

## SECTION 931

### CONCRETE – CONSTRUCTION

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**931.01 SCOPE**

This specification covers the Department's requirements for all concrete placement, finishing, curing and repairs. All work and equipment shall be in strict accordance with CSA A23.1 and CSA A23.2.

**931.02 REFERENCES**

Reference standards shall be the latest revision at the date of Tender closing. This specification refers to the following standards, specifications or publication:

- ACI 306 “Guide to Cold Weather Concreting”
- ACI 305 “Guide to Hot Weather Concreting”
- CSA A23.1 “Concrete materials and methods of concrete construction”
- CSA A23.2 “Test methods and standard practices for concrete”
- CSA A23.3 “Design of concrete structures”
- CSA A23.4 “Precast concrete – Materials and Production”
- CSA S6 “Canadian Highway Bridge Design Code”
- Portland Cement Association “Design and Control of Concrete Mixtures”
- International Concrete Repair Institute Technical Guideline 310.2R

### **931.03 DEFINITIONS**

**Cold Joint:** An unplanned weakened plane or joint caused from premature set, excessive drying or improper consolidation between successive concrete lifts during a concrete placement.

**Cold Weather Concreting:** When the air temperature is at or below 5°C or when, according to meteorological forecasts, it is likely to fall below this limit within the next 24 hours, then the Contractor shall take special precautions to protect the concrete placed. This is defined as “Cold Weather Concreting”.

**Construction Joint:** A planned separation between two bridge elements and/or a deliberate divide within a single concrete element to promote ease of construction or for thermal control reasons. These joints can be horizontal, vertical or on a prescribed angle.

**Control or Contraction Joint:** A contraction joint is a sawed, formed, or tooled groove in a concrete element that creates a weakened plane to help control where a crack forms.

**Engineer of Record:** The Professional Engineer who completed and sealed the design of the specific component or system.

**High Performance Concrete (HPC):** Concrete that meets performance requirements (increase strength and durability) that cannot always be achieved routinely by using conventional materials and normal placing and curing practices.

**Hot Weather Concreting:** When the air temperature is at or above 27°C or when, according to meteorological forecasts, is expected to rise above this limit then special measures shall be taken by the Contractor to protect the concrete. Surface moisture evaporation must not exceed 0.50kg/m<sup>2</sup>/hr

**Infill Concrete:** A body of concrete used to fill in an excavated area or void space with dimensions large enough (thickness > 1m) for which consideration is given to temperature rise caused by the hydration of cement in order to keep cracking to a minimum.

**Owner's Representative:** An applicable Government employee responsible for the project or any Third Party who has been authorized by the Department to conduct work on the Department's behalf.

**Professional Engineer:** An individual who is registered and in good standing with PEGNL.

**Tremie Concrete:** Concrete deposited underwater through a pipe or tube fitted with a hopper at its upper end.

## 931.04 CONCRETE OPERATIONS

### 931.04.01 Planning & Submittals

#### 931.04.01.01 Concrete Placement Plan

At least four (4) weeks prior to the scheduled start date of any major concrete placement, the Contractor shall submit a concrete placement plan to the Owner's Representative. The Contractor shall allow two (2) weeks for the Department's review and five (5) business days for any subsequent review of the plan. Components requiring a Concrete Placement Plan are:

- All HPC
- Footings
- Abutments & Wingwalls
- Girders
- Retaining Walls
- Bridge decks
- Structural Precast

The Concrete Placement Plan shall include but is not limited to:

- Unique mixture design code of approved concrete mixture design.
- Concrete supply and delivery schedule, including number of dedicated trucks for mixing and delivery.
- Plan to deal with adverse weather conditions during placement and curing.
- Personnel identification including roles and responsibilities.
- Proof of Journeypersons Concrete Finisher status, where applicable for finishing large slabs. In lieu of Proof of a Journeyperson Concrete Finisher status, the

Department will accept a Concrete Finisher with a minimum of 5 years experience on previous Transportation & Infrastructure projects. A proof of proficiency listing all qualifications and previous projects must be submitted and signed by their employer attesting to the validity of the information provided.

- List of available tools and equipment on site, including backups.
- Pump truck manufacturer's specifications detailing pumping capacity and pressure at the required elevations.
- Plainview layout of pump truck setup (if being used and if multiple setups are required) to show reach limits within the pour.
- Concrete placing backup plan. This shall include but not be limited to what will happen in cases of pump truck breakdown, safety incident, unexpected stoppage that will permanently stop the pour, etc.
- Thermal Control Plan (if required). See 931.04.01.02.
- The use of retarders in various concrete trucks to maintain a "live" edge (if required).
- Plan for placement depths greater than 1500 mm.
- Plan to consolidate difficult areas (under embedment plates/around box girders etc).
- Plan to provide safe and necessary access to adequately consolidate all areas of the concrete placement.
- Plan for access once concrete consolidation has occurred. Rebar and other embedded items shall not be disturbed by walking, finishing machines or other means.
- Plan to prevent concrete surface drying/shrinkage cracking during the pour.
- Plan to finish the concrete as required by the drawings and specifications.
- Plan to prepare the concrete joint post concrete placement i.e. green cutting or sandblasting.
- Temperature Control Plan post-concrete placement (if required).
- Plan to cure the concrete surface.

A pre-pour concrete meeting shall be held prior to any major concrete placement to discuss all aspects of the concrete pour plan. This meeting is to be called by the Owner's Representative; the Contractor and all others deemed necessary shall be in attendance. The Contractor shall conduct a trial run, 48 hours prior to placing concrete, to verify their equipment, methods and workmanship to meet the specifications. The Owners Representative shall be advised 48 hours in advance of the trial run.

The Contractor shall provide at least 48 hours notice (not including Saturday, Sundays, or holidays) of their intention to place concrete. Failure to notify DTI will result in rejection

of any concrete produced and placed and no payment shall be made. Third party testing results will not be accepted in place of Department QA. Before concrete is placed, forms, reinforcement, foundations, granular bases, placing procedures and materials must comply with the project specifications and CSA A23.1.

### **931.04.01.02 Thermal Control Plan**

At least four (4) weeks prior to the scheduled start date of any major concrete placement, the Contractor shall submit a Thermal Control Plan to the Owner's Representative. The Contractor shall allow two (2) weeks for the Department's review and five (5) business days for any subsequent review of the plan. Components requiring a Thermal Control Plan are:

- All concrete that may be negatively impacted by undesirable thermal stresses
- HPC
- Girders
- Footings, Abutments & Bridge Decks
- Retaining Walls & Wingwalls
- Infill Concrete

Adequate protection of concrete shall be provided that will maintain the concrete temperature at a minimum of 10°C, a maximum of 70°C and respect the concrete temperature differentials in Table 1.0 for the duration of the required curing period. CSA A23.1 provides further guidance on developing a thermal control plan for various concrete placements.

The Temperature Control Plan shall include the following but is not limited to:

- Concrete element for which the plan applies.
- Any modification to the mixing process for temperature control purposes.
- Type of cold weather protection to be provided as per 931.08.02 (if applicable).
- Temperature Monitoring System:
  - Temperatures shall be monitored using thermocouples at:
    - Centre of mass of each placement.
    - Top of the concrete element, located 50 mm from the surface.
    - Mid-point of an exterior corner, located 50 mm from the surface.
    - Ambient air temperature to provide a representative sample of the area and to the satisfaction of the Owner's Representative.
  - Temperature Data Logger(s) shall have the following minimum requirements:

- i. Record the temperature, time and date at the specified locations above.
- ii. High quality wires and thermocouples, recommended by the manufacturer of the data logger, and rated for the anticipated temperature range. Calibration records prior to installation shall be provided to the Owners Representative.
- iii. Have at least four (4) recording channels or provide sufficient recorders to capture the required data.
- iv. Provide a data point on each channel every 15 minutes or approved equal.
- v. All temperatures must be accurate within  $\pm 1^{\circ}\text{C}$ .
- vi. Real time digital displays of the temperatures on each channel with at least 3 significant figures i.e.  $13.2^{\circ}\text{C}$ .
- vii. Capabilities to provide temperature vs time graphs of each channel once downloaded to a computer and as per 931.04.01.02.01.
- Type of insulation and/or tarpaulins R value, and number of layers, if utilized.
- Type and layout of heaters, if utilized, by the Contractor.
- A plan to ensure concrete temperature differentials are maintained for the duration of the protection period as per Table 1.0 below. Differentials shall include but not be limited to the comparison of temperatures at various locations in a concrete element, such as, center and the surface, surface and the ambient, etc. It shall also include the Contractor's plan to complete corrective actions as identified by the Owner's Representative (if required).

**TABLE 1.0**

	Maximum permissible temperature differential, surface to ambient – wind up to 25 km/h $^{\circ}\text{C}$ ‡				
	Length-to-height ratio of structural elements*				
Thickness of concrete (m)	0†	3	5	7	20 or more
< 0.3	29	22	19	17	12
0.6	22	18	16	15	12
0.9	18	16	15	14	12
1.2	17	15	14	13	12
> 1.5	16	14	13	13	12

\*Length shall be the longer restrained dimension and the height shall be considered the unrestrained dimension.

†Very high, narrow structural elements such as columns.

**# For high performance concrete, the maximum temperature differential for all structural components shall be 20°C.**

Note: See also Figure D.2 of CSA A23.1

- How the temperature of the concrete shall be gradually reduced, respecting the permissible temperature differentials as specified in Tables 3.0 and 4.0.
- Protection shall be gradually removed or reduced in such a manner that the maximum allowable drop of concrete temperature, as shown in Table 2.0 below, 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.

**TABLE 2.0**

Thickness	> 2.0 m	1 – 1.99 m	< 1.0 m
Maximum Allowable Drop in Concrete Temperature per 24 hours	10 °C	15 °C	20 °C

- Other applicable information as required by the Owner's Representative.

#### **931.04.01.02.01 Contractor Temperature Monitoring**

The Contractor shall continuously monitor the data loggers until there is no risk of the concrete exceeding the allowable temperature differentials. The Contractor shall take necessary action to maintain the temperature within the specified limits and remediate items identified by internal checks or the Owner's Representative immediately upon discovery.

The Contractor shall prepare a basic daily checklist, at a minimum it shall include the following information:

- Name of element curing, date poured, current date.
- Times of the daily checks and temperatures at the time.
- Comments on if temperatures were within requirements.

At the end of the temperature monitoring period the Contractor shall compile the following information for submission to the Owner's Representative:

- Project title, location, name of element curing, date poured, date temperature monitoring ended.

- Location of monitoring points within the placement on a project drawing.
- All daily temperatures including calculations of temperature differentials in accordance with Table 1.0 and 2.0.
- Temperature vs. Time Graphs of
  - i. All internal temperature recorded channels graphed individually with the ambient channel and the applicable differential as per Table 1.0.
- Raw data from the data loggers.

Digital displays must be available for visual verification by the Owner's Representative. The Owner's Representative shall be provided access to verify temperature readings at all times.

#### **931.04.01.03 Inspection Checklists**

The Contractor shall complete project specific checklists at project startup depending on the specific scope of work and submit the checklists to the Owner's Representative within two (2) weeks of project startup for review. All checklists shall be completed to the satisfaction of the Owner's Representative. The Owner's Representative shall be provided with five (5) business days for subsequent reviews required by resubmittals.

The Contractor shall ensure all inspection checklists are completed and submitted to the Owner's Representative for acceptance no later than 48 hours prior to concrete placement or as agreed with the Owner's Representative. If the work applicable to the checklist is not complete, is modified in anyway, has risk for rework or movement due to other activities, the Owner's Representative has the right to reject the work.

The Owner's Representative shall be provided access to verify the items within all checklists at all times.

Specific checklists and contents shall include but not be limited to the information provided in Section 932.

#### **931.04.02 Concrete Placement**

All work and tolerances shall confirm to CSA A23.1.

##### **931.04.02.01 General**

Concrete delivered to site must conform to the temperature requirements within 930.06.04.

The pumping of concrete from the delivery vehicle to its place of final deposition will be permitted as authorized by the Owner's Representative in accordance with Section 931.04.01.01. Aluminum pipelines shall not be used.

The use of long troughs, chutes and pipes for conveying from the mixer to the forms shall be permitted only on written authority of the Owner's Representative. In case an inferior quality of concrete is produced by the use of such conveyers, the Owner's Representative may order discontinuance.

Pump priming admixtures used to prime concrete pump truck lines shall not be deposited within the formwork.

Concrete shall be placed to avoid segregation, have no adverse effects on concrete properties or displace the reinforcement. Concrete should be placed at the lowest point first. Concrete shall be deposited within 1.5 m of its final position. Concrete shall not be placed with a free fall greater than 1500 mm. When the planned concrete placement is greater than 1500mm in depth, the Contractor shall provide temporary spacing(s) between reinforcing bars to lower the placement hose. The Contractor may attach a reduction hose to fit between the bars or use a small hopper attached to a lay-flat rubber hose to reach the bottom of the forms. All temporary openings shall be re-instated as per drawings prior to encasement in concrete.

When concrete is placed in a deep beam, a wall or a column, at the same time as the slab above, the vertical section, if deeper than 1.5 m, shall be poured first and a delay between one and three hours shall be left for the concrete to settle before pouring the slab above. After this delay, the concrete must still be plastic enough to allow a complete homogeneous mix with the slab concrete through re-vibration.

During wet weather, concrete must not be placed unless suitable means, approved by the Owner's Representative, has been provided to prevent washing of freshly deposited concrete or marring of the exposed surface.

In the event of an unanticipated heavy rainfall, all water shall be pushed ahead of the concrete and not vibrated in. The water shall be drained from a hole in the forms or pumped as deemed necessary by the Contractor or the Owners Representative.

If the concrete details are such that a feather edge or thin section might be created by the sequence of placing, a bulkhead shall be introduced to maintain an edge thickness of at least 100 mm.

An adequate supply of concrete must be supplied to ensure it is placed in a continuous manner. Concrete for all elements shall be deposited uniformly in complete layers or lifts at the height and at the speed as required by the formwork design. All subsequent layers shall be stitched together as per 931.04.02.04.

If concrete placement has been temporarily discontinued but the concrete has not reached initial set or is still plastic, the concrete surface shall be prevented from dehydration by misting or fogging. If the placing of concrete is discontinued or the concrete has reached initial set or is no longer plastic, the concrete surface shall be prepared in accordance with 931.04.04.

The Contractor shall notify the Owner's Representative immediately of any interruption resulting in a cold joint.

See 931.09 for specifics surrounding defects and repairs for bridge deck concrete.

#### **931.04.02.02 Levelling and Infill Concrete**

Levelling concrete shall be used to level excavated areas underneath footings or other structures where indicated on the contract drawings. It may also be used to fill large voids between structures and underlying materials. Where levelling concrete exceeds 300 mm thickness, the Engineer of Record and Owner's Representative shall be contacted. Levelling concrete shall be placed after all unwatering operations have been made effective in maintaining dry and controlled conditions as authorized by the Owner's Representative.

If the excavated area/void requires a thickness of 1.0 m or greater of concrete it is considered infill concrete and additional requirements must be satisfied as per CSA A23.1. The Contractor must prepare a temperature control plan in accordance with 931.04.01.02 and CSA A23.1 that shall be reviewed and authorized by the Owner's Representative.

#### **931.04.02.03 Tremie Concrete**

Concrete shall not be deposited in water except with the authorization of the Owner's Representative and shall be in strict accordance with CSA A23.1 Section 7.5.5, 7.5.6 and 7.5.7.

Concrete shall not be placed in water having a temperature below 5°C.

Prior to any placing of the tremie concrete, vertical shaft reinforcing bars in the tremie area shall be securely held in proper alignment by steel templates. The lower template shall be located a maximum of 1 m above the top of the tremie. The upper template is to be positioned near the top of the cofferdam.

Concrete shall be placed underwater by use of a hopper and tremie pipe(s) or a concrete pump with a discharge line used as the tremie pipe. Still water shall be maintained at the point of discharge and the forms underwater shall be watertight to avoid localized eddies at the joints.

The tremie pipe(s) shall have a minimum diameter of eight times the maximum size of aggregate. Sections of the tremie pipe shall have flanged couplings fitted with rubber gaskets and must be watertight.

The discharge end of the tremie pipe shall be plugged at the start of the work to prevent water from filling the pipe. The tremie pipe shall be slowly filled allowing time for air pockets to escape until the tremie pipe and hopper are full. The flow of concrete shall be induced by slightly raising/jerking the discharge end removing the plug. The discharge end shall always be kept deposited within the concrete at least 300mm.

No concrete shall be allowed to spread greater than 3 m from the discharge end of the tremie pipe. All required tremie pipes shall be installed prior to beginning concrete placement and shall be placed at a maximum of 3 m centres or as authorized by the Owner's Representative. Exact spacing shall depend on the geometry of the cavity, mix design and shall be at the discretion of the Owner's Representative. All tremie pipes shall be exhausted sequentially, in a linear matter, to prevent the trapping of large air voids within the cavity. Regardless of the method, the flow of concrete shall be continuous until the work is completed.

If the tremie operation is interrupted below water level, the surface laitance shall be removed by jetting one day after placing and removed by pumping.

#### **931.04.02.04 Consolidation**

Concrete, during and immediately after depositing, shall be consolidated thoroughly and uniformly by hand-tamping tools, mechanical vibration or finishing machines. The structure shall be homogenous, free of cold joints, voids, honeycombing and large surface defects. Concrete must be in full contact with reinforcement, hardware and other embedded items.

Vibration shall be in accordance with the requirements of CSA A23.1. The Contractor shall provide a sufficient number of vibrators to ensure proper consolidation for the rate of concrete placement. Back-up vibrators shall be available on site at all times.

The Contractor shall size vibrators such that the zone of influence does not extend outside the limits of the concrete area. Vibrators shall also be selected to fit between the rebar.

Vibrators shall be inserted vertically and at intervals spaced so the zones of influence overlap. Vibrators must be sized to suit the elements dimensions. Vibrators shall project 150 mm into the preceding layer and then shall be slowly withdrawn to remove entrapped air. Vibration shall not be continued to cause segregation.

The Contractor shall provide safe and necessary access to adequately consolidate all areas of the element for concrete placement. Details of this access shall be outlined in the concrete placement plan. Once initial concrete consolidation has occurred, protruding rebar shall not be disturbed by walking, finishing machines or other means.

If galvanized reinforcement is used, vibrators shall have rubber or non-metallic vibrating heads.

The vibrator shall not come in contact with reinforcing steel or embedded items in the concrete. No vibrating shall occur in the cover zones.

The vibrator shall not be used to move the concrete laterally.

All methods of consolidation shall be subject to approval by the Owner's Representative.

#### **931.04.02.05 Evaporation Retardant**

When the concrete placement is complete and immediately after the straight edge requirements have been met for the deck concrete and the broom finish applied, the fresh concrete shall be coated with an evaporation retardant to preclude rapid evaporation of the bleed water. The Contractor must submit the material data sheets of the evaporation retardant intended to be utilized on the project prior to its use. Evaporation retardant to be MasterKure ER 50 manufactured by Master Builders Company Ltd, SikaFilm manufactured by Sika, or an equivalent satisfactory to Owner's Representative.

In some cases the film may need to be reapplied prior to the completion of the finishing operations and before the final curing conditions can be implemented. The supply and application of the evaporation retardant is deemed incidental to the placement of the deck concrete and as such, no separate payment will be made.

### **931.04.03 Concrete Surface Retarders & Scarification of Construction Joints**

Construction joints in concrete shall be positioned at the location shown on the drawings or where otherwise approved by the Owner's Representative.

Where construction joints are planned or occur for reasons beyond the Contractor's control, the concrete interface shall have the surface film of concrete paste (mortar) removed to expose all aggregates by the process of high pressure washing while the concrete surface is sufficiently fresh (Green Cutting).

Surface retarders may be selected by the Contractor for various reasons to complete the green cutting or scarification of the concrete surface. All surface retarders shall be approved by the Owners Representative in accordance with 930.04.13.

The Contractor shall protect adjacent final finish surfaces from retarder overspray by means of plastic sheeting partitions or approved equal.

Areas slated to be sprayed with surface retarder shall be lightly finished to close air pockets and slightly depress the aggregates. Sprayed areas shall be covered in plastic sheeting (where possible) immediately after application until scarification can start. The Contractor shall not apply wet burlap to these areas until surface scarification has been completed. All other concrete surfaces shall be cured as per 931.10 at all times.

The Contractor shall monitor the set progression depth of the retarded mortar versus that of normal setting mortar. Once the retarded mortar reaches the desired depth as defined by the International Concrete Repair Institute (ICRI), and the adjacent normal setting mortar has reached a desirable strength to prevent damage, scarification/green cutting may begin. The Contractor will be required to complete field trial(s) as requested by the Owners Representative.

Final finish surfaces shall be protected during green cut operations (from water damage) by using sumps, pumps and barriers.

The Contractor shall be cautious at the formwork perimeter and other locations where the surface retarder may have penetrated deeper than intended. High pressure washing can cause cavities in these locations. All defects shall be subject to repair method(s) at the Owner's Representative discretion and at the Contractors expense.

All areas of the joint requiring future concrete placement shall be roughened to a Concrete

Surface Profile (CSP) level 7, as defined by the International Concrete Repair Institute (ICRI) including the required cover zone. Care shall be taken not to overcut or undermine the aggregates while trying to achieve the desired profile. If overcut is observed, the aggregated shall be removed and scarified using a method satisfactory to the Owner's Representative.

If the Contractor misses the timeline to green cut the required concrete area or fails to achieve the required profile, including overcutting, the Contractors shall roughen the area at their expense to meet the requirements of this specification.

Locations on precast elements to be in contact with future cast in place concrete shall be green cut or sandblasted to CSP level 7.

The Contractor shall not sandblast any construction joint which may damage galvanized, GFRP, or stainless steel rebar.

All wash water containing cementitious materials and surface retarder shall be disposed of as hazardous waste.

#### **931.04.04 Construction Joints**

A construction joint is a planned separation in a concrete placement. Bonding of the new and existing concrete is required.

Joints in concrete members shall be formed in location as shown on the plans.

#### **931.04.05 Contraction Joints**

A contraction joint is a control joint to encourage shrinkage cracking at a specific location.

Contraction joints shall extend to a depth equal to one-quarter of the member thickness. As soon as feasible the joint shall be thoroughly flushed out with compressed air and an approved flexible joint sealing compound utilized to fill the joint. The joint sealer compound shall be flexible over the extreme temperature conditions in the local area and must be approved by the Owner's Representative.

#### **931.04.06 Sealing of Joints**

Backing rod or sealant shall be applied to all contraction and expansion joint locations as indicated on project drawings.

All joints greater than 10mm in width and 25mm deep shall receive a backing rod.

Joint backing shall be a closed-cell non gaseous backer rod, such as Softrod specified by Tremco (Canada) Limited or an approved equal.

Joint backing rod diameter shall be determined after measuring the joint opening, the rod shall be 25% larger than the joint opening.

Joint sealant shall be in accordance with 930.04.14. The filler or sealant and the substrate material must have a temperature greater than 5°C at the time of application unless otherwise specified by the manufacturer. Under no circumstances should sealant be applied to any surface which contains moisture, condensation, or frost. Joint surfaces are to be clean, free of dust, dry and free of foreign matter before application of primer and sealant.

Payment shall be considered incidental to the works associated with concrete work pay items.

## **931.05 SURFACE FINISHING**

### **931.05.01 General**

All tolerances and finishing methods shall conform to CSA A23.1.

All concrete surfaces that will be exposed on completion of the work shall be formed finish, with the exception of the bearing seats, deck, approach slabs, expansion joint end dams, curbs, sidewalks and tops of barriers which shall be a floated finish.

All surfaces shall be uniform in colour and texture to the satisfaction of the Owner's Representative and in accordance with Table 3.0.

The Contractor shall take special care during the planning, forming, concrete placing, curing and stripping phases to ensure defect-free surfaces.

**TABLE 3.0**

Concrete Element	Finish Type	Impression Depth
Concrete Approach Slabs - Exposed	Broom - Coarse	≤ 3-5 mm
Concrete Approach Slabs - To Be Water Proofed	As per Waterproofing Manufacturer <sup>1</sup>	-
Concrete Decks - Exposed	Broom - Coarse	≤ 3 mm

Concrete Decks - To Be Water Proofed	As per Waterproofing Manufacturer <sup>1</sup>	-
Sidewalks	Broom – Coarse	≤ 3 mm
Curbs	Broom – Fine	≤ 1 mm
Expansion Joints – End Dams	Broom – Coarse	≤ 3 mm

**NOTES:**

1. Contractor shall provide a letter from the waterproofing manufacturer indicating the recommended finish requirement of the element to be waterproofed.

Concrete bridge decks and approach slabs to be waterproofed shall have all protrusions, ridges, trowel marks and sharp edges removed by grinding so there are no areas exceeding 5 mm or depressions exceeding 10 mm.

Brooms shall be sized with the appropriate bristles to complete the finishes specified in Table 3.0. The strikes shall be square across the slab, from edge to edge, with adjacent strokes slightly overlapped and shall be made by drawing the broom without tearing the concrete but so as to produce regular corrugations.

All finished surfaces shall be free from porous spots, irregularities, depressions and small pockets or rough spots.

The Owner's Representative may decide to delete the broom finish requirements but tolerances in CSA A23.1 will still apply.

### **931.05.02 Small Slabs**

All finishing equipment shall be equipped and operated in accordance with the manufacturer's literature for the particular concrete and work being performed.

For (a) decks less than fifteen metres in length, (b) thin overlay strips wider than two metres finishing shall be achieved with a self-propelled air operated vibrating Allen Screed or approved equal.

For thin overlays less than two metres wide refer to Section 919.13.

Deck repairs by overlay shall also meet the requirements in Section 919.

Screed elevations shall be obtained as detailed in Section 907.

After the deck surface has been floated and any bleed water evaporated, but while the

concrete is still plastic, the Contractor shall finish using a 3 m straight edge swung from handles half the width of the slab.

The straight edge shall be held in successive positions parallel to the road centre line maintaining contact with the surface while finishing from one side of the slab to the other as necessary. Advancement along the deck shall be in successive stages of not more than one-half the length of the straight edge. Any depressions found shall be immediately filled with freshly mixed concrete, struck off, consolidated and refinished. The straight edge testing and refloating shall continue until the entire surface is found to be free from observable departures from the straight edge and the slab has the required grade and contour, until there are no deviations of more than 8 mm under the 3 m straight edge.

### **931.05.03 Large Slabs**

All finishing equipment shall be equipped and operated in accordance with the manufacturer's instructions for the particular concrete and work being performed

Deck repairs by overlay shall also meet the requirements in Section 919.

For a) new bridge decks and rehabilitated bridge decks where the total deck length is greater than fifteen metres, (b) wharf decks and (c) bridge approach slabs greater than 3 metres in length, finishing shall be achieved with a GOMACO 450 bridge deck finishing machine with a vibrating screed/rotating drum, reversing screw power auger and movable work bridge(s) or approved equal. Here after known as the finishing train.

The screed machine shall be set-up to match the skew of the bridge when the skew angle exceeds 10°.

The Contractor shall supply sufficient quantities of the required guides or rails to support the finishing train such that the deck finishing machine extends slightly beyond the placement area. While the finishing train is travelling the guides or rails it shall completely clear the finished surface, with the exception of the finishing drum or screed.

The rails shall be made of metal and be straight to within 3 mm in a 3 m length. Screed rail chairs/supports 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.

The finishing train shall be independently supported to prevent deflection of the rebar or any other embedded parts. Supports shall not be embedded with the concrete unless approved by the Owner's Representative. The support system for the finishing train shall

be designed and stamped by a Professional Engineer in the Province of Newfoundland & Labrador.

The finishing train must be accompanied by a working platform with two (2) Red Seal Journeyperson Concrete Finishers assigned to the platform at all times.

The decks haunch shall be adjusted for the actual camber of pre-stressed members, deck concrete self weight as well as any other contributing loads. Screed elevations shall be obtained as detailed in Section 907.

A dry run of the finishing train over the entire deck shall be completed to insure the designed deck thicknesses, concrete cover and profiles will be attained. The Contractor shall provide the Owner's Representative at least 24 hours notice prior to starting the dry run. The dry run shall be completed at least 24 hours prior to commencing the deck concrete placement.

After the completion of screeding operations concrete shall be worked with a bull float or darby to remove any high spots, ridges or to fill voids in the concrete surface. Bull floating or darbying shall follow as close as practically possible behind the screed. If the concrete surface has the required smoothness/textured after screeding than bull floating or darbying may not be necessary.

Water from fog misting operation shall not be worked into the concrete surface or used as a finishing aid.

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.

#### **931.05.04 Concrete Beam Seats and Bearing Surfaces**

Concrete beam seats which will not have a bearing placed directly against them shall be magnesium floated to the levels and slopes as shown on the drawings and to prevent the accumulation of water.

Concrete surfaces which are used as bearing surfaces shall be dead level and finished in accordance with Section 912 and the bearing manufacturer's recommendations.

## **931.06 CURING**

### **931.06.01 General**

All curing work shall follow CSA A23.1. Water used for curing shall be in accordance with 930.04.03. C-XL and C-1 concrete exposure classes shall follow Type 3 curing as per Table 19.0 of CSA and requires a minimum seven day wet cure.

Curing shall begin immediately following the placing and finishing operations and provide the temperature and moisture conditions for the period of time necessary for concrete to develop the required properties, including strength and durability. The Contractor must have all necessary equipment and personal on site ready to commence curing processes prior to the placement of concrete.

Concrete temperature must be maintained at no less than 10°C, a maximum of 70°C and respect the temperature differentials in Table 1.0 throughout the curing period for a minimum of 7 days and for the time required to reach 70% of the specified strength. The concrete shall then be cooled as per the requirements in 931.04.01.02.

Curing of concrete surface shall start as soon as the concrete has hardened sufficiently to prevent damage. The following methods may be used for curing concrete surfaces:

- Ponding or continuous sprinkling of water.
- Applying water and covering with absorptive burlap as per 930.04.10.
- Curing compounds as per 930.04.11. This shall only be used on non-structural elements and for mixes that do not contain silica fume.
- Applying water and covering with polyethylene sheets as per 930.04.12.
- Forms in contact with concrete surfaces with wet curing.

All concrete must be cured by means of burlap and water unless otherwise approved by the Owner's Representative.

All water used for curing shall be a minimum temperature of 10 °C and be clean, free of chlorides, oils, dirt, other deleterious materials and any other material which would cause staining or discoloration of the concrete. The temperature of curing water shall be within 20°C of the concrete surface temperature at all times and shall not cause temperature differentials greater than those specified in Table 1.0.

During freezing weather, water curing of concrete shall be terminated 12 hours before the end of the protection period. Surfaces shall be free of surface water before permitted to

freeze.

### 931.06.02 Curing of Precast Concrete

Curing of Precast Concrete structures shall follow the requirements set forth in CSA A23.4. Temperature monitoring during the curing period shall be in accordance with 931.04.01.02.

Curing of non accelerated concrete shall be as indicated in 931.06.01.

Accelerated curing shall be achieved by as per CSA A23.4 Clause 23.2.3 and be in accordance with Table 4.0:

**TABLE 4.0**

Minimum holding period (delay) before application of heat and maximum concrete temperature during the holding period	3h at 30°C or 4h at 40°C
Maximum heating rate of concrete, °C/h*	20
Maximum concrete temperature, °C	70
Maximum cooling rate of concrete, °C/h†	15

\*For structural low and semi-low-density concrete, the heating rate shall be limited to 10°C/h

†Monitoring shall continue until the concrete temperature is not more than 20°C above the ambient temperature.

Throughout the entire accelerated curing cycle, concrete surfaces shall be protected from moisture loss ensuring that 95% relative humidity is present in the curing enclosure, by covering the surfaces with properly sealed tarpaulins, plastic sheeting, or a supply of moisture such as water spray or live steam. Proper curing shall be provided and care shall be taken to retain moisture and avoid excessively high or low ambient temperatures. Concrete shall not be exposed to combustion gasses during the accelerated curing cycle.

Protection and curing of accelerated concrete shall continue for the time necessary to achieve 70% of the specified strength. When accelerated curing methods are used, the governing maximum concrete temperatures shall be those achieved within the core of the concrete elements.

Where concrete curing has been accelerated, and detensioning is required, the detensioning shall be performed immediately following the curing period, while the concrete is still warm and moist.

### **931.06.03 Burlap**

Burlap must be in accordance with 930.04.10. All burlap must be pre-soaked by immersing it in water for a period of at least 24 hours immediately prior to placing. Two layers of burlap must be applied to the surface of the concrete. Strips must overlap by 150 mm and must be held in place without marring the surface of the concrete.

Curing with burlap and water must be maintained for a minimum period of seven days. The burlap must be maintained in a continuously wet condition throughout the curing period by means of a soaker hose. The burlap must be covered with a layer of moisture vapour barrier within 12 hours of placing the concrete, in a manner which will prevent deformation of the surface of the concrete.

Air flow in the space between the moisture vapour barrier and the burlap must be prevented. Regardless of ambient temperature, moist curing with burlap and water must be provided at all times. During cold weather, burlap must be prevented from freezing.

### **931.06.04 Liquid Membrane Curing**

Liquid membrane curing compounds meeting the requirements of 930.04.11, shall be used in conjunction with moist curing on vertical surfaces or as accepted by the Owner's Representative. Curing compounds are not permitted on construction joints, surfaces requiring weatherproofing sealants, bridge decks and HPC.

All liquid membrane curing compounds shall be rolled on and not sprayed unless the Contractor can prove a uniform finish satisfactory to the Owner's Representative.

### **931.06.05 Curing of Bridge Decks and Horizontal Surfaces**

A continuous fog mist shall commence immediately behind the screeding operation until the concrete has hardened sufficiently to permit covering with burlap. Misting shall be conducted through the use of a pressure washer capable of sustaining a minimum 14 MPa pressure and equipped with an atomizing type nozzle. Water shall not be allowed to drip, flow or puddle on the fresh concrete surface during fog misting at any time before concrete has reached final set.

Water from fog misting operation shall not be worked into the concrete surface or used as a finishing aid.

The curing time required for deck concrete (including sidewalks and curbs) and bridge deck repairs is Type 3 curing as per CSA and requires a minimum seven day wet cure and a further 30 days for air drying. Also, the specified design strength must be obtained.

Until the above conditions are satisfied, the application of waterproofing and the opening of the bridge to traffic will not be permitted.

### **931.06.06    Improper Curing**

Failure to carry out proper curing procedures, including temperature control and timelines as described within this specification shall result in the following liquidated damages:

- 1<sup>st</sup> occurrence, \$1000 liquidated damages.
- 2<sup>nd</sup> occurrence, \$2000 liquidated damages.
- Each occurrence thereafter, \$5000 each occurrence.

An occurrence shall be defined as when an inspection by the Department or Owner's Representative reveals that a concrete surface during the curing period is not visibly wet or does not have measures in place to ensure proper curing temperatures.

If the Contractor fails to reinstate proper curing conditions within 30 minutes of notification, this will be treated as a separate occurrence. If there are two or more occurrences on the same section of concrete, it shall be removed and replaced at the Contractor's expense.

Payment for curing shall be considered incidental to the placement of Concrete.

### **931.07       HOT WEATHER CONCRETING**

When the air temperature is at or above 27°C or when, according to meteorological forecasts, is expected to rise above this limit then special measures shall be taken by the Contractor to protect the concrete. Surface moisture evaporation must not exceed 0.50kg/m<sup>2</sup>/hr. The rate of surface moisture evaporation can be estimated from Figure D.1 of CSA A23.1.

Hot weather placing of concrete shall not proceed without the approval of the Owner's Representative.

Concrete placed in the forms shall be maintained at or below 25°C and in accordance with the temperature limits in Table 2.0. The Contractor shall ensure all measures to achieve the temperature requirement are to the satisfaction of the Owner's Representative and in accordance with 931.04.01.02.

The temperature of the formwork, reinforcing steel, and material against which new concrete is to be placed, shall not exceed 30°C.

Exposed surfaces of concrete shall be shaded from the direct rays of the sun and sheltered from direct wind.

## **931.08 COLD WEATHER CONCRETING**

### **931.08.01 General**

Cold weather placing of concrete shall not proceed without the approval of the Owner's Representative.

Calcium chloride or other de-icing salts shall not be used as a de-icing agent in or around the forms. Concrete shall not be placed on or against frozen ground or any surface that will lower the temperature of the concrete in place below the minimum values shown in Table 2.0 or below 10°C.

Concrete for bridge decks (or approach slabs) shall not be placed between October 1 and May 1 unless otherwise approved by the Owner's Representative.

For additional guidance on Cold Weather Concreting see ACI 306 "Guide to Cold Weather Concreting", the Portland Cement Association publication "Design and Control of Concrete Mixtures", and "CSA A23.1 section 7.1.2 Cold Weather Concreting".

### **931.08.02 Protecting Placed Concrete**

Protection shall be provided by means of heated enclosures, coverings, insulation, or a suitable combination of these methods. The proposed method of protection and curing must be included in the Thermal Control Plan.

If protective housing is utilized as indicated in the Thermal Control Plan it shall be reviewed and stamped by a Professional Engineer and meet the requirements of the National Building Code.

The equipment required for heating shall be of adequate capacity and be accepted, prior to installation, by the Owner's Representative. Heating equipment shall be available, installed and tested ready for use before the Owner's Representative will authorize concrete placement.

If temperatures are less than 5°C the Contractor shall preheat the area in which the concrete is to be placed. Additional heating may be necessary if large quantities of steel elements are present, however care must be taken to avoid heating elements more than 5°C above the temperature of the concrete mixture. Once temperatures are satisfactory to the Owner's Representative, the Owner's Representative will authorize the placement

of concrete provided other requirements of this specification have been met.

The Contractor is advised that insulation or supplemental heat may be required year-round in order to maintain required temperature differentials and to protect the concrete from thermal cracking. Alternative methods of keeping concrete temperatures at acceptable levels may be accepted.

The Contractor shall make suitable arrangements for any heating equipment outside normal working hours where required.

### **931.09 CONCRETE REPAIRS**

The Contractor shall notify the Owner's Representative of all defective areas and their proposed repair method(s). Where possible, the Contractor and Owner's Representative shall complete a walkthrough and agree on the standard repairs to be completed and their repair method(s). Where repairs do not meet the general guidelines of the items below or abnormalities are encountered, the Engineer of Record shall be contacted.

All defects shall be subject to repair method(s) at the Owner Representative's discretion and at the Contractors expense. Concrete that has, in the Department's opinion, has excessive defects shall be rejected and replaced at the Contractor's expense. No time extension will be given for repairs or replacement of rejected concrete.

Concrete defects may include but is not limited too:

- Surface projections/excess paste
- Entrapped air voids
- Voids
- Cold joints
- Honeycombs
- Formwork tie rod holes
- Corner Spalls
- Cracks
- Depressions in slabs.

The Contractor shall submit all repair materials intended for use to the Owner's Representative as per 930.04.06. All mortars shall have a corrosion inhibiting compound where in contact with reinforcing steel. Curing of the mortar/compound shall follow the manufacturer's instructions.

Defective concrete shall have its edges saw cut 25 mm vertically, and be chipped to a

depth reaching sound concrete with no feathered edges, thoroughly cleaned, and be in a saturated surface dry (SSD) condition prior to patching with any repair mortar or compound.

Chipping, sandblasting and other destructive tools are prohibited around GFRP, galvanized and stainless steel rebar unless authorized by the Owner's Representative.

If rebar is exposed within a defect **OR** exposed from chipping to find sound concrete and:

- Less than 50% of the bars circumference is exposed **AND** the concrete around the bar is sound, the bar does not need to be chipped all the way around.
- Greater than 50% of the bars circumference is exposed, it must be chipped to sound concrete **AND** around the bar to a minimum of  $\times 1.5$  the maximum aggregate size.

Following the removal of forms, irregular projections, fins, offsets, streaks or other surface imperfections shall be removed from all surfaces except the surfaces which are not exposed or waterproofed. Concrete bridge decks and approach slabs to be waterproofed shall have all protrusions, ridges, trowel marks and sharp edges shall be removed by grinding so there are no areas exceeding 5 mm or depressions exceeding 10 mm.

Any air voids or bug holes less than 12mm wide and 6mm deep need not be repaired. All bug holes greater than 12mm wide, and 6mm deep and are concentrated in a local area shall have the overlying mortar removed to open the bug hole, be washed and repaired with a mortar accepted by the Owner's Representative.

All form tie elements (rod and/or plastic cones) shall be removed from the cover area, mechanically roughened, cleaned, pre-soaked to a SSD condition and repaired with a mortar accepted by the Owner's Representative.

Spalled corners/edges shall be saw cut 25 mm, chipped to sound concrete with feathered edges removed, thoroughly cleaned, pre-soaked to an SSD condition and formed or hand patched to the original profile at the discretion of the Owner's Representative.

All cracks 0.3 mm and greater in width shall be repaired within the warranty period, regardless of location, size, or cause in accordance with the following methodology:

Hairline cracks are defined as less than 0.1 mm, narrow cracks 0.1 mm to 0.3 mm, medium cracks 0.3 mm to 1 mm, and wide cracks are greater than 1 mm. Cracks less than 1 mm identified for repair shall be filled with a low viscosity epoxy resin such as Sika

Canada's Sikadur 52, Sikadur 55 SLV, or Master Builder's MasterInject 1380 or an approved equal. The resin shall be applied by pressure injection or by gravity feed into the crack and allowing the sealant to be absorbed.

Additional applications may be required, depending on the absorption and crack depth. Subsequent applications, if required by the Engineer of Record, shall be made as soon as possible after the prior application has sufficiently set. All use and placement of resin materials shall be in accordance with the manufacturer's written instructions.

Wider cracks, as identified from the survey may require a higher viscosity resin for repair. Polyurethane or other appropriate flexible sealants may be required to repair larger cracks where active movement occurs. The Contractor shall submit manufacturer's data for the proposed resin in this case for approval prior to use. Excess resin in the vicinity of the crack shall require removal by grinding and/or abrasive blast cleaning at the Engineer of Record's direction.

All voids, cold joints, wide cracks, honeycombs, and slab out of tolerances shall be discussed with the Owner's Representative for remedial action and shall be repaired on a case by case basis at the Contractors expense.

## **931.10 MEASUREMENT FOR PAYMENT**

### **931.10.01 Measurement for Payment for concrete placement work where the Unit Price Table states the unit to be cubic metres**

For those concrete work contract items, except infill, levelling and tremie concrete, where the unit of measurement on the Unit Price Table is stated as cubic metre, then measurement for payment will be by the volume of concrete placed, measured in cubic metres rounded to two decimal places, based on the neat lines called for in the plans.

Measurement for payment purposes for infill concrete shall be based upon cross sections measured in cubic metres to the nearest one decimal place. Prior to concrete placing and forming operations, the Owner's Representative shall establish the lateral and vertical limits for infill concrete.

Measurement for payment purposes for tremie concrete shall be made based upon the number of cubic metres of batched concrete rounded to the nearest one decimal place and incorporated into the works as accepted by the Owner's Representative. Every precaution must be taken to prevent waste of concrete, i.e. carelessness resulting in the escape of concrete from within the confines of the forms or inaccuracy in placing. In the event of such occurrence(s) an estimate of the wastage will be made by the Owner's

Representative and an appropriate deduction from the batch quantity will be made. All additional concrete required to be placed above the estimated quantity, accepted by the Owner's Representative.

No deductions will be made from the volume of concrete for:

- a) Volume of reinforcement, prestressing steel or prestressing ducts.
- b) Inserts of cross-sectional area of less than 0.1 square metres.

When it is specified that concrete is to be placed against undisturbed soil or set in rock, and where the excavation is made wider than the neat lines of the footings or the excavation is at a lower elevation than the footing grade, the excess amount of concrete will not be measured for payment quantities.

Where the concrete footings are placed lower than that authorized by the Owner's Representative, any excess amount of concrete will not be measured for payment quantities.

#### **931.10.02 Measurement for Payment for concrete work where the Unit Price Table states the unit to be a unit other than cubic metres**

For those concrete work contract items where the unit of measurement on the Unit Price Table is stated in some unit other than cubic metre, then the measurement for payment shall be in accordance with that stated in the appropriate specification for the item.

### **931.11 BASIS OF PAYMENT**

#### **931.11.01 Basis of Payment for concrete work where the Unit Price Table states the unit to be cubic metres**

For those concrete work items where the unit of measurement in the Unit Price Table is stated as cubic metre, then payment at the contract price shall be full compensation for all materials, labour, equipment, plant and services necessary to complete the concrete work as outlined herein.

In particular no separate payment will be made for:

- a) supply of cement, aggregates and other materials, plant and equipment-use required for producing the concrete
- b) Mix design, production, mixing, transportation, placing, consolidation, curing and quality control during production

- c) Formwork and falsework
- d) Precautions to be taken for hot weather
- e) Precautions to be taken for cold weather
- f) Provisions of shipping crates for concrete test specimens

No payment shall be made for any concrete required for normal testing procedures.

Where excessive camber in girders is permitted by the Owner's Representative, the extra concrete due to the camber in excess of the specifications will not be paid for.

Concrete not placed in accordance with the provisions of 931, will not be paid for unless and until it can be established to the satisfaction of the Owner's Representative that there has been no harmful effect to the concrete. The onus for establishing this will belong to the Contractor.

#### **931.11.02 Basis of Payment for concrete work where the Unit Price Table states the unit to be a unit other than cubic metres**

For those concrete work contract items where the unit of measurement in the Unit Price Table is stated in some unit other than cubic metre, then the basis of payment shall be in accordance with that stated in the appropriate specification for the item.

Concrete not placed in accordance with the provisions of 931, will not be paid for unless and until it can be established to the satisfaction of the Owner's Representative that there has been no harmful effect to the concrete. The onus for establishing this will belong to the Contractor.

#### **931.11.03 Concrete Acceptance Payment Criteria**

A lot is defined as the quantity of concrete placed within one calendar day for the required strength class or as established by the Owner's Representative at the preconstruction meeting.

Concrete of a given strength class must meet the compressive strength requirements as per Table 1.0 of Section 930.

Concrete of a given strength class having a strength of less than that specified will be accepted into the job at a reduced payment, as per below, provided the difference between specified strength and tested strength is no greater than 5 MPa.

$\$ \text{ (Adjusted Concrete Unit Price)} = \$ \text{ (Bid Concrete Unit Price)} - \$50 \text{ for Specified Concrete}$

Strength of 35MPa or less

$\$ \text{ (Adjusted Concrete Unit Price)} = \$\text{(Bid Concrete Unit Price)} - \$100 \text{ for Specified Concrete Strength of greater than 35MPa.}$

Concrete of a given strength class having a strength of less than that specified by more than 5 MPa shall be rejected. The Department reserves the right to reject any concrete which does not meet all the requirements for the class of concrete specified. The Department also reserves the right to reject any portion of a placement if there exists evidence that this portion has a strength that is below the minimum acceptable required under this section. When the concrete is rejected, the Engineer of Record or Owner's Representative, may determine if the concrete can remain in the work. All expenses related to such determination will be at the Contractor's expense. If it is determined the rejected concrete cannot remain in the work, it shall be removed and replaced at the Contractor's expense. The new concrete will be subject to all conditions of Section 930 and 931. Should the rejected concrete remain in the work it will be subject to a reduction, as outlined below:

$\$ \text{ (Adjusted Concrete Unit Price)} = \$\text{(Bid Concrete Unit Price)} * 0.5 \text{ for strength between 5 and 8 MPa of the specified strength}$

*\*\*No payment will be made for strength less than 8 MPa of the specified strength that is allowed to remain in the work.*

If all strength results, for a C-1 exposure class, is maintained within 10 MPa of the required strength than the following bonus will apply. The average strength will be determined based on all lot strength results for the given strength class. If any individual lot strength result falls below the specified strength no bonus will be paid.

$$\text{BA} = V \times (\$2.0 \times (\text{SS}/((\text{AS}-\text{SS})^2)))$$

BA = Bonus Adjustment

V = Volume place ( $\text{m}^3$ )

SS = Specified Strength (MPa)

AS = Actual Strength (MPa)