = 0–1.5 m/s.
   - Level 3: Moderate Abrasion – moderate bedloads of sand and gravel. Anticipated Flow Velocity = 1.5–4.5 m/s.
   - Level 4: Severe Abrasion – Heavy bedloads of sand, gravel, and rock. Anticipated Flow Velocity > 4.5 m/s.

Table 2: Performance Requirements (All Types) – During Construction

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Design	Design review and monitoring during construction.	Design shall meet the requirements of CSA/CAN-S6, IFCD, and the Contract Documents.	Remove and replace culvert when design does not meet the CSA/CAN-S6, IFCD or the Contract Documents.
Culvert Installed and Constructed According to Design	Measurement and visual assessment.	• Culvert shall be installed and constructed according to the IFCD, and Contract Documents. • Dimensions shall be within acceptable tolerances specified in CSA/CAN-S6.	• Re-evaluate the design of the structure. • Where required, repair, strengthen or remove and replace, subject to ministry approval.
Geometry & Alignment of Components	Geometric and alignment measurement.	All edges of the culvert shall be set true to the elevations, alignment, geometry, and camber specified in the IFCD within the following variations: • Variations in alignment shall not exceed: – ± 25 mm vertically along the length of the culvert. – ± 300 mm horizontally. (Measure from the invert or top of footing) • Variations from plumb or a specified slope shall not exceed 1:400 for concrete culverts. • Side-to-side racking of SPCS culverts shall not exceed 1% of the rise.	Remove and realign components that are outside the acceptance criteria.
Flow of Water	Visual assessment.	Stream shall flow through the culvert.	Reassessed and modify culvert as necessary.

Table 3: Performance-Based Requirements (Plastic Concrete) - During Construction

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Plastic Concrete Properties (Slump, Air and Temperature)	• The Contractor shall sample and test the plastic concrete for slump, air content, and temperature according to CSA A23.1/A23.2 and OPSS 1350 until satisfactory control is established. • Satisfactory control shall be established each day. • It is established when concrete from 5 consecutive loads (ready-mix trucks) or 5 batches (not delivered by a truck) are within the specified requirements without field adjustments. • After satisfactory control has been established, testing shall be carried out on every third load or batch.	Contractor shall reject all concrete loads: • Outside target range specified in the mix design for slump and air. • Where the concrete temperature is outside the range of 10-28ºC. • Where SCC is accepted for use, the plastic concrete testing requirements of the Special Provision "Self-Consolidating Concrete (SCC) Cast-In-Place and Repairs" shall be followed for cast-in-place concrete and Special Provision "Self-Consolidating Concrete (SCC) in Precast Products" shall be followed for precast concrete.	• Rejectable concrete shall not be incorporated into the work. • Remove unacceptable concrete.
Free of Lumps	Visual assessment.	Concrete shall contain no lumps.	Contractor shall reject all concrete loads that contain more than three visible lumps

Table 4: Performance-Based Requirements (Concrete) - During Construction

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Concrete Temperature During Curing and Protection Period	Contractor shall monitor and control the concrete temperature according to the requirements of this specification.	• Concrete temperature shall be between 10.0-70.0°C. Cast-In Place Concrete: • Temperature difference, as measured between thermocouples shall be according to subsection, "Control of Temperature and Temperature Difference" of OPSS 904 for bridge decks. • Maximum allowable drop in concrete temperature per 24 hours shall be 20.0°C Precast Concrete • Temperature difference, as measured between thermocouples shall be according to subsection, "Control of Temperature" of OPSS 909.	Remove and replace concrete culvert when the concrete temperature is outside the acceptance criteria.
Hardened Concrete Properties 28 Day Compressive Strength, Air Void System (AVS), Rapid Chloride Permeability (RCP), and Linear Shrinkage.	28 Day compressive strength testing on cores shall be according to LS-445.	28 Day Compressive Strength: • The 28 Day Compressive strength is the Average of three cores per lot. • Compressive strength ≥ specified strength.	Remove and replace the lot when the average strength falls below the minimum strength by more than 4 MPa. Payment adjustments will be applicable for marginal material according to Table 13.
	AVS testing shall be carried out on one half of the core according to LS-432.	AVS: • Air void content ≥ 3%. • Spacing factor ≤ 0.230 mm.	• Lots that do not meet the acceptance criteria shall be removed and replaced, except where the Owner permits the work to remain in place. • The replacement lots shall be evaluated for acceptance on the same basis as the original lot. • When Owner permits the work to remain in place, it shall be subject to the payment adjustment in Table 14.
	RCP testing shall be carried out according to LS-433 on two 50 mm samples cut from a single core.	RCP: • RCP at 28 to 32 Days ≤ 2500 coulombs.	• Remove and replace lots when the RCP is greater than 4000 Coulombs Payment adjustment will be applicable for marginal material according to Table 15.
		Linear Shrinkage: • Average linear shrinkage for the lot ≤ 0.04%.	• Remove and replace lot when average is ≥0.06%. • Payment adjustment shall be applied according to Table 16 when the average is >0.04% and <0.06%.

Table 5: Performance Requirements (Concrete) - During Construction

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Spalls, and Delaminations	Visual assessment and sounding.	Concrete shall be free of spalls, delaminations, and physical damage.	Remove and repair affected areas.
Cracks	• Visual inspection and measurement by means of crack comparator. • Width of crack is measured at the widest point of the crack (not average width of crack). • Cracks shall be measured after the air drying period and prior to waterproofing and backfilling.	**Concrete Surfaces to be Waterproofed:** • Width of crack shall be less than 0.50 mm. • Linear measurement of cracks ≥0.50 mm within 1 m^2 shall be less than 2 m. **Exposed Concrete and Concrete Surfaces not Waterproofed:** • Width of crack shall be less than 0.30 mm. • Linear measurement of cracks ≥0.30 mm within 1 m^2 shall be less than 2 m.	• Repair cracks greater than the crack width specified according to OPSS 932. • Remove and replace components where the total linear measurement of cracks greater than the width specified per m^2 is ≥ 2 m.
Surface Appearance	Visual assessment.	• Concrete shall be uniform in colour, pattern, and texture when viewing from a 15 m distance. • Concrete surface shall be free from open texture, undulations, projections, ridges, excessive frequency of bugholes, placement lines, stains and rust marks.	Remove and repair affected areas.
Uniformity of Consolidation & Integrity of Concrete	• Visual inspection of concrete surface and cores. • Other methods (as required).	Concrete shall be free of the honeycombing, voids, segregation, poor consolidation, and cold joints.	• Components containing unacceptable concrete shall be removed and replaced, except where the Owner permits the work to remain in place. • When the Owner permits the work to remain in place, the Contractor shall submit a repair proposal to the Contract Administrator.
Surface Tolerance	The gap is measured between a 3 m straight edge and the surface of the concrete.	Concrete surface shall be: • True to grade/cross section. • Finished flush with adjacent and existing concrete. • Gap shall be < 6 mm along the concrete surface and < 3 mm across construction joints. • Constructed in a manner that prevents water from ponding to a depth of 3 mm or more.	
Concrete Cover to Reinforcement	Carry out covermeter survey according to the "MTO Covermeter Users' Guide for Concrete Cover Survey".	Concrete cover shall be as specified on the Contract Documents.	
Joints in Precast Concrete Units	Visual assessment and measurement.	The gap between adjacent units shall be uniform and not deviate from the design by more than 10 mm.	Adjust or remove and install precast units correctly.

Table 6: Performance Requirements (Steel) – During Construction

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Base Steel Thickness	Measurement with caliper or ultrasonic method according to ASTM E797 prior to installation.	Base steel thickness shall be as specified in the IFCD within the tolerances specified in CSA G401 Table 6.	Remove and replace all sections less than the design thickness.
Protective Coating Thickness	Measurement method according to SSPC-PA2 prior to installation.	Protective coating thickness shall be as specified in the IFCD within the tolerances specified in CSA G401.	Remove and replace all sections not meeting the thickness requirement.
Protective Coating Defects	Visual assessment prior to installation.	Galvanizing/Thermoplastic copolymer coating shall be free of any defects.	• Remove and replace any plate that has evidence of peeling or other fabrication defects. • Remove and replace any plate where the total of any areas damaged during construction exceeds 100 cm^2. • Remove and replace all of the damaged plates when the total damaged area for the culvert is greater than 200 cm^2. • Damaged plates not subject to removal based on the above criteria shall be repaired according to CSA G401 for thermoplastic copolymer coating and OPSS 911 for galvanizing coating.
Corrosion	Visual assessment prior to installation.	Culvert including bolts, plates, and structural steel shall be free of corrosion.	Remove and replace affected sections or components.
Deformation	Visual assessment.	Culvert including bolts, plates and structural steel shall be free of bending, buckling, twisting, elongation.	Remove and replace affected sections or components.
Cracking	Visual assessment.	Culverts shall be free of any linear fracture in the steel.	Remove and replace affected sections or components.
Crimping of Corrugations, Cusping	Visual assessment.	Culverts shall be free of crimping or cusping.	Remove and replace affected plates.
Piles	Performance requirements shall be according to DBSP 903.		
Installation of Bolts & Nuts	Visual assessment and torque measurement.	• Bolts and nuts shall be installed and torqued according to the IFCD.	• Install missing bolts and nuts. • Tighten bolts not meeting the requirements.

Table 7: Performance Requirements (Waterproofing Systems) - During Construction

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Waterproofing System (Hot Poured) for Concrete Surfaces	Waterproofing thickness: measure according to OPSS 914 and the "Field Guide For the Acceptance of Hot Mix and Bridge Deck Waterproofing".	Waterproofing membrane thickness shall be 5 mm ± 1 mm.	Remove and replace waterproofing system not meeting acceptance criteria.
	Waterproofing properties: Testing shall be according to OPSS 1213.	Physical properties of the waterproofing membrane shall meet the requirements of OPSS 1213.	
	Protection Board: testing according to OPSS 1215.	Protection board shall meet the requirements of OPSS 1215.	
Waterproofing System for SPCS Culverts	• Visual Assessment prior to backfilling.	Waterproofing system shall be: • Free from tears, perforations or any other defects. • watertight. • Installed according to the manufacturer's instructions.	Remove and replace waterproofing system not meeting acceptance criteria.

Table 8: Performance Requirements (All Types) – During Warranty Period (0 to 10 Years)

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Drainage and Hydrology	Visual assessment and measurement.	Performance of culvert shall be according to the required drainage and hydrology criteria.	Reassess and modify culvert as necessary to meet the drainage and hydrology criteria.
Leakage And Infiltration	Visual assessment	There shall be no leakage of water or infiltration of pipe fill material along the full length of the culvert, including joints, seams, bolts, or cracks.	• Repair areas that are leaking or have infiltration. • Remove and replace culvert if repairs cannot be made.
Roadway Settlement	Visual assessment and measurement.	• Roadway surfaces over culverts and approaches shall be free of settlement exceeding the limits of Tables 11 and 12. • Embankments shall be stable and free of signs of distress such as tension cracks, sloughing and creep.	Repair when settlement exceeds maximum limits specified.
Sediment Build-Up	Visual assessment.	There shall be no significant sediment build-up inside the culvert beyond that which has been accounted for in design, such that the flow is restricted.	• Remove sediment build-up. • Design and install modifications to culvert to prevent sediment build up. • Re-design and replace culvert if modifications do not prevent future sediment build up.
Vegetation Growth	Visual assessment.	There shall be no significant vegetation growth inside the culvert beyond that which has been accounted for in design, such that the flow is restricted.	• Remove vegetation. • Design and install modifications to culvert to prevent vegetation growth inside the culvert. • Re-design and replace culvert if modifications do not prevent future vegetation growth inside the culvert.
Ice Build Up	Visual assessment.	There shall be no significant ice build-up around or within the culvert attributable to the design, such that the flow is restricted.	• Remove accumulated ice. • Design and install modifications to culvert to prevent ice from building up. • Re-design and replace culvert if modifications do not prevent future ice accumulation.
Debris Blockage	Visual assessment.	There shall be no significant blockage by debris around or inside the culvert attributable to the design, such that the flow is restricted.	• Remove accumulated debris. • Design and install modifications to culvert to prevent debris from blocking or depositing inside the culvert. • Re-design and replace culvert if modifications do not prevent future debris blockage or accumulation.

Table 8: Performance Requirements (All Types) – During Warranty Period (0 to 10 Years) con't

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Piping	Visual assessment.	There shall be no removal of fines from bedding or backfill due to stream flowing outside the culvert.	• Repair and close flow path along the outside of the culvert. • Replace culvert if a repair cannot be made.
Scour	Visual assessment.	There shall be no scour around the culvert attributed by the design.	• Repair any damaged areas. • Culvert shall be reassessed and modified as necessary to avoid reoccurrence. • Design and install modifications to culvert to prevent scour and erosion. • Re-design and replace culvert if modifications do not prevent future scour and erosion.
Erosion	Visual assessment.	• There shall be no erosion of the crossing embankment slopes. • There shall be no erosion of the stream bed or banks of the watercourse in both the upstream and downstream directions.	
Flooding	Visual assessment and measurement.	• There shall be no flooding over the structure and roadways unless crossing has been designed for relief flow. • There shall be no increased upstream or downstream flooding beyond that which has been accounted for in design.	• Culvert hydraulics shall be reassessed to determine cause of flooding. • Design and install modifications to culvert to remove or alleviate flooding impacts. • Re-design and replace culvert if modifications do not remove or alleviate flooding impacts.
Fish Passage	Visual assessment and measurement.	There shall be no impediments to fish migration through the culvert.	If impediments to fish migration are evident: • Culvert hydraulics shall be reassessed to determine cause of impediment. • Design and install modifications to culvert to remove impediment or reinstate fish passage. • Re-design and replace culvert if modifications do not remove the impediment.
Separation of Culvert Extensions	Visual assessment and measurement.	There shall be no separation of culvert extensions or relative displacement.	• Repair if relative displacement is less than 10 mm. • If relative displacement exceeds 10 mm, culvert shall be reassessed and modified as necessary to avoid reoccurrence.
Culvert Settlement/ Heaving	Visual assessment and measurement.	Culvert shall not deviate from the permissible tolerances of the original design.	Remove and realign culvert if settlement/heaving of culvert is outside the permissible tolerances of the original design.

Table 9: Performance Requirements (Concrete) – During Warranty Period (0 to 10 Years)

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Spalls, and Delaminations	Visual assessment and sounding.	Concrete shall be free of spalls, delaminations, and physical damage.	Remove and repair affected areas.
Scaling	• Visual inspection and assessment of severity of scaling according to Figures 1-6. • Additional cores may be required to evaluate air void system parameters of the scaled area.	At the end of the warranty period there shall be no medium, or severe scaling and the total area of light scaling shall be no more than 20% of the component.	For light scaling between 5-20% of the exposed area of culvert, seal the entire exposed concrete surface. <u>Remove & Replace</u>: • Areas of light scaling >20% of the surface area of the component when additional coring indicates non-conforming AVS parameters. • Areas of medium and severe scaling.
Disintegration, Freeze Thaw Damage, Abrasion, Erosion	Visual assessment.	Concrete shall be free of disintegration, freeze thaw damage, abrasion, and erosion.	• <20% - Remove & replace affected area and the Contractor shall demonstrate that remaining concrete in the component is not affected. • >20% - Remove and replace entire component.
Softening, Loss of Strength and Section	Visual assessment and core testing.	• Original structural properties shall be maintained. • Concrete shall be free of softening and section loss.	
Corrosion of Reinforcement	Visual assessment and carry out corrosion potential survey to confirm corrosion of reinforcement.	• No rust stains on the concrete surface due to corrosion of reinforcement. • No areas of actively corroding reinforcement.	Remove and replace culvert component if any reinforcement is actively corroding.
Cracks (Concrete)	• Visual inspection and measurement by means of crack comparator after air drying period and prior to waterproofing and backfilling. • Width of crack is measured at the widest point of the crack (not average width of crack).	**Waterproofed Concrete Surfaces:** • Width of crack shall be < 0.50 mm. • Linear measurement of cracks ≥ 0.50 mm within 1 m^2 shall be less than 2 m. **Exposed Concrete Surfaces:** • Width of crack shall be < 0.30 mm. • Linear measurement of cracks ≥ 0.30 mm within 1 m^2 shall be less than 2 m.	• Repair cracks greater than the crack width specified in the acceptance criteria according to OPSS 932. • Remove and replace components where the total linear measurement of cracks greater than the width specified in the acceptance criteria per m^2 is ≥ 2 m.
Joints for Precast Units	Visual assessment and measurement.	• Gap between adjacent units shall be uniform and shall not deviate from the design by more than 10 mm. • Gap along a joint shall not vary by more than 10 mm. • Vertical displacement between adjacent units shall be within 10 mm.	• Repair culvert joints with gaps or vertical displacement > 10 mm. • Remove and replace culvert if joint repairs do not prevent future separation or if joint repairs are not possible.

Table 10: Performance Requirements (Steel) – During Warranty Period (0 to 10 Years)

Performance Requirement	Performance Measurement	Acceptance Criteria	Remedial Work
Galvanizing Coating Thickness	Measurement method according to SSPC-PA2 at locations randomly selected by the Contract Administrator.	Galvanizing coating thickness shall be no less than 80% of the specified thickness in the IFCD within the tolerances specified in CSA G401.	Remove and replace all sections not meeting the thickness requirement, unless repair is permitted by the ministry. Repairs if permitted by the ministry shall be according to OPSS 911 for galvanizing coating.
Protective Coating Defects	Visual assessment.	Galvanizing/Thermoplastic copolymer coating shall be free of any defects.	Remove and replace any plate that has evidence of: a) Cracking, peeling or debonding of the thermoplastic copolymer coating. b) Galvanizing defects. Repairs if permitted shall be according to CSA G401 for thermoplastic copolymer coating and OPSS 911 for galvanizing coating.
Corrosion	Visual assessment.	Culvert including bolts, and other associated hardware shall be free of visible corrosion damage.	Remove and replace affected sections or components.
Deformation	Visual assessment.	Steel components shall be free of bending, buckling, twisting or elongation.	Remove and replace affected plates or components.
Cracking	Visual assessment.	Steel components shall be free of any linear fracture in the steel.	Remove and replace affected plates or components.
Crimping of Corrugations, Cusping	Visual assessment.	Culverts shall be free of any crimping, and cusping.	Remove and replace affected plates.
Separation of Joints or Seams	Visual assessment.	There shall be no open separation of joints or seams.	• Repair culvert joints. • Replace culvert if joint repairs cannot be made.
Curvature of Culvert	Visual assessment and measurement.	Span and height of the culvert shall not change by more than 3% of the design .	• Remove and replace culvert.
Bolts and Nuts	Visual assessment.	Bolts shall be installed and securely fastened.	• Replace affected bolts. • Culvert shall be reassessed and modified as necessary to avoid reoccurrence.

Table 11 – Roadway Settlement

	Maximum Limits During Warranty Period	
	Total Settlement (mm)	**Differential Settlement Rate**
Non-Compressible Soils	50	200:1
Freeways on Compressible Soils	100	200:1
Non-Freeways On Compressible Soils	200	200:1
Surface Treated on Compressible Soils	300	100:1
Gravel on Compressible Soils	300	50:1

Notes to Table:

Differential Settlement is calculated by:

1. Establishing baseline readings at two or more points along a transverse/longitudinal section(s).
2. Measuring these points for absolute settlement over time.
3. Differential settlement is calculated at each time interval by measuring the difference in the settlement over the distance of the settlement points. This is also known as angular distortion.

Table 12 – Roadway Settlement (Transitions)

	Maximum Settlement Limits During Warranty Period (mm)			
Distance From Transition Point	**0-20 m**	**20-50 m**	**50-75 m**	**≥75 m**
Freeways	25	50	75	100
Non-Freeways	25	50	100	200
Surface Treated and Gravel	25	75	150	300

Note to Table:

1. A transition point is a point where there is no settlement expected.

Table 13 - Payment Adjustment for 28-Day Compressive Strength

28 Day Compressive Strength of a Component (MPa)	Payment Adjustment($/m^3)
Individual core strength more than 4 MPa below specified strength and average ≥ specified strength	25
Average up to 1 MPa less than specified strength (≤1)	50
Average up to 2 MPa less than specified strength (>1, ≤2)	100
Average up to 3 MPa less than specified strength(>2, ≤3)	150
Average up to 4 MPa less than specified strength (>3, ≤4)	200

Table 14 - Payment Adjustment for Air Void System Parameters of Hardened Concrete, $/m^3

Spacing Factor, mm	Air Content, %				
	≤1.5	**>1.5 and ≤ 2.0**	**>2.0 and ≤2.5**	**>2.5 and ≤3.0**	**>3.0**
≤0.230	200	100	70	30	0
>0.230 and ≤ 0.350	300	300	200	100	70
>0.350 and ≤0.400	400	300	200	100	100
>0.400	400	400	300	150	100

Note:

When a sample in an unacceptable component has an air content of 3% or higher and a spacing factor lower than 0.230 mm in concrete, the sample shall be assigned a value of 0 $/m3 for the purpose of calculating a payment adjustment.

Table 15 - Payment Adjustment for Rapid Chloride Permeability in Culverts

Rapid Chloride Permeability of a Component (coulombs)	Payment Adjustment($/m^3)
Individual RCP>3000 coulombs, average ≤ 2500 coulombs	10
Average >2500 and ≤3000	30
Average >3000 and ≤3500	70
Average >3500 and ≤4000	150

Table 16 – Payment Adjustment for Linear Shrinkage

Linear Shrinkage	Tender Opening Date (Year)	Payment Adjustment ($/m^3) Note 1
>0.04% and ≤0.06%	2015	0.50 x (S-0.04) x 2500
	2016	0.75 x (S-0.04) x 2500
	2017 and beyond	1.00 x (S-0.04) x 2500
> 0.06 %	Not applicable	Remove and replace
Note 1: S = average linear shrinkage of a lot		

Figure 1. Example of Light Scaling

Figure 2. Example of Light Scaling

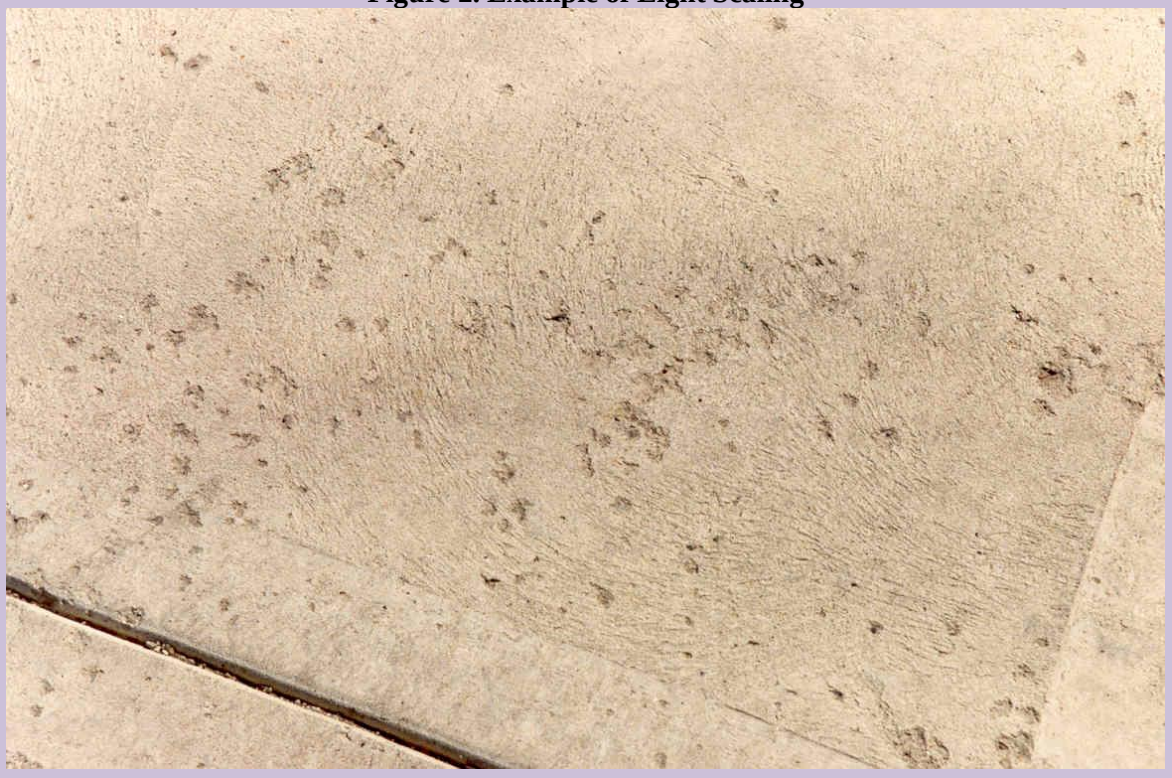

Figure 3. Example of Medium Scaling

Figure 4. Example of Medium Scaling

Figure 5. Example of Severe Scaling

Figure 6. Example of Severe Scaling