



**CONSTRUCTION SPECIFICATION FOR
CONCRETE STRUCTURES**

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904.01 SCOPE

This specification covers the requirements for the construction of concrete structures.

904.02 REFERENCES

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

Ontario Provincial Standard Specifications, Construction

OPSS 501	Compacting
OPSS 905	Concrete Reinforcement
OPSS 908	Metal Traffic Barriers and Metal Railings for Structures
OPSS 919	Formwork and Falsework
OPSS 920	Deck Joint Assemblies, Waterstops, Joint Fillers, Joint Seals and Joint Sealing Compounds - Structures
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 1202	Bearings - Elastomeric Plain and Steel Laminated
OPSS 1301	Cementing Materials
OPSS 1302	Water
OPSS 1315	White Pigmented Curing Compounds for Concrete
OPSS 1350	Concrete - Materials and Production

Ontario Ministry of Transportation Publications

Laboratory Testing Manual:

LS-413	Method of Test for Non-Volatile Content of Chemical Admixtures, Latex Admixtures and Curing Compounds
LS-414	Method of Test for Relative Density of Chemical Admixtures, Air Entraining Admixtures, Latex Admixtures and Curing Compounds
LS-416	Method of Test for Settling Rate - Curing Compound

CSA Standards

G30.18.09 (R2018)	Carbon Steel Bars for Concrete Reinforcement
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ASTM International

A 955M/A 955M-16a	Deformed and Plain Stainless Steel Bars for Concrete Reinforcement
C 171-16	Sheet Materials for Curing Concrete

American Association of State Highway and Transportation Officials (AASHTO)

M 182-05 (2017)	Standard Specification for Burlap Cloth Made from Jute or Kenaf
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904.03 DEFINITIONS

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

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 5 °C. It is also considered to exist when the ambient air temperature is at or is likely to fall below 5 °C within 96 hours after completion of concrete placement. Temperature refers to shade temperature.

Concrete Toe Wall means a low unreinforced concrete gravity type retaining wall no greater than 2 m in height.

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.

Culvert means a structure that provides an opening through an embankment and in which roadway loads are distributed to the structure through fill or that is designated as a culvert in the Contract Documents.

Designated Limits means the dimensions of the component as shown on the Contract Drawings or the limits of the component as revised in the field in writing by the Contract Administrator.

High Performance Concrete (HPC) means concrete with a minimum specified 28-Day compressive strength of at least 50 MPa that includes silica fume and may include other supplementary cementing materials and having a specified rapid chloride permeability at 28 to 32 Days of 1,000 coulombs or less.

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

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

R Value means the metric thermal resistance value that is a measurement of the resistance to heat transfer of insulation.

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.

Stainless Steel Reinforcing Bars means deformed stainless steel bars as defined in ASTM A 955 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.

Structure means any bridge, culvert, tunnel, retaining wall, wharf, dock, 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 purposes of this specification, a working slab is not considered a structural component.

Tremie means a hopper with a vertical pipe extending from the bottom of the hopper to the lowest point of concrete deposit, used to place concrete under water.

904.04 DESIGN AND SUBMISSION REQUIREMENTS

904.04.01 Submission Requirements

904.04.01.01 Request to Place Structural Concrete

Prior to each placement of concrete operation, a Request to Place Structural Concrete form accompanied with all supporting documentation as specified on the form, shall be submitted to the Contract Administrator.

The placement of concrete shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

904.04.01.02 Bridge Deck Placement Plan

A work plan shall be submitted to the Contract Administrator a minimum of seven Days prior to commencement of placing concrete in bridge decks, for information purposes. The work plan shall include:

- a) The proposed methods and sequence of placing operations to be used.
- b) Complete details of all equipment to be used during the concrete placement.

904.04.01.03 Temperature Control Plans

A temperature control plan shall be submitted to the Contract Administrator a minimum of seven Days prior to commencement of placing any concrete that requires temperature control for review of compliance with the requirements as specified in the Contract Documents.

The plan shall include methods for monitoring and controlling concrete temperature and the temperature difference prior to, during, and after placement for:

- a) Concrete subject to cold weather.
- b) HPC.
- c) Bridge decks.
- d) Large concrete components where the smallest dimension is 1.5 m.

The temperature control plan shall include, as a minimum, the following:

- a) Concrete element for which the plan applies.
- b) Temperature monitoring system, including the locations and depths, number of thermocouples, and frequencies of recordings to be used in each placement.
- c) Method of ensuring concrete temperature and temperature difference are maintained for the duration of the protection period.
- d) Any alterations to work schedule, production, delivery schedule, and time of placement for temperature control purposes.
- e) Any modification to mix design for temperature control purposes.
- f) Any other specific measures to be taken.
- g) Method of withdrawal of protection.

In addition, for concrete subject to cold weather the temperature control plan shall also include the following:

- a) Type of insulation, R value and number of layers, including test data verifying the R value. The submission for cold weather protective measures shall be accompanied by samples of insulation, if requested by the Contract Administrator.
- b) Type and layout of heaters and type and extent of housing.

904.04.01.04 Curing Compound

A minimum of seven Days prior to the application of the curing compound, the following shall be submitted to the Contract Administrator, for information purposes:

- a) Literature stating the manufacturers recommended rate of application.
- b) Description of the equipment to be used.
- c) A statement from the manufacturer of the curing compound approving the equipment.

904.04.01.05 Approach Slab Seat Elastomers and Ballast Wall Elastomers

A copy of the manufacturer's certificate verifying compliance with OPSS 1202 shall be submitted to the Contract Administrator prior to installation of the approach slab seat elastomer or ballast wall elastomer or both.

904.05 MATERIALS

904.05.01 Concrete

Concrete shall be according to OPSS 1350.

904.05.02 Portland Cement

Portland cement shall be according to OPSS 1301.

904.05.03 Sand

Sand shall be according to OPSS 1002.

904.05.04 Bonding Agents

Bonding agent shall consist of Portland cement, Type GU, and sand in the ratio of 1:1 by volume and sufficient water to produce a consistency so that it can be applied with a stiff brush to the existing concrete in a thin even coating that shall not run or puddle.

904.05.05 Mortar

Mortar shall be a 2:1 mixture by volume of sand and Portland cement, Type GU, and shall contain 12% entrained air with water sufficient to make a stiff mix.

904.05.06 Burlap

The burlap shall be according to AASHTO M182, Class 4, and shall be free from substances that are deleterious to concrete. The burlap shall have no tears or holes.

904.05.07 Water

Water used for curing and fog misting of concrete, including pre-soaking of burlap, and for making bonding agents and mortar and mixing proprietary patching materials shall be according to OPSS 1302.

904.05.08 Moisture Vapour Barrier

The material shall be a white opaque polyethylene film according to ASTM C 171, at least 100 µm thick.

904.05.09 Curing Compound

Curing compound shall be according to OPSS 1315.

904.05.10 Approach Slab Seat Elastomers and Ballast Wall Elastomers

Elastomers delivered to the site shall exceed the required length to allow for a 600 mm test sample to be taken from the approach slab seat or ballast wall elastomers on each structure.

The elastomer shall be according to the plain bearing requirements of OPSS 1202.

904.05.11 Insulation Material

Insulation material shall be mineral wool, glass fibre, plastic foam or other suitable material, having an R value not less than 0.02 m² C/W per 1 mm thickness.

Straw insulation shall not be used. Loose or absorbent insulation material shall not be used, unless it is completely contained within waterproof wrapping.

904.06 EQUIPMENT

904.06.01 General

Equipment made of aluminium material shall not come in contact with the plastic concrete.

904.06.02 Concrete Pump

The concrete pump shall be a reciprocating pump equipped to fit a pipeline at least 100 mm in diameter.

904.06.03 Consolidating Equipment

Internal vibrators shall be of the high frequency type with 8,000 minimum to 12,000 maximum vibrations per minute when immersed in concrete.

External vibrators shall have a minimum frequency of 3,600 vibrations per minute.

904.06.04 Mixer for Bonding Agents

The mixer for the bonding agent shall be a stationary mixer, power driven, and capable of uniformly mixing the materials.

904.06.05 Bridge Deck Finishing Machine

The bridge deck finishing machine shall:

- a) Be self-propelled and capable of forward and reverse movement under positive control.
- b) Be fitted with wheels that travel on adjustable screed rails.
- c) Be fitted with a reversing rotating cylinder screed capable of finishing the concrete without subsequent hand finishing.
- d) Be fitted with a reversing screw power auger.
- e) Be capable of externally vibrating the surface of the concrete by means of a plate or roller.
- f) Be fitted with a means to raise all screeds to clear the screeded surface and to accurately reposition them without adjusting the legs.
- g) Have adjustable legs fitted with locking devices.

904.06.06 Screed Rails

The rails shall be made of metal and be straight to within 3 mm in a 3 m length. Screed rail chairs shall be adjustable in height, made of metal, and spaced at a maximum of 1.2 m and be placed under all rail joints. Maximum deflection of the screed rails under load shall be 2 mm in a 1.2 m length.

904.06.07 Work Bridges

Work bridges shall be provided to facilitate surface finishing of unscreeded areas, corrections to surface finish, concrete inspection, and placing of curing materials.

Work bridges shall ride on the screed rails and the top surface of a work bridge shall not be higher than 1.0 m above the finished surface.

904.06.08 Hand Finishing Tools

Floats shall be made of magnesium or wood. Magnesium bull floats shall be commercially made.

904.06.09 Straight Edges

Two straight edges commercially made of metal, one 3 m and one 500 mm long shall be used.

904.06.10 Tremie

The tremie shall be equipped with a foot valve at the bottom of the pipe. The pipe shall have a 300 mm \pm 50 mm inside diameter and shall be long enough to extend to the lowest point of concrete deposit.

904.06.11 Spray Equipment for Curing Compound

The curing compound shall be applied to the concrete surface by means of motorized spraying equipment approved by the manufacturer of the curing compound. The equipment shall include a mechanical agitator.

904.06.12 Compressor - Air Blasting

The compressor for air blasting shall have a minimum capacity of 3.5 m³/minute. The compressed air shall be free of oil or other contaminants.

904.07 CONSTRUCTION

904.07.01 Formwork and Falsework

Formwork and falsework shall be according to OPSS 919. Textile form liners shall not be used.

904.07.02 Steel Reinforcement, Mechanical Connectors, and Associated Hardware

Steel reinforcement, mechanical connectors, and associated hardware shall be according to OPSS 905.

Where the superstructure is continuous over a support, all the deck steel reinforcement shall be placed in the entire deck prior to any concrete is placed. This requirement does not apply to the bottom slab of post-tensioned decks with trapezoidal voids.

904.07.03 Deck Joint Assemblies and Joint Material

Deck joint assemblies, joint fillers, joint seals, joint sealing compounds, and external waterstops shall be according to OPSS 920.

904.07.04 Preparation for Concrete Placement

904.07.04.01 General

All concrete surfaces against which new concrete is to be placed, including formed and sawcut surfaces, shall be clean, solid, and free from loose or unsound fragments, coatings, and any other foreign substances or debris and shall be sufficiently rough to ensure that a full bond is developed with the new concrete. The concrete surface shall be uniformly roughened to a surface profile of 5 ± 2 mm by means of methods such as scabbling, chipping, or bush hammering to expose the aggregates across the entire surface. Roughening is not required for the vertical faces of slope paving or for new concrete substrate with a roughened finish imparted at the time of placement meeting the profile requirement.

904.07.04.02 Abrasive Blast Cleaning

The following surfaces shall be abrasive blast cleaned according to OPSS 929:

- a) All existing steel reinforcement that shall be incorporated into the rehabilitation of a concrete structure component.
- b) All surfaces of existing structural steel against which new concrete shall be placed for the rehabilitation of a concrete structure component.
- c) All new or existing concrete surfaces against which new concrete shall be placed.

904.07.04.03 Cleaning

All concrete and structural steel surfaces against which new concrete is to be placed shall be cleaned by power washing no more than 24 hours prior to placing concrete.

904.07.04.04 Pre-Wetting

All concrete surfaces to receive concrete shall be maintained in a wet condition for a period of one hour prior to placing any new concrete.

Immediately prior to wetting the concrete surface, all dust and loose material shall be removed from the prepared surface by using compressed air.

Prior to placing concrete, excess water shall be removed from the surface using compressed air.

904.07.04.05 Bonding Agent

A bonding agent shall be used for:

- a) Exposed vertical surfaces of concrete, less than 300 mm in height, against which new concrete is to be placed.
- b) Blockouts in concrete for installation and modification of deck joint assemblies.
- c) Stressing tendon anchorage recesses.

A thin uniform coating of bonding agent shall be brushed onto the prepared surface immediately prior to placing fresh concrete. Bonding agents shall be mixed by means of a mixer. Any bonding agent not used within 30 minutes of mixing shall be discarded. Bonding agent that has dried shall be removed and replaced prior to placing concrete against it.

904.07.04.06 Element-Specific Preparation

For concrete in footings; when specified in the Contract Documents that the concrete is to be placed against undisturbed soil or set in rock, any over-excavation shall be filled with concrete of the same strength as the footing concrete.

For parapet and barrier walls and curbs on structures; all anchorages shall be fastened in place accurately and securely prior to proceeding with concrete placement. The railing anchorage inserts shall be fastened in place according to OPSS 908.

For concrete in approach slabs; the approach slab seat elastomer, polystyrene, and joint filler shall be installed and the grade thoroughly wetted down prior to placing the concrete in the approach slab.

For concrete in slope paving; the slope face shall be shaped, excavation completed, granular A placed and compacted according to OPSS 501 and the crushed rock, moisture vapour barrier, wood strips, and joint filler placed as required prior to placing the concrete. Sealant shall be installed as specified in the Contract Documents.

904.07.05 Placing of Concrete

904.07.05.01 General

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

Concrete placing and transporting devices shall not be supported by the steel reinforcement.

Concrete shall be deposited within 1.5 m of its final position. Chutes shall have sufficient slope to deliver concrete of the approved consistency and shall have a maximum length of 15 m.

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

When there is an interruption in placing concrete greater than 20 minutes, the surface of the concrete shall be covered with wet burlap. The Contractor shall notify the Contract Administrator immediately of any interruption resulting in a cold joint and shall submit a proposal for remedial action for approval.

904.07.05.02 Concrete Placing Restrictions

The placement of concrete shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

No concrete shall be placed until all curing material and, in cold weather, all cold weather protection material has been delivered to the site.

Barrier and parapet walls on structures shall not be slipformed.

When concrete is to be placed on a surface that has a slope greater than 3%, the placing operation shall begin at the lower end of the slope and progress upwards.

All surfaces against which concrete is to be placed shall be free of standing water, except for tremie concrete. Fresh concrete shall be protected from contact with rain or snow.

The temperature of formwork, steel reinforcement, or any other material on which the concrete is to be placed shall not exceed 30 °C.

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

Ice and snow shall be removed from the area where concrete is to be placed. Deicing chemicals shall not be used. Concrete shall not be placed on or against frozen ground. Excavations prepared for concreting and any existing concrete, steel reinforcement, structural steel, forms, or other surfaces against which concrete shall be placed shall be at a minimum temperature of 5 °C for a period of 12 hours prior to commencement of placing concrete.

904.07.05.03 Concrete in Structure and in Deck

Concrete diaphragms shall be placed monolithically with the deck.

All bridge deck placements 3 m or wider shall be finished using a finishing machine and a work bridge. Where placements are longer than 40 m or wider than 10 m, a second work bridge shall be used. For deck placements narrower than 3 m, the Contractor shall submit a proposal detailing a method of finishing to the Contract Administrator for approval. Small localized areas may be hand finished subject to approval by the Contract Administrator.

Where the superstructure is continuous over a support, the screed rails shall be placed for the entire length of the structure prior to any concrete is placed.

A dry run shall be carried out in the presence of the Contract Administrator to ensure that the specified camber, crown, slab thickness, and concrete cover are achieved. In those areas of the deck where a finishing machine will be used to finish the concrete, the dry run shall be carried out by means of the finishing machine fitted with an attachment suitable for checking the required cover, securely fastened to the finishing machine strike-off with the strike-off set in its lowest position. This operation shall be repeated to cover the entire area to be concreted.

For HPC and silica fume overlay, at the time of the dry run the Contractor shall demonstrate that the performance of the fog misting equipment meets the specified requirements.

Screed rails and the supports for the screed rails shall not be removed until the concrete has hardened sufficiently to withstand the weight of workers and equipment used to remove them without marring the surface of the concrete. Any part of the screed rail supports that remain in the deck shall have 100 mm of concrete cover. Chairs used to support screed rails shall not be welded to structural steel but may be welded to shear connectors.

The holes in the deck resulting from removal of the screed rail supports shall be thoroughly cleaned of all deleterious material and abrasive blast cleaned immediately prior to filling with proprietary patching material. The work of cleaning and filling the holes shall be completed within 96 hours after the end of the deck curing period.

904.07.05.04 Tremie Concrete

Concrete shall be placed using a tremie or concrete pump. No air or water pockets shall be introduced into the tremie concrete by the placing equipment.

Pipe of a tremie or hose of a concrete pump shall be positioned vertical and shall be long enough to reach the lowest point of concrete deposit. A continuous flow of concrete at a minimum rate of 15 m³/h shall be maintained through the pipe or hose. The concrete shall be placed in its final position and to its full depth in a continuous placing operation without interruption. The top under water surface of the concrete shall be kept level during concrete placement. After placement, the concrete shall not be disturbed, puddled, or vibrated. Tremies or concrete pumps shall be located a maximum distance of 5 m apart and a maximum of 2.5 m from forms.

Concrete shall only be placed in water that has a temperature of 2 °C or greater. The velocity of water flow inside the forms shall not be more than 3 m/min.

When placing the tremie pipe or concrete pump hose and at the start of the concreting operation, the pipe or hose shall be sealed at the bottom to prevent ingress of water. Once concrete is flowing through the pipe or hose, the discharge end shall be kept continuously immersed in the freshly placed concrete. If the seal is lost, thereby allowing the pipe or hose to fill with water, the pipe or hose shall be withdrawn, the seal re-established, and the concreting operation restarted. Separate cranes shall be used to deliver the tremie concrete and to move and position the tremie or concrete pump.

Tremie concrete shall not be placed above the existing water level.

When a placement operation is interrupted below water level, the surface laitance shall be removed to expose the coarse aggregate within 36 hours after the interruption and prior to continuation of the operation.

When a placement operation is completed, and work is to continue in the dry, a construction joint shall be prepared by removing surface laitance to expose the coarse aggregate.

Unwatering shall not be permitted until at least 24 hours after the concrete placement is completed.

904.07.06 Consolidation

Internal or external vibrators or both shall be used to thoroughly consolidate concrete at the point of deposit within 15 minutes of placement.

Each layer of concrete shall be vibrated. Vibrators shall extend into the previous layer to produce a homogenous mixture at the layer interface.

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

904.07.07 Concrete Finishing

Finishing of the concrete surface shall be done immediately following placement.

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

The surface shall be smooth, free from open texturing, undulations, projections, and ridges and shall be struck off true to grade and cross-section and, except as specified for bridge deck placements, shall be hand finished with a float.

Bridge decks shall be finished according to the Concrete in Structure and in Deck clause. In addition, for bridge decks where the concrete forms the wearing surface, the surface shall be textured. After a tight, uniform surface has been achieved, texturing shall be done with a wire broom or comb having a single row of tines. The required texture shall be transverse grooves that may vary from 1.5 mm width at 15 mm centres to 4.5 mm width at 20 mm centres with a groove depth varying from 3.0 to 4.5 mm. The texture shall extend uniformly to within 150 to 300 mm of the curb.

Bearing seats and expansion joint dams shall receive a wooden float finish. The top surface of sidewalks and curbs shall be given a broomed finish.

Concrete surfaces against which new concrete is to be placed shall be left with a rough surface finish.

904.07.08 Curing

904.07.08.01 General

Curing shall be applied immediately after finishing the concrete surface. For continuing operations, such as barrier wall or sidewalk, the curing shall be applied within 2 to 4 m of the finishing operation, and for bridge decks, within 2 to 4 m of the pan or screed of the finishing machine.

Any concrete containing silica fume shall be cured according to the HPC curing requirements.

The curing period shall be a minimum of seven Days for concrete subject to cold weather, concrete cured with curing compound, and HPC. For all other concrete, the curing period shall be a minimum of four Days.

When the ambient air temperature is 0 °C or higher at the time of placing, components of structures shall be cured with burlap and water, except as specified in the Curing Formed Surfaces clause. When the ambient air temperature is below 0 °C at the time of placing, components shall be cured with moisture vapour barrier, except for HPC, which shall be moist cured with burlap and water, regardless of ambient air temperature. During cold weather, burlap shall be prevented from freezing.

Curing compound shall only be permitted for non-structural elements such as slope paving and shall not be used when cold weather concreting is in effect.

Where waterproofing is to be applied to a structure deck following curing with burlap and water or moisture vapour barrier, the deck shall be air cured for at least 72 hours prior to the application of waterproofing.

904.07.08.02 Fog Misting of High Performance Concrete

Fog misting for high performance concrete shall be provided by means of hand held fogging wands; a fogging system mounted on the finishing machine may be used, in addition to hand held fogging wands.

Fog mist shall be applied from the time HPC is deposited in the deck, approach slab, median, curb, or sidewalk until it is covered with burlap.

Fog mist shall be applied using a misting nozzle in such a way as to maintain a fog mist above the concrete surface to maintain high relative humidity above the concrete and prevent drying of the concrete. No accumulation of water shall be permitted on the concrete surface. Water from fog misting nozzles shall not be worked into the concrete surface or used as a finishing aid.

904.07.08.03 Curing with Burlap and Water

Burlap shall be pre-soaked by immersing it in water for a period of at least 24 hours immediately prior to placing. Two layers of burlap shall be applied to the surface of the concrete. Burlap strips shall overlap 150 mm and shall be held in place without marring the surface of the concrete.

The burlap shall be maintained in a continuously wet condition throughout the curing period by means of a soaker hose. The burlap shall be covered with a layer of moisture vapour barrier within 12 hours of placing of the concrete in a manner that shall prevent deformation of the surface of the concrete.

Air flow in the space between the moisture vapour barrier and the burlap shall be prevented.

Water shall not be allowed to drip, flow, or puddle on the concrete surface when placing the burlap or at any time prior to the concrete has achieved final set.

904.07.08.04 Curing with Moisture Vapour Barrier

Air flow in the space between the moisture vapour barrier and the concrete surface shall be prevented. The moisture vapour barrier strips shall overlap 150 mm and shall be held in place at the edges and laps to prevent displacement without marring the surface of the concrete.

904.07.08.05 Curing with Curing Compound

Immediately prior to application, the curing compound shall be agitated by mechanical means to provide a homogeneous mixture. It shall be applied to completely cover the surface of the concrete. A second application of curing compound shall be applied within 30 to 60 minutes after the first application. Each application shall be such that the membrane formed is uniform in thickness and colour and free of breaks and pinholes.

The rate of each application shall not be less than the rate specified by the manufacturer of the compound.

904.07.08.05.01 Curing Compound Sampling

The Contractor shall be responsible for sampling of curing compounds and handling, identification, and delivery of curing compound samples to Regional Quality Assurance Laboratory for Quality Assurance testing. Curing compounds shall be sampled at the site from the spray nozzle during application. Samples shall be taken at a frequency of one sample per Contract or one sample per 1,000 lineal meters, whichever provides the greater number of samples.

904.07.08.06 Curing Formed Surfaces

Forms for structure barrier wall, parapet wall, and curb on deck shall be removed no later than 24 hours after concrete placement, and the concrete shall be cured according to the Curing with Burlap and Water clause for the remainder of the minimum curing period.

For all concrete other than HPC, when ambient air temperatures are 5 °C or less, forms for concrete barrier wall, parapet wall, and curb on deck may be left in place for the duration of the curing period.

Other formed surfaces shall require no additional curing where the formwork is left in place for the minimum specified curing period. Where the formwork is removed prior to the curing period is completed, formed surfaces shall be cured with burlap and water according to the Curing with Burlap and Water clause for the remainder of the minimum curing period.

904.07.09 Control of Temperature and Temperature Difference

904.07.09.01 General

During the curing period, the concrete temperature shall not fall below 10 °C or exceed 70 °C. The temperature difference between the centre of the concrete component at a location where the concrete is expected to reach the highest temperature and the surface shall not exceed 20 °C, for:

- a) All bridge decks.
- b) HPC.
- c) Large concrete components where the smallest dimension is 1.5 m.
- d) Any concrete subject to cold weather.

904.07.09.02 Monitoring

The Contractor shall monitor, record, and submit records for the concrete and ambient air temperature for:

- a) All bridge decks.
- b) HPC.
- c) Large concrete components where the smallest dimension is 1.5 m.
- d) Any concrete subject to cold weather.

The Contractor shall supply and install thermocouple wires and associated instrumentation with a combined accuracy of ± 1.5 °C capable of recording and displaying temperature. The instrumentation shall include data loggers capable of recording at hourly intervals or less and shall allow direct reading of temperature.

The thermocouples for concrete temperature measurement shall be installed as shown in Table 1 prior to placing concrete. Thermocouples for monitoring ambient air temperature shall be installed in the shade close to the surface of the concrete at a minimum frequency of one thermocouple per stage.

Recording of concrete temperatures shall begin at the start of placement. The temperature shall be recorded automatically at intervals no greater than one hour until the end of the monitoring period. The monitoring period shall be seven Days, or longer when necessary, in order to meet the requirements of the Withdrawal of Protection clause. The digital temperature indicators shall be left in place until the end of the monitoring period.

The Contractor shall also physically monitor and verify concrete and ambient air temperature readings every six hours, or more frequently, for the first three Days and every 12 hours for the remainder of the monitoring period. The Contractor shall take necessary action to maintain the temperature within the specified limits.

The Contract Administrator shall be provided access to verify temperature readings. If the datalogger does not have a digital display that allows the Contract Administrator to verify temperature, the Contractor shall provide the Contract Administrator with the necessary instruments to allow the Contract Administrator to verify thermocouple function and readings.

The Contractor shall prepare a record of temperatures for each Day during the temperature monitoring period and at the end of the temperature monitoring period shall prepare complete temperature records, including graphical plot of temperature versus time.

904.07.09.02.01 Submission of Temperature Records

Datalogger temperature records and a record of any actions taken to maintain control of temperature and temperature difference shall be forwarded to the Contract Administrator at the end of each Business Day during the temperature monitoring period. At the end of the temperature monitoring period, the Contractor shall submit to the Contract Administrator a complete temperature record.

904.07.09.03 Concrete Subject to Cold Weather

For concrete subject to cold weather, a protection system shall be designed for the worst conditions that can be reasonably anticipated from local weather records, forecasts, site conditions, and past experience for the time period during which the protection is required. The conditions shall be monitored and the protection system modified as required.

For cold weather conditions, minimum protection of concrete shall be as shown in Table 2 and shall be maintained for the duration of the curing period. This period may need to be extended in order to meet the requirement of the Withdrawal of Protection clause.

904.07.09.03.01 Housing and Heating

The design of the protective housing shall take into account the effects of construction activities such as placing concrete, stressing, and grouting. Heating equipment of sufficient capacity to establish and maintain the specified curing conditions shall be used throughout the curing period and for such time thereafter, as is necessary, for the completion of the work. Heating equipment used within the housing shall be vented outside the housing. Heating equipment having an open flame shall not be permitted.

The ambient air temperature adjacent to the concrete or formwork within the housing shall not be permitted to vary by more than 8 °C.

904.07.09.04 Withdrawal of Protection

For concrete subject to cold weather and for large concrete components where the smallest dimension is 1.5 m, the protection shall be gradually removed or reduced in such a manner that the maximum allowable drop of concrete temperature, as shown in Table 3, for each 24-hour period is not exceeded.

The protection shall not be totally removed, nor shall the concrete be fully exposed to the air until the average concrete temperature is within 10 °C of the ambient air temperature.

904.07.10 Removal of Formwork and Falsework

The removal of formwork and falsework shall be according to OPSS 919 and as specified in the Contract Documents.

904.07.11 Construction Joints

Construction joints shall be formed at the locations specified in the Contract Documents.

In addition, construction joints can be formed where control joints are specified in barrier walls and parapet walls. No other construction joints shall be permitted, unless approved in advance by the Contract Administrator.

A straight 20 mm V-groove shall be formed at the exposed face of the concrete at all construction joints. V-grooves shall not be used on bridge deck surfaces, except for the bottom slab of post tensioned box voided slabs.

A bulkhead shall be used to form vertical or inclined construction joints.

904.07.12 Surface Finish

904.07.12.01 General

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

Within 3 Days following the removal of forms or curing materials, all holes left in the concrete surface with any dimension greater than 15 mm and less than 50 mm shall be filled with mortar or a proprietary patching material. The holes shall be moist at the time of filling. Mortar shall be tamped into place. Proprietary patching materials shall be placed according to the manufacturer's instructions.

Surfaces with cavities with any dimension greater than 50 mm or with honeycombing are considered deficient and shall be repaired. A repair proposal shall be submitted to the Contract Administrator for approval.

904.07.12.02 Exposed Surfaces

The appearance of the concrete shall be uniform in colour, pattern, and texture when viewed from a distance of 15 m. Care shall be taken to select material, including proprietary patching materials, to achieve uniformity of colour and appearance.

All projections, such as fins and bulges, and all blemishes, such as stains and rust marks shall be removed.

904.07.12.03 Surface Tolerance

Formed and unformed surfaces shall be such that when tested with a 3 m long straight edge placed anywhere in any direction on the surface, there shall be no gap greater than 6 mm between the bottom of the straight edge and the surface of the concrete. When the straight edge is placed across a construction joint, the gap between the straight edge and the surface of the concrete shall not be greater than 3 mm.

All unformed construction joint surfaces against which sidewalks, curbs, medians, and barrier walls are to be placed shall be such that when tested with a 500 mm straight edge placed anywhere in any direction on the surface, there is no gap greater than 20 mm between the bottom of the straight edge and the surface of the concrete.

904.07.12.04 Contamination of Surface

Contamination by oil or other deleterious substances shall be prevented. Contaminated concrete in bridge decks or against which new concrete is to be placed shall be removed according to OPSS 928, procedure for Concrete Removal-Partial Depth, Type A, B, and C.

904.07.13 Alignment of Components

The position of the inner and outer top edges of structural components shall be set true to the elevations, alignment, and camber as specified in the Contract Documents without visible deviation from one end of the structure to the other. All concrete items or structural components shall be constructed to the specified geometry.

Variations from plumb or a specified slope shall not exceed 1H:400V. Departure from specified alignment shall not exceed ± 25 mm.

904.07.14 Testing for Early Strength

The Contractor may elect to prepare sets of cylinders for early strength determination in addition to the cylinders required for determination of strength at 28 Days.

The Contractor shall be responsible for all aspects of the preparation, storing, and transportation of cylinders for early strength determination. Curing of cylinders for early strength determination shall consist of storing the cylinders in or on the structure as near as possible to the component that they represent. The cylinders shall receive the same protection from the elements on all surfaces as is given to the portions of the structure that they represent. The Contractor shall identify the time of testing for early-break cylinders and provide the Contract Administrator with one Business Day advance notice to arrange testing. The Contractor shall deliver cylinders for early strength determination immediately prior to the time of testing. The Owner shall test a reasonable number of cylinders for early strength determination at the laboratory designated in the Contract Documents.

Early strength determination of concrete in post-tensioned structures shall be carried out on a minimum of four sets of cylinders representative of the concrete placed in the structure. At least one set of cylinders from the start, middle, and end of the deck section being placed shall be cast. All cylinder test results shall reach the minimum stressing strength as specified in the Contract Documents prior to stressing can commence.

904.07.15 Early Loading of Structural 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 is permitted, unless expressly stated otherwise in the Contract Documents, 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 by preparing, curing, and transporting early strength cylinders according to the Testing for Early Strength subsection.
- b) Subsequent placement of reinforcement, formwork and falsework on a footing, culvert base slab, or caisson shall not begin until at least 24 hours after concrete placement, provided that concrete in the footing, culvert base slab, and caisson can withstand the forces exerted. Placement of concrete on the footing, culvert base slab, or caisson shall not be carried out until the concrete has reached a compressive strength of 20 MPa.
- c) Subsequent placement of reinforcement, formwork, falsework, and concrete on all other structural components shall not be carried out until the concrete has reached a compressive strength of 20 MPa.
- d) Early loading of concrete is not permitted where cold weather protection is required.
- e) Construction vehicles shall not be permitted on bridge decks until the concrete has reached a compressive strength of 20 MPa and construction vehicles shall not be permitted on the cantilever portion of the bridge deck until the specified 28-Day compressive strength has been achieved. Gross vehicle weight of the construction vehicles shall not exceed 20,000 kg.
- f) Full curing is to be maintained at all times as specified in the Contract Documents.

904.07.16 Cracks in Formed and Unformed Surfaces

All concrete shall be inspected to identify and document any cracks including, their location, width, and density. The results of the inspection shall be reported to the Contract Administrator. Cracks shall be inspected and monitored up to the date of Completion of the Work.

Based on criteria as shown in Table 4, the limits of areas requiring repair or replacement and shall be identified and provided to the Contract Administrator along with a proposal for remedial action to be taken. No repairs shall proceed until the proposal has been accepted by the Contract Administrator in writing.

Repairs shall be according to OPSS 932. Where removal is required, the removals and preparation of concrete shall be according to OPSS 928 and OPSS 930.

For bridge decks to be waterproofed, the inspection of the surface to be waterproofed shall be carried out after completion of curing and prior to application of tack coat for waterproofing. Waterproofing of a bridge deck shall not proceed until repairs have been completed and permission to waterproof has been given by the Contract Administrator.

For all other concrete, the inspection shall be carried out in a timely manner, but no later than one month following completion of curing.

904.07.17 Concrete Cover

All debris and obstructions shall be cleared to provide unhindered access to allow the Contract Administrator to carry out the concrete covermeter survey as specified in the Concrete Cover subsection of the Quality Assurance section. The Contract Administrator shall be notified in writing when the test area is ready for the concrete covermeter survey.

The Contract Administrator shall be allowed a time period of three Business Days to complete the survey, including review of the survey by the Owner. This time period shall commence upon receipt of the Contractor's written notification to carry out the survey. The time period required to complete the concrete survey shall be extended if inclement weather or the ambient air temperatures below 5 °C fall within that time period.

Where the cover does not meet the requirements as specified in the Contract Documents, a proposal for remedial action shall be submitted to the Contract Administrator for approval.

Waterproofing of a bridge deck shall not proceed until the survey has been completed and permission to waterproof has been given by the Contract Administrator.

For all other components, the inspection of the surface shall be carried out in a timely manner, not more than one month after removal of curing.

904.07.18 Management of Excess Material

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

904.08 QUALITY ASSURANCE

904.08.01 Acceptance

Acceptance shall be according to OPSS 1350 and this specification, including satisfactory completion of all remedial action associated with surface tolerance, surface finish, concrete cover, alignment, cracks, and any other deficiencies.

904.08.02 Concrete Cover

The concrete cover shall meet the requirements as specified in the Contract Documents. Concrete cover determination shall be carried out by the Contract Administrator on the front faces of barrier or parapet walls, and the top surface of decks, including medians and sidewalks. The Contract Administrator shall provide the survey report to the Contractor.

904.08.03 Approach Slab Seat and Ballast Wall Elastomers

The Contract Administrator shall select a random sample of the approach slab seat and ballast wall elastomers, 600 mm in length each, from each structure for testing.

Elastomers that do not meet the requirements as specified in the Contract Documents shall be considered unacceptable and a financial penalty shall be applied.

904.08.04 Curing Compounds

Curing compounds shall be tested for relative density, non-volatile content, and settlement according to LS-413, LS-414, and LS-416. The individual test results shall be forwarded to the Contractor as they become available.

Curing compound that fails to fall within the specified tolerances for relative density, non-volatile content, or settlement shall be deemed unacceptable and curing compound represented by samples that do not comply with the requirements of this specification shall not be used for curing of concrete.

904.09 MEASUREMENT FOR PAYMENT

904.09.01 General

No deductions from the volume of concrete shall be made for any of the following:

- a) Drainage openings, load reducing devices, embedded timbers, and Utility and prestressing steel ducts, each of which has a cross-sectional area of less than 0.1 m².
- b) Timber, steel, concrete, or concrete filled tubular piles.
- c) Steel reinforcement, miscellaneous hardware, and structural steel.

904.09.02 Actual Measurement

**904.09.02.01 Concrete in Culverts
Mass Concrete
Tremie Concrete
Concrete in Footings
Concrete in Barrier Wall Footings**

Measurement of concrete shall be by volume in cubic metres.

Measurement shall be made within the designated limits of the work.

Tremie concrete volume may be measured using the concrete delivery tickets, when so designated by the Contract Administrator.

904.09.03 Plan Quantity Measurement

When measurement is by Plan Quantity, such measurement shall be based on the units shown in the clauses under Actual Measurement.

904.10 BASIS OF PAYMENT

**904.10.01 Concrete in Culverts - Item
Mass Concrete - Item
Tremie Concrete - Item
Concrete in Footings - Item
Concrete in Barrier Wall Footings - Item
Concrete in Structure - Item
Concrete in Substructure - Item
Concrete in Substructure and Retaining Walls - Item
Concrete in Deck - Item
Concrete in Barrier Walls - Item
Concrete in Parapet Walls - Item
Concrete in Approach Slab - Item
Concrete in Slope Paving - Item
Concrete in Toe Wall - Item
Prestressed Concrete Bridge Deck - Item**

High Performance Concrete in Substructure - Item
High Performance Concrete in Structure - Item
High Performance Concrete in Approach Slab - Item
High Performance Concrete in Deck - Item
High Performance Concrete in Barrier Walls - Item
High Performance Concrete in Parapet Walls - Item
High Performance Concrete in Substructure and Retaining Walls - Item

Payment at the Contract price for the concrete tender items shall be full compensation for all labour, Equipment, and Material to do the work, subject to payment adjustments as specified in the Contract Documents.

Surface cavities greater than 50 mm and honeycombing shall be repaired at no additional cost to the Owner.

904.10.02 Formwork and Falsework

Payment for formwork and falsework shall be included in the work in which it is used.

Where formwork is required for the work under a concrete tender item, it shall be deemed for progress payment purposes that the formwork, together with its supporting falsework, when installed, constitutes 35% of the work to be carried out under the tender item.

Partial payment for construction of the formwork and falsework shall be made on a prorated basis.

904.10.03 Working Slabs

When a concrete working slab is required by the Contract Administrator, payment shall be made as a Change in the Work at the unit price of the concrete in the footing to be placed on it.

904.10.04 Deck Joint Assemblies, Bearings, and Deck Drains

When the Contract does not contain a separate tender item for deck joint assemblies, bearings, and deck drains, the Contract price for the concrete tender items in which the deck joint assemblies, bearings, and deck drains are incorporated shall include full compensation for all labour, Equipment, and Material to place the deck joint assemblies, bearings, and deck drains.

904.10.05 Reinforcing Steel Bars, or Stainless Steel Reinforcing Bars

When the Contract does not contain a separate tender item for reinforcing steel bar or stainless steel reinforcing bar, the Contract price for the concrete tender item in which the steel reinforcement is incorporated shall include full compensation for all labour, Equipment, and Material to place the reinforcing steel bars or stainless steel reinforcing bars.

TABLE 1
Minimum Number of Thermocouple Sets for Concrete Temperature Measurement

	Concrete Elements Requiring Temperature Monitoring	Number of Thermocouple Sets in Each Element	Number of Thermocouples in Each Set	Thermocouple Set Locations
Cold Weather Protection	Each concrete element.	Minimum of 3 per element or stages thereof.	2	At locations where the concrete is expected to reach the highest temperature and at the surface of concrete.
Bridge Decks	All.	a) Minimum of 3 per stage, or per deck if deck is not placed in stages. b) When diaphragm is cast together with a deck, a minimum of 4 per stage.	3	The beginning, middle, and final portion of the deck placement and in the diaphragm. At locations where the concrete is expected to reach the highest temperature and at the surfaces of concrete. (Note 1)
HPC	Substructure elements: abutments, pier columns, and pier caps.	Minimum of 3 per element or stages thereof.	2	At locations where the concrete is expected to reach the highest temperature and at the surface of concrete.
Large Concrete Components Where the Smallest Dimension is 1.5 m	Elements with smallest dimension of 1.5 m or more.	Minimum of 3 per element or stages thereof.	2	At locations where the concrete is expected to reach the highest temperature and at the surface of concrete.

Notes:

1. For bridge decks, thermocouples shall be installed in sets of three consisting of one mid-depth thermocouple and two surface thermocouples. The surface thermocouples shall be placed immediately above or the shortest distance from the corresponding mid-depth thermocouple. The surface thermocouples shall be installed beneath the burlap in contact with the surface concrete or imbedded in the concrete within 5 mm of the surface and, for bridge decks, the second surface thermocouple shall be placed inside the bottom form.

TABLE 2
Minimum Cold Weather Protective Measures

Footings and Slabs on the Ground				
Anticipated Minimum Ambient Air Temperature °C	Thickness			
	> 1.0 m	1.0 - 0.5 m	< 0.5 - 0.25 m	< 0.25 m
+5 to 0	PM1	PM1	PM1	PM2
-1 to -10	PM2	PM2	PM2	PM3
-11 to -20	PM3	PM3	PM4	PM5
Less Than -20	PM3	PM4	PM5	PM5
All Other Components				
+5 to 0	PM1	PM1	PM1	PM2
-1 to -10	PM2	PM2	PM3	PM4
-11 to -20	PM3	PM3	PM4	PM5
Less Than -20	PM4	PM5	PM5	PM5
Notes:				
A. Protective Measures				
PM1 - Cover components with a moisture vapour barrier as specified for curing with moisture vapour barrier.				
PM2 - Cover components as for PM1, then cover the moisture vapour barrier with insulation having an R-Value of 0.67.				
PM3 - Cover components as for PM1, then cover the moisture vapour barrier with insulation having an R-Value of 1.33.				
PM4 - Cover components as for PM1, then cover the moisture vapour barrier with insulation having an R-Value of 2.00.				
PM5 - Housing and heating.				
B. All R-Values are metric.				
C. The conversion factor from metric to imperial units is:				
Metric R-Value x 5.678 = Imperial R-Value.				

TABLE 3
Maximum Allowable Drop in Concrete Temperature

Thickness	> 2.0 m	1.0 - 1.99 m	< 1.0 m
Maximum Allowable Drop in Concrete Temperature per 24 hours	10 °C	15 °C	20 °C

TABLE 4
Criteria for Treatment of Cracks

Components	Width of Crack at Widest Point mm	Treatment of Cracked Areas
Decks to be Waterproofed and Paved	≥ 0.50	Repair.
Exposed Decks	> 0.30	Repair cracks in the areas where total linear measurement of crack per m ² is < 5 m. Remove and replace the cracked areas where total linear measurement of crack per m ² is ≥ 5 m.
	≤ 0.30	Apply sealer acceptable to the ministry to cracked areas where total linear measurement of crack per m ² is ≥ 5 m.
Barrier Wall, Parapet Wall, Sidewalk, and Median on a Structure	> 0.30	Repair cracks in the areas where the total linear measurement of crack per linear meter of the wall, sidewalk or median measured along the side facing traffic is < 5 m. Remove and replace the cracked areas where the total linear measurement of crack per lineal meter of the wall, sidewalk, or median measured along the side facing traffic is ≥ 5 m.
	≤ 0.30	Apply sealer acceptable to the ministry to cracked areas where total linear measurement of crack per m ² is ≥ 5 m.
Curb on a Structure	> 0.30	Repair cracks in the areas where the total linear measurement of crack per linear meter of the curb is < 1.5 m. Remove and replace the cracked areas where the total linear measurement of crack per linear meter of the curb is ≥ 1.5 m.
Piers, Pier Caps, Abutments, and Other Structural Components Within 3 m of Roadway	> 0.30	Repair.
	≤ 0.30	Apply sealer acceptable to the ministry to cracked areas where total linear measurement of crack per m ² is ≥ 5 m.
All Other Components	≥ 1.00	Repair.