



CONCRETE PAVEMENT SPECIFIERS GUIDELINES

MUNICIPAL EDITION



READY MIXED CONCRETE ASSOCIATION OF ONTARIO

August 2009

FOREWORD

Portland cement concrete (PCC) pavement refers to the rigid concrete layer of the pavement structure that is in direct contact with the traffic. Typical concrete is composed of coarse aggregate (crushed stone and gravel), fine aggregate such as sand, Portland cement, admixtures and water. Concrete can be modified in a number of ways, including the addition of cementitious materials such as Slag or Fly Ash (which are materials that are added to the mixture to enhance the properties of the fresh or hardened concrete) keeping them from landfill sites. Once the concrete has been mixed, it is placed on a prepared base coarse, consolidated and shaped.

In pavement construction, three different concrete pavement design types are commonly used: jointed plain concrete pavements (JPCP), jointed reinforced concrete pavements (JRCP), and continuously reinforced concrete pavements (CRCP). Each of these design types can provide long-lasting pavements that meet or exceed specific project requirements. Each type is suitable for new construction, reconstruction, and overlays (resurfacing) of existing roads.

With the state of our environment and the economy in the forefront of people's minds, concrete pavements provide high-quality assurance, and will continue to be more competitive in the future. Concrete pavements are cost competitive (both initial and life cycle) and are now being recognized as the environmental responsible choice among pavement alternatives for both new and rehabilitation projects. They simply last longer than flexible pavements (MTO LCCA) which means they don't need rehabilitation or reconstruction as often. Another consideration is that concrete pavements use significantly less aggregate in total than flexible pavements. This conserves our non-renewable resources and results in less truck traffic and congestion. Less soil needs to be excavated for a concrete road (when compared to the flexible alternatives) due to the rigid nature of concrete pavement allowing for thinner base cross-sections. This is a huge advantage with the increased difficulty in finding areas to dump any contaminated soils. Equally important is that longer lasting concrete helps reduce traffic congestion and vehicle emissions because there are simply fewer construction zones slowing traffic flow during the life of the pavement.

Some other advantages of concrete pavements are that they save fuel and reflect light and heat rather than absorbing it. Studies from National Research Council (Canada) show substantial savings on diesel fuel with heavy trucks, and new studies are available from Sweden and United States showing gasoline savings on cars and light vehicles. These savings result in lower vehicle operating costs and greatly reduced CO₂ emissions. Concrete pavement's ability to reflect light can lead to a 20 to 30% reduction in the cost to purchase and operate light standards, and because concrete pavements reflect heat, they also contribute to cool communities and reduce the Urban Heat Island Effect.

Every attribute of concrete can be tied back to a sustainable benefit. Concrete pavements are an excellent choice for Responsible Materials Procurement. To address sustainable materials procurement, the Ready Mixed Concrete Association of Ontario (RMCAO) has developed the "ECO CERTIFIED Concrete Facility" certification program.

MESSAGE TO SPECIFIER

This “Concrete Pavement Specifiers Guidelines” document is intended solely for use by professional personnel who are competent to evaluate the significance and limitations of the information provided in this document, and who will accept full responsibility for the application of this information. The Ready Mixed Concrete Association of Ontario (RMCAO) disclaims any and all responsibility and liability for the accuracy and application of the information included in this guideline document to the fullest extent permitted by law. Please note that each project will have different circumstances that the owner and/or consultant must assess due to factors such as geographical area, locally available materials, subgrade conditions, environmental conditions, traffic loading, etc.

For information on Pervious Concrete for Storm Water Management, please refer to the RMCAO’s “Pervious Concrete Specifiers Guidelines”.

For information on other products and applications please contact the RMCAO (www.rmcao.org).

DESIGN

One of the tools that can be used to assist in the design process is the “[StreetPave](#)” software program. StreetPave is the latest in concrete thickness design software for streets and local road pavements, produced by the American Concrete Pavement Association (ACPA). This software utilizes proven engineering analysis to produce optimized concrete pavement thicknesses for municipal streets and roads (collector, minor and major arterial). A “Life Cycle Cost Analysis” module also allows you to perform a detailed informed decision of your pavement design project. StreetPave is now available as a free-use online version and as a fully-featured windows version. Note: You cannot save your project files in the free online version.

“[CANPav™](#)” is another concrete pavement tool designed to offer the specifier and owner an easy initial cost comparison through material cost and design inputs. Developed by the RMCAO, this program is online starting September 2009 in collaboration with the Cement Association of Canada (CAC) and is available to anyone interested in comparing the initial construction costs of different pavement alternatives. Visit <http://www.canpav.com/>.

CONSIDERATIONS

- It is important to realize the capabilities and limitations of all placing equipment, when developing your initial design.
- It is also important to realize that all technologies may not be suitable for all projects. It is also important to fully understand a technology before including it in a specification.
- Joint design and details should be considered carefully, and it is recommended that you request input from the contractor.

REFERENCES

- Ontario General Contractor Association (OGCA) & RMCAO Publication “Best Practices Guidelines for Concrete Construction”.
- FHWA Publication No. HIF – 07 – 004 “Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual”.
- American Concrete Pavement Association Publication “Concrete Pavement Field Reference *Pre-Paving*”.

FINAL NOTE

If you have any questions regarding the content of this document, please contact:

Ready Mixed Concrete Association of Ontario
365 Brunel Road, Unit 3, Mississauga, Ontario, L4Z 1Z5
Tel 905-507-1122
Fax 905-890-8122
pavement@rmcao.org
www.rmcao.org

1.0 GENERAL PROVISIONS

1.1 GENERAL DESCRIPTION

This document is intended for use by engineers and/or owners in preparing detailed construction specifications for Portland cement concrete pavements on municipal streets and roads (major/minor arterial and collector roads).

Specifications for subgrade and subbase construction are limited to its effects on concrete pavement construction.

A Pre-Job Meeting should be held with the owner, engineer, concrete producer, testing company and concrete paving contractor. The purpose of the meeting is to review the job specification and construction procedures to ensure that all parties understand the job requirements and to clarify responsibilities. Refer to the *“Best Practices Guidelines for Concrete Construction”* for a sample pre-job meeting form.

The contractor should develop and submit for approval a Traffic Management Plan as well as designate a qualified person to administer the safety aspects of the contract.

1.2 SCOPE

This sample specification covers the requirements for the construction of concrete pavements. Requirements for both the fixed-form and slip-form methods of concrete construction are covered. The choice between paving methods will depend on the project size, geometry, as well as accessibility and construction constraints. This document is applicable to both plain jointed undowelled and dowelled pavements.

1.3 DEFINITIONS

Alkali-Aggregate Reactivity (AAR)

AAR is the production of expansive gel caused by a reaction between aggregates containing certain forms of silica or carbonates and alkali hydroxides in concrete.

Cementing Material

Cementing material is any material having cementing properties or contributing to the formation of hydrated calcium silicate compounds. When proportioning concrete, the following are considered common cementing materials: Portland cement, blended hydraulic cements, fly ash, ground granulated blast-furnace slag, and silica fume.

Cold Weather

Those conditions when the air temperature is at or below 5°C in the shade. It also applies when the air temperature is at or is likely to fall below 5°C within 24 hours after concrete placement.

Concrete Pavement

A rigid pavement structure with an exposed concrete surface which may include concrete shoulders.

Curing

Maintenance of a satisfactory moisture content and temperature in concrete for a suitable period of time during its early stages (immediately following placing and finishing) so that the desired properties of the material can develop. Curing assures satisfactory hydration and hardening of the cementing materials.

D-Cracking

D-cracking is damage that occurs in concrete due to expansive freezing of water in some aggregate particles. The damage normally starts near joints to form a characteristic D-shaped crack. This problem can be reduced either by selecting aggregates that are less susceptible to freeze-thaw deterioration or, where marginal aggregates must be used, by reducing the maximum aggregate size. Also, providing drainage for carrying water away from the base may prevent saturation of the pavement.

ECO CERTIFIED Concrete Facility

The RMCAO's ECO CERTIFIED Concrete Facility is a certification program that addresses current environmental requirements such as C of A for Air, Noise, Sewage Works and Permits to Take Water. The ECO CERTIFICATION program is also designed to highlight many practices and methodologies that concrete facilities have regarding the use of SCM's, energy conservation, emissions control, water conservation and recycling and more.

Engineer

Engineer means a licensed professional engineer designated by the owner to administer the contract.

Frost Heave

Frost heave occurs when ice lenses form in the soil, which continue to attract water and expand further. The heaving itself is not a problem for concrete pavements; rather, it is the subsequent thawing and differential settling of the concrete slabs that can lead to roughness and/or cracking. For frost heave to occur, all three conditions must be present: a frost-susceptible soil, freezing temperatures that penetrate the subgrade, and a supply of water. Controlling any one of the three conditions will dramatically reduce the potential for frost heave.

Hot Weather

Those conditions when the air temperature is at or above 28°C in the shade. It also applies when the air temperature is at or is likely to rise above 28°C within 24 hours.

Isolation Joints

Joints placed to allow differential movement at intersecting streets, drainage structures, or other fixed objects.

Load Transfer

Is the effective transfer of traffic loads from one side of the joint to the other. Load transfer across joints is developed either by aggregate interlock and/or by using dowel bars.

Longitudinal Joints

A joint between two slabs which allows slab warping without appreciable separation or cracking the slabs. Longitudinal joints are used to relieve warping stresses and are generally needed when slab widths exceed 4.6m. Longitudinal joints should coincide with pavement lane lines whenever possible, to improve traffic operations.

Percent Within Limits (PWL)

PWL means an estimate of the percentage of the lot population that is within specification limits, determined by using the mean and standard deviation of the lot.

Standard Deviation

Standard deviation means the square root of the value found by summing the squares of the difference between each test result and the mean of the test results divided by the number of test results minus one.

Subbase

Granular material placed immediately above the subgrade.

Subgrade

The native soil upon which the subbase is to be placed.

Tining

Small grooves of specified dimension (longitudinal or transverse) which are hand or machine made in the concrete surface.

Transverse Construction Joints

Joints installed at the temporary end of a paving operation. Whenever possible, these joints should be installed at the location of a planned joint.

Transverse Contraction Joints

Joints that are constructed transverse to the centerline and spaced to control cracking from stresses caused by shrinkage, moisture and thermal differentials. Typically, transverse contraction joints are oriented at right angles to the centerline and edge of the pavement.

Unshrinkable Fill

Unshrinkable fill is a controlled density backfill material used in utility cuts and trenches. It is a mixture of cementitious materials, water, fine and coarse aggregates and may contain an air-entraining admixture. It is an extremely low-strength material with a maximum strength usually specified, rather than a minimum strength as for normal concrete (0.7MPa as per OPSS 1359).

1.4 REFERENCED STANDARDS

ACI Standards

ACI 309 Standard Practice for Consolidation of Concrete

ASTM Standards

ASTM C260 Standard Specification for Air-Entraining Admixtures for Concrete

ASTM C494 Standard Specification for Chemical Admixtures for Concrete

ASTM C666 Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing

CSA Standards

- CAN/CSA A23.1 Concrete Materials and Methods of Concrete Construction
- CAN/CSA A23.2 Methods of Test and Standard Practices for Concrete
- CAN/CSA A3001 Cementitious Materials for Use in Concrete

Ministry of Transportation Ontario

- MTO LS 101 Procedures for Calculating Percent Within Limits

Ontario Provincial Standards Specifications

- OPSS 350 Construction Specification for Concrete Pavement and Concrete Base
- OPSS 369 Construction Specification for Sealing or Resealing of Joints and Cracks in Concrete Pavement and Concrete Base
- OPSS 904 Construction Specification for Concrete Structures
- OPSS 919 Construction Specification for Formwork and Falsework
- OPSS 1002 Aggregates for Concrete
- OPSS 1308 Material Specification for Joint Filler in Concrete
- OPSS 1350 Material Specification for Concrete – Materials and Production
- OPSS 1441 Material Specification for Load Transfer Assemblies
- OPSS 1442 Material Specification for Epoxy Coated Reinforcing Steel Bars for Concrete

2.0 MATERIALS

2.1 CONCRETE

Concrete and concrete materials shall be according to OPSS MUNI 1350, and be tested for compliance with the specifications in accordance with procedures given in CSA Standard A23.2, with the following amendments.

- a. The coarse aggregate for concrete pavement shall have a combined gradation of nominal maximum size 37.5mm and 19.0mm aggregate and shall be according to the requirements of OPSS 1002.
- b. The minimum compressive strength shall be Class C-2 32MPa with a maximum water cementitious materials ratio (w/cm) of 0.45 (as per CSA A23.1).
- c. For all concrete pavement and concrete base, the air content shall be (as per CSA A23.1):
 - i. $6.5\% \pm 1.5\%$ when using aggregate with nominal maximum size between 14-20mm, and
 - ii. $5.5\% \pm 1.5\%$ when using aggregate with nominal maximum size between 28-40mm.

- d. The slump shall be selected by the contractor. Acceptance ranges (as per CSA A23.1) are as follows:
 - i. Less than 80mm slump \pm 20mm
 - ii. 80mm – 180mm slump \pm 30mm
- e. Concrete shall be placed with a mix temperature between 10°C and 27°C, as per OPSS 1350.

2.1.1 Portland Cements

Portland cement & blended hydraulic cements shall meet the requirements of CSA Standard A3001.

2.1.2 Supplementary Cementing Materials

Supplementary cementing materials and blended supplementary cementing material shall meet the requirements of CSA Standard A3001.

2.1.3 Aggregates

All coarse aggregates proposed for use shall be listed on the MTO's Aggregate Source List for Concrete Base and Concrete Pavement. Aggregates for use on concrete pavement shall not be susceptible to D-cracking and AAR. Unless field experience or prior laboratory testing have proven otherwise, aggregate for use in concrete pavement shall be tested in accordance with ASTM C666, Test Method for Resistance of Concrete to Rapid Freezing and Thawing. Testing shall be in accordance with Procedure A for a period of 350 cycles and appropriate AAR tests.

2.1.4 Water

Water used in mixing or curing shall meet the requirements of CSA A23.1.

2.1.5 Admixtures

Air-entraining admixtures shall conform to the requirements of ASTM C260. Chemical admixtures shall conform to the requirements of ASTM C494.

2.2 JOINT MATERIALS

Expansion joint filler shall be in accordance to OPSS 1308. Joint sealant material shall be in accordance to OPSS 369.

2.3 TIE BARS

Tie bars are epoxy coated deformed bars placed in longitudinal joints to prevent slabs from separating, and shall be in accordance to OPSS 1442.

2.4 DOWELS

Dowel bars are smooth, round steel bars placed across transverse joints to provide load transfer while permitting a joint to open and close. Dowels shall be in accordance to OPSS 1441.

3.0 SUBMITTALS

3.1 RMCAO CERTIFICATION OF CONCRETE FACILITIES

For the supply of concrete the contractor shall submit to the owner a valid Certification of Concrete Facilities for each concrete supply plant from the Ready Mixed Concrete Association of Ontario (RMCAO) two weeks prior to the start of the project.

3.2 ECO CERTIFICATION OF CONCRETE FACILITIES

To address sustainable materials procurements, the Contractor shall submit to the Owner a valid ECO CERTIFIED Concrete Facility certificate, from the RMCAO, for each concrete supply plant two weeks prior to the start of the project.

4.0 EQUIPMENT

4.1 BATCHING PLANT AND EQUIPMENT

Use a batching plant conforming to CSA A23.1 and the RMCAO's Audit and Check List.

4.2 MIXERS

Mix the concrete in a central-mix plant or in truck mixers conforming to CSA A23.1, and the RMCAO's Truck Certification Program. Operate all equipment within the manufacturer's recommended capacity to produce concrete of uniform consistency.

4.2.1 Central Mix Plant

Use a batching plant conforming to CSA A23.1 and the RMCAO's Audit and Check List. Combine cementitious materials, aggregates, admixtures and water in the mixer. Dispense liquid admixtures through controlled flow-meters or use dispensers with sufficient capacity to measure, at one time, the full quantity of each admixture required for a batch. If the mixture requires more than one admixture, dispense each with separate equipment.

4.2.2 Truck Mixers and Truck Agitators

Use truck mixers for mixing and hauling concrete and truck agitators for hauling central-mixed concrete that meet the requirements of CSA A23.1, and the Ready Mixed Concrete Association of Ontario's Truck Certification Program.

4.2.3 Non-Agitator Trucks

Use non-agitator trucks for hauling central-mixed concrete that meet the requirements of CSA A23.1, and the RMCAO's Truck Certification Program.

4.3 PAVING EQUIPMENT

Furnish the paving and finishing equipment applicable to the type of construction in this contract.

4.3.1 Slip-Form Machines

Where used, furnish machines capable of spreading, consolidating, screeding, and finishing the freshly placed concrete in one pass to provide a dense and homogenous pavement requiring minimal hand finishing. Equip the paving machine with the following:

- a. Automatic controls to control line and grade from either or both sides of the machine, or from averaging-skis that reference the grade.
- b. Vibrators to consolidate the concrete for the full width and depth of the strip of pavement being placed.
- c. A positive interlock system to stop all vibration and tamping elements when forward motion of the machine stops.

4.3.2 Self-Propelled Form-Riding Machines

- a. Where used, furnish mechanical, self-propelled spreading and finishing machines capable of consolidating and finishing the concrete with minimal hand finishing. Do not use machines that displace the fixed side forms.
- b. Furnish internal immersed tube or multiple spud vibrators. Attach vibrators to the spreader or finishing machine, or attach them on a separate carriage that precedes the finishing machine.

4.3.3 Manual Fixed-Form Paving Machines

Where used, furnish spreading and finishing machines capable of consolidating and finishing concrete up to 200mm thick.

Note: Where the contractor wishes to place slabs greater than 200mm, authorization shall be obtained from the engineer prior to concrete placement.

Note: Slabs greater than 200mm shall be internally vibrated to provide full depth consolidation without segregation.

4.3.4 Vibrators

Concrete shall be consolidated by means of surface vibrators, internal vibrators, or a combination of both that provides full depth consolidation without segregation.

- a. Furnish internal immersed tube or multiple spud vibrators for all paving more than 200mm thick. Operate the vibrators at frequencies as per manufacturer's recommendations.
- b. For the construction of irregular areas, use handheld vibrators. Operate the vibrator at a frequency in the range recommended by the manufacturer for the vibrator's head diameter.

4.4 CONCRETE SAWS

Furnish concrete saws that are capable of sawing new concrete for crack control on all concrete pavements in this contract. Equip all saws with blade guards and guides or devices to control alignment and depth.

4.5 FORMS

Furnish straight, steel, wood or metal plate wood forms with a height equal to the nominal pavement thickness at the edge. For curved edges with radii less than 30m, furnish flexible or curved forms. Forms shall be according to OPSS 919 and conform to the following:

- a. Use straight forms that are 3m minimum in length.
- b. Use forms with a maximum top face deviation of 3mm in 3m.
- c. Use forms with a maximum inside face deviation of 6mm in 3m.
- d. Equip each form with devices to adequately secure the form to the subbase or subgrade, and to withstand operation of the paving equipment and pressure of the concrete.
- e. Equip each form with devices to tightly join and lock each end to the abutting section.

4.6 JOINT SEALING

Furnish joint sealing equipment, if required, according to the sealant manufacturer's recommendations for the sealant specified in the plans.

4.7 FINISHING TOOLS

Furnish magnesium hand finishing tools.

4.8 DOWEL ASSEMBLIES FOR PRE-PLACED DOWEL BARS

Where dowel bars are required, and dowel assemblies (baskets) are used, and are fastened to the subbase using steel staking pins for granular materials or nailing clips for stabilized materials. Care must be taken in positioning the baskets so that the joints can be sawed directly over the basket and perpendicular to the centerline. Consolidation of the concrete around the dowel bars must be completed during concrete placement.

4.9 AUTOMATIC DOWEL BAR INSERTER

Where dowel bars are required, and an automatic dowel bar inserter is used, it must be capable of placing dowels as specified. The dowel bars shall be inserted to mid-depth of the slab and centered on the transverse joint locations and spaced as shown on the plans. The equipment shall be capable of consolidating the concrete around the dowel bars.

4.10 DIAMOND GRINDER

Where a diamond grinder is used, it shall be power-driven, self propelled equipment specifically designed to grind and texture concrete pavement and concrete base. It shall be equipped with a grinding head with at least 50 diamond blades per 300mm of shaft. The grinding head shall be at least 0.9m wide. The grinder shall be equipped with the capability to adjust the depth, slope and crossfall to

ensure that concrete is removed to the desired dimensions and uniformly feathered and textured across the width and length of the required area. The equipment shall also include a slurry pick-up system.

5.0 CONSTRUCTION REQUIREMENTS

5.1 SUBGRADE PREPARATION

Preparation of the subgrade shall include the following activities:

- a. Compacting soils shall be completed at moisture contents and densities that will ensure uniform and stable pavement support.

Note: All soft, yielding material or other portions of the subgrade that will not compact to specification shall be removed and replaced with suitable material. The subgrade shall be brought to a firm unyielding condition with a uniform density. It shall be compacted at or above optimum moisture content to 95% Standard Proctor density.

Note: High plasticity subgrade soils should be compacted at moisture contents slightly above optimum values to minimize the potential for future swelling.

- b. Whenever possible, set grade lines high enough and make side ditches deep enough to increase the distance between the water table and the pavement.
- c. Cross-hauling and mixing soils to achieve uniform conditions in areas where there are abrupt horizontal changes in soil types.

Note: Concrete pavements require continuous and uniform support. Subgrades having abrupt changes in material type or moisture content may result in differential movement causing non-uniform support for the pavement slab.

- d. Using selective grading in cut and fill areas to place the better soils nearer to the top of the final subgrade elevation.
- e. Improving extremely poor soils by treating them with lime, cement, cement kiln dust, or fly ash, or by importing better soils, whichever is more economical.

Note: When concrete is placed directly on the subgrade, it should be checked for conformity with the cross-section tolerance. The finished surface should not deviate more than 0mm above and 20mm below the specified grade and cross-section, and the surface should not deviate more than 10mm at any place on a 3m template.

Note: In areas where frost heave may be a concern, placement of a layer of insulation in the road bed to retard geothermal heat loss, thereby reducing the depth of frost penetration has been used as an economical solution to the problem of frost heave dating back to the late 1960's. This is a technique still being used today.

5.2 SUBBASE PREPARATION

The subbase shall consist of specified material and have a compacted thickness and density of not less than that specified in the contract documents. Prior to placing concrete, the subbase shall be thoroughly wetted.

Note: Wetting of the subbase shall be carried out, such that standing water is not present.

Note: Although a subbase may not be needed for pavement structural design, it is often provided as a working surface for the concrete placement operation, to prevent subgrade pumping from heavy, frequent truck traffic, or to provide a drainage layer.

Note: For slip-form paving, it is important that the subbase travelled by the tracks of the paving machine be firm and have a smooth surface.

Note: The prepared subbase shall be checked for conformity with the cross-section and grade tolerances. The finished surface of the subbase shall not deviate more than 0mm above and 20mm below the specified grade and cross-section, and the surface shall not deviate more than 10mm at any place on a 3m template.

5.3 CURB, GUTTERS, MANHOLES AND CATCH BASINS

Manholes, catch basins and their frames shall be isolated full-depth from the mainline pavement by round-outs using the jointing procedures described in section 5.9.

5.4 FORMS AND GUIDE LINES

5.4.1 Fixed-Form Paving

- a. Sideforms shall be steel, wood or metal plate wood forms. They shall be of such cross section and strength, and so secured as to resist the pressure of the concrete when placed, and the impact and vibration of any construction equipment they support without springing or settlement. For curves of 30m radius or less, flexible or curved forms should be used. Where required, forming strips for keyways should be accurately dimensioned and securely fastened against the form face.
- b. Forms shall be pinned securely, tolerances of 6mm in 3m in horizontal alignment and 3mm in 3m in vertical alignment.
- c. Forms should be fully and continuously supported over the subgrade or subbase by one or both of the following methods:
 - i. The subgrade or subbase under the forms should be trimmed and compacted to ensure the forms are uniformly supported over their entire length at the correct level and grade.

- ii. Forms should be adjusted to the correct level by the use of steel shims or wedges, and the space between the subgrade or subbase and the form should be filled solid and trimmed flush with the inside of the form.
- d. Forms shall be set sufficiently in advance of concrete placement to permit inspection.
- e. Forms shall be cleaned and coated with acceptable form release agent before each use.
- f. Forms should remain in place until the concrete has set sufficiently to avoid damage to the pavement edge or any projecting tie-bars or dowels upon removal.

5.4.2 Stringlines for Slip-Form Paving

- a. Stringlines shall be placed on both sides of the slip-form equipment. Stringlines may be omitted when abutting existing pavement.
- b. Stringlines should be fixed sufficiently in advance of the paver to permit inspection.

5.5 TRANSPORTING AND PLACING CONCRETE

5.5.1 Transporting

- a. The concrete mixing, delivering and spreading operations shall be coordinated to provide a uniform rate of progress of the paving equipment minimizing stopping and starting.
- b. Concrete mixed at a central mixing plant shall be transported to the paving site in truck mixers, truck agitators or non-agitating trucks. When non-agitating trucks are used to haul concrete, no more than 30 minutes shall elapse from the time water is added to the mix until the concrete is deposited at the paving site. When truck agitators are used, the elapsed time should not exceed 90 minutes.
- c. During mixing and transportation of concrete, truck mixers shall be operated at the speeds designated by the manufacturer, as shown on the manufacturer's rating plate attached to the drum unit.
- d. Concrete shall be transported to its final position, such that segregation or loss of slump is minimized and the concrete has the required workability at the point and time of discharge.
- e. Concrete trucks or truck mixers shall not operate from previously paved lanes until the concrete has achieved a compressive strength of 20MPa, as per OPSS 350. If equipment operating in the paving lane causes rutting or displacement of the subbase or subgrade material then lighter trucks, suitable runways, tracked equipment, or combination of these procedures shall be used.

5.5.2 Placing Concrete

- a. Concrete shall be placed on a dampened subgrade or subbase, and as close as possible to its final position, so as to minimize rehandling.
- b. Hand spreading of concrete shall be done with a come-along or square ended shovel (rakes shall not be used).

- c. Concrete shall be placed as near as possible to a dowel assembly, but shall not be dumped directly onto the assembly.
- d. Concrete shall not be placed in snow or ice or on a frozen subgrade or subbase.

5.6 PAVING

5.6.1 Equipment

Place concrete with fixed-form or slip-form paving equipment. Operate the paving equipment with a continuous forward movement, as practicable, and coordinate mixing, delivering, and spreading concrete to provide uniform progress.

Note: Except in an emergency, apply no tractive force to a slipform-paving machine, except that which is controlled from the machine.

5.6.2 Reinforcing Steel

Place reinforcing steel as shown in the contract documents. Either firmly position the reinforcement on acceptable supports before placing the concrete or mechanically insert the reinforcement into the plastic concrete to the required location and alignment tolerances.

5.6.3 Irregular Areas

In irregular areas or areas inaccessible to self-propelled paving equipment, construct the pavement using fixed forms and manual fixed-form paving equipment. Thoroughly and uniformly vibrate and consolidate the concrete during placement without segregating the material. Use handheld internal vibrators along forms and around embedded objects, including dowel baskets and utility fixtures, where necessary to ensure adequate consolidation.

5.6.4 Hot and Cold Weather

When paving in extremely hot or cold air temperatures, use adequate concrete protection measures. Concrete that the engineer suspects was damaged by frost action or excessive heat is subject to additional testing to determine its quality.

5.7 CONSOLIDATING AND FINISHING

5.7.1 Consolidation

- a. The sequence of operations shall be the strike-off and consolidation, floating, if necessary, straight-edging, and final surface finish.
- b. Concrete shall be thoroughly consolidated against and along the face of all forms and into the face of previously placed concrete.

Note: The rate of progress of either slip-form or fixed-form paving machines should be adjusted to ensure complete consolidation of the concrete along the full width of the paver.

Note: See ACI 309, *Standard Practice for Consolidation of Concrete*, for guidance.

Note: Thorough consolidation is important and necessary for: maximum strength, sharp details at edges and joints, and good bond to tie bars.

- c. For fixed-form pavers with vibrating screeds, hand-held vibrators shall be used to supplement consolidation adjacent and along the full length of the form. They should also be inserted at regularly spaced intervals along both sides of dowel assemblies. The vibrators shall not come in contact with the subgrade or subbase, forms or dowel assemblies. Vibrators shall never be operated longer than 15 seconds in any one location, as per ACI 309.
- d. Speed and operation of vibrating beam pavers should be in accordance with manufacturers' recommendations.

Note: Some pavers require two passes or two beams set in tandem to achieve desired consolidation and surface profile. The speed is usually in the 0.5 to 1.0 m/min range.

- e. For slip-form pavers, the concrete shall be consolidated by internal vibrators of sufficient number, spacing and frequency to provide uniform consolidation to the entire pavement width and depth. The vibrators shall not operate while the paver is stopped.

Note: For slabs up to 250mm thick, the vibrators should be mounted at mid-depth and parallel to the subgrade or subbase. For depths greater than 250mm, vibrators should be mounted with the tips a minimum of 50mm above the subgrade or subbase and the top a minimum of 50mm below the surface of the concrete.

Note: Proper consolidation has been achieved when the surface of the concrete has a uniform texture, with no mortar streaking, uniform sheen, with the coarse aggregate barely visible on or immediately below the surface.

Note: Prior to the construction of the pavement, a test section of pavement should be constructed to evaluate the paving machine operation and performance. The air void system and density of the concrete should be checked, as well as its compressive or flexural strength. Approval of the test section by the engineer should be obtained.

5.7.2 Finishing

- a. Adding water to the surface of the concrete to assist the finishing operation shall not be permitted. A fine spray of water shall be permitted only to prevent drying shrinkage cracking caused by rapid evaporation of surface moisture. Only approved spray equipment may be used.
- b. Following strike-off and consolidation, the concrete pavement shall be struck-off with a magnesium straightedge 3m long, equipped with a handle to permit operation from the edge of the pavement, if required.
- c. The straightedge shall be drawn perpendicular to the centerline of the pavement and should be moved forward, in the direction of the paving, one-half of its length after each pass. Irregularities should be corrected by the addition or removal of concrete. All disturbed surfaces should again be straightedged.

Note: When slip-form pavers exhibit edge slumps in excess of specified tolerances, the engineer may direct that the contractor use temporary side forms for surface correction during the scraping operation.

- d. The final surface texture shall be applied, as specified, following the straightedge and edging operation.

Note: A burlap drag or broom is acceptable on low speed facilities; on high-speed facilities, a burlap or astro-turf drag with a tined texture should be used.

- e. A burlap drag shall be wide enough to cover the entire pavement slab and should be at least 1m long with a minimum of 500mm in contact with the concrete surface. The burlap shall be kept in a clean and damp condition, free from encrusted mortar. It should be placed on the surface and dragged in the direction the pavement was placed.
- f. A broom finish shall be obtained by the use of a stiff, coarse fibre broom. A tined finish should be obtained by the use of a device having randomly spaced wire tines with spacing varying from 10 to 40mm with 50 percent of the spacings less than 25mm. The device used shall be dragged transversely across the pavement to form grooves in the surface of the pavement. The width of grooves should range from 2 to 3mm, and the depth of the grooves from 3 to 5mm. Texturing shall be delayed until the concrete is sufficiently hard to retain the ridges. Longitudinal tinning may also be specified by the owner.
- g. Final texturing shall be determined in the field on the pavement to the satisfaction of the authorities having jurisdiction.
- h. The contractor shall have available material to protect the surface of the plastic concrete from damage by rain. These materials may consist of burlap, cotton mats, waterproof paper or plastic sheeting. Pavement protection shall be employed when rain, sufficient to spoil the texture of the concrete surface, is expected. When slip-form construction is used the edges of the pavement shall be protected.

Note: No concrete should be placed during rain. When rain appears imminent, paving operations should cease and the necessary steps for complete protection of plastic concrete pavement surface commenced, as well as the provision of a construction joint as shown on the drawings.

5.8 CURING AND PROTECTION

5.8.1 Curing

- a. The contractor shall have the material and equipment needed for adequate curing on hand and ready to install before actual concrete placement begins.
- b. Curing shall be according to OPSS 904 with the following exceptions:

Note: Desirable properties of concrete pavements, such as strength, durability and wear resistance, improve with continuous hydration of the cement as a result of good curing practice.

- i. Curing shall be applied to all exposed surfaces as soon after the texturing operation as can be achieved without damaging the surface.
- ii. As soon as forms are removed, the sides of the exposed concrete faces shall be sprayed with the white pigmented curing compound at the specified rate of application. Curing compound shall not be applied to joint faces receiving sealant or to concrete surfaces to which concrete or mortar is to be bonded.
- iii. In extremely hot temperatures, consideration should be given to adding set-retarding admixtures, early morning or evening placement, or other means to keep the concrete temperature as low as possible when placed.
- iv. When concrete has been placed in cold weather and the air temperature is expected to drop below 5°C, insulated curing blankets or other suitable material shall be placed on the concrete pavement and weighted to prevent movement. Curing shall continue until the cumulative number of days, or fraction thereof, during which the temperature of the concrete is above 10°C, has totaled a minimum of 7 days.

Note: Corners and edges are most vulnerable to damage from freezing and should receive additional insulation protection.

- v. Concrete pavement placed in cool weather shall experience a minimum 30 day air-drying period, following final curing, before the first application of de-icing salts.

Note: A period of air-drying increases the resistance of the surface of the pavement to possible damage caused by deicer applications. Membrane-forming curing compounds tend to delay air-drying. In some jurisdictions, use of membrane-forming curing compounds is not permitted following October 15.

5.8.2 Protection

- a. During the seven days following placing, the concrete temperature shall not fall below 10°C or exceed 27°C.
- b. Concrete shall not be placed in the rain. The contractor shall take all necessary precautions to protect plastic concrete from the rain.
- c. Traffic, other than foot traffic, rubber-tired sawing equipment, and rubber-tired side wheels of form mounted placing and finishing equipment necessary to construct adjacent lanes, shall not be permitted on the concrete until it has attained 20MPa.
- d. The concrete pavement shall be protected from damage to the surface at all times when steel-tracked equipment is used.

5.8.3 Hot Weather Concreting

- a. The temperature of the concrete at the time of placement shall be between 10°C and 28°C.
- b. The temperature of formwork, reinforcing steel or the material on which the concrete is to be placed, shall not exceed 30°C.

5.8.4 Cold Weather Concreting

- a. The temperature of the concrete at the time of placement shall be between 10°C and 28°C.
- b. Ice and snow shall be removed from the area where concrete is to be placed. Deicing chemicals shall not be used.
- c. Concrete shall not be placed on or against frozen ground. Excavations prepared for concreting and any existing concrete, reinforcing steel, structural steel, forms or other surfaces against which concrete will be placed, shall be at a minimum temperature of 5°C for a period of 12h prior to commencement of placing concrete.
- d. All cold weather protection material shall be on site prior to each concrete placement.
- e. The 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.
- f. The contractor shall monitor the conditions and modify the protection system as required.

5.9 JOINTING

Joint layout is critical for prevention of uncontrolled cracks, especially for complex geometries and intersections. Joints shall be of the type and at the location shown in the Contract, and cleaned and sealed according to OPSS 369. Load transfer devices shall be as shown in the contract.

Note: For joint layout – match existing joints or cracks; place joints to meet in-pavement structures; remember maximum joint spacing; place isolation joints where needed; understand that adjustments to joint locations can be made in the field; and be practical.

Note: Avoid – slabs less than 0.6m or greater than 4.5 wide; angles less than 60° (~90° is best, do this by dog-legging joints through curve radius points); creating interior corners; odd shapes (keep slabs near-square or pie-shaped).

5.9.1 Contraction Joints

- a. Transverse contraction control joints and all longitudinal joints shall be constructed and located as indicated on the drawings.
- b. Transverse and longitudinal joints shall consist of planes of weakness created by forming or cutting vertical grooves in the pavement surface.

Note: The method of constructing control joints will depend on the construction method, the size of the project and the required riding quality.

- c. Transverse contraction joints shall extend to a minimum depth of 1/3 the thickness of the slab. They shall be located at a spacing not exceeding 30 times the thickness of the slab, with a maximum distance of 4.5m between joints.

- i. Sawed transverse control joints shall be located on the surface of the pavement by suitable marking in advance of sawing. A standby saw and blades must be available in the event of equipment breakdown.
- ii. Sawing shall commence as soon as the concrete has hardened sufficiently to permit sawing without excessive raveling (usually within 6 to 12 hours). Earlier sawing may be achieved with specialized methods if approved by owner.

Note: Air temperature, wind and humidity levels will dictate how soon sawing can commence.

- iii. Sawing of any joint shall be omitted if a random crack has developed at or near the joint location before the time of sawing. Sawing should be discontinued if a crack develops ahead of the saw.

Note: When a crack occurs ahead of the sawing, usually as a result of sawing too late, remedial measures may be required, such as sawing every third or fourth joint followed by sawing the intermediate joints.

- iv. Sawed grooved forming a reservoir for joint sealant shall be formed to requirements or manufacturer specifications.
- v. Concurrent with the reservoir sawing operation, the grooves shall be cleaned of laitance and grit by high pressure water jets.
- vi. Transverse contraction joints shall extend continuously across the mainline pavement and curb or shoulder.

5.9.2 Longitudinal Joints

- a. Longitudinal joints shall consist of planes of weakness created by cutting or forming grooves in the surface of the pavement at the locations shown on the drawings. The depth of the joint shall be at least one-third the slab thickness.
 - i. Sawed longitudinal joints shall be constructed similar to the procedure for transverse contraction joints – Clause 5.9.1.c.i.

5.9.3 Construction Joints

- a. Transverse construction joints should be made at the end of each day's run or whenever the placing of concrete is interrupted for more than 30 minutes.
- b. Longitudinal construction joints shall be of the dimension shown on the drawings. When a key is required, it shall be constructed by forming or extruding when the first lane adjacent the joint is placed. Dimensions of the keyway shall not vary more than 2mm from the dimensions shown on the drawings, and not more than plus or minus 4mm the mid-depth of the pavement.
 - i. Longitudinal construction joints shall be edged with a small radius edger and textured to match adjacent concrete.

5.9.4 Isolation Joints

Isolation joints shall be constructed around maintenance holes in catch basins and against existing structures or objects within or abutting the pavement, and at intersections as shown on the drawings. The isolation joint filler shall be held in a vertical position, and shall be continuous from edge to edge with no gaps, and should extend the full depth of the pavement. The joint shall be edged and textured to match the adjacent surface. The finished joints should not deviate in horizontal alignment more than from a straight line.

5.9.5 Dowel bars

Dowel bars are smooth, round steel bars placed across transverse joints. Dowel bars are used to provide load transfer while permitting a joint to open and close.

- a. Dowel bars when required shall conform to the requirements of OPSS 1441.
- b. Dowels shall be epoxy coated, smooth, straight and free from dirt. The free ends shall be beveled. For at least half their length, the dowels shall be coated with a bond-breaking compound, such as, oil or a form release agent, or be enclosed in a tight-fitting plastic sheath.
- c. When specified, dowels shall be placed at transverse joint locations using either dowel basket assemblies or automatic dowel bar inserters.

Note: Dowel baskets shall be pinned to remain stable and undisturbed during the paving operation.

- d. Tolerances for dowel placement shall be a deviation of not more than one degree from alignment of the pavement; and within a tolerance of ± 6 mm in the vertical and horizontal planes of the pavement.

Note: Failure to accurately align the dowels may result in a locked joint causing cracking or spalling.

- e. Dowel locations shall be visibly marked on the form, adjacent slab or by stakes or pins on the shoulder to permit accurate location for joint forming operation.

5.9.6 Tie bars

Tie bars are deformed bars used to hold adjacent pavement slabs tightly together.

- a. Tie bars shall be deformed reinforcing bars. Bent tie bars may be used. Epoxy-coated tie bars shall be used and shall conform to the requirements of OPSS 1442.
- b. Tie bars shall be free of any lubricant or coating which may reduce the bond with the concrete. They shall be located at the mid-depth of the slab, as shown on the drawings and installed so they do not deviate more than 20mm from mid-depth.

Note: For fixed-form paving, tie bars may be located in openings in the form face.

Note: For slip-form paving, tie bars may be inserted through temporary side forms located behind the paver, or mechanically inserted into the plastic concrete by approved devices associated with the slip-form paver.

- c. Tie bars shall be inserted in such a manner that no voids are created around the tie bar, and no distortion of the pavement surface occurs.

5.9.7 Sealing Joints

- a. Joint sealing shall be according to OPSS 369.
- b. Joint sealants shall be installed to joint sealant manufacturer's specification.
- c. Joints specified to be sealed shall be filled with joint sealing material before pavement is open to traffic.
- d. Just before sealing with field-moulded sealants, joints shall be abrasive blast cleaned, followed by air-blasting with compressed air free of oil and moisture. The joint faces should be clean and dry when the sealing material is applied.

5.10 OPENING TO CONSTRUCTION EQUIPMENT

Protect previously-constructed lanes from damage by construction equipment. Only allow equipment on the previously constructed concrete after the concrete attains a compressive strength of 20MPa, as per OPSS 350.

6.0 STRENGTH TESTING AND EVALUATION

6.1 ACCEPTANCE REQUIREMENTS

Acceptance of the concrete pavement for each lot will be based on the mean and standard deviation of the lot measurements for compressive strength, slab thickness and smoothness. The engineer will calculate the Percent Within Limits (PWL) for each criterion as described in LS-101.

6.1.1 Concrete Strength Evaluation

- a. Compressive strength test results shall be used as the basis for acceptance or rejection of the concrete. Performance based mix submissions shall include a correlation of compressive strength to flexural strength.
- b. When cylinders are specified, the average compressive strength of all sets of three consecutive strength tests, made and tested in accordance with CSA A23.2-3C and CSA A23.2-9C, should not be less than that specified in 2.1.b of this document at age 28 days. No individual strength test should be more than 3.5MPa below the specified strength.
- c. When cores are specified, the compressive strength shall be tested when the concrete is 28 to 35 days old. If the contractor elects to core prior to 28 days, the compressive strength test will be performed within two days of coring. The cores shall be stored in the laboratory at an ambient air temperature of $\geq 15^{\circ}\text{C}$ and $\leq 25^{\circ}\text{C}$ and moisture conditioned for 40-48

hours prior to testing. The testing shall be in accordance with CSA A23.2-9C. The PWL shall be greater than 50%, with no individual core less than 60% of the specified compressive strength, as per OPSS 350.

6.1.2 Thickness

The slab thickness will be determined based on core length for each subplot; each core shall be measured for length prior to trimming. Four measurements rounded to the nearest millimeter shall be made around the perimeter of the core to determine the actual concrete thickness. These measurements shall be taken at the ends of two perpendicular diameters. The PWL shall be greater than 50%, with no individual core less than 60% of the specified slab thickness, as per OPSS 350.

6.1.3 Smoothness

The finished surface shall be tested for smoothness by use of a 3m long straightedge placed parallel to the center line of the pavement in each wheel line.

6.1.4 Tolerance in Pavement

The surface of the concrete is to be such that when tested with a 3m long straightedge placed in any location and direction, including the edge of pavement, except across the crown or drainage gutters, there shall not be a gap greater than 3mm between the bottom of the straightedge and the surface of the pavement.

6.1.5 Frequency and Number of Tests

The frequency and number of tests for compressive strength, air content, slump and temperature of the plastic concrete shall be in accordance with CSA Standard A23.1, unless otherwise specified in the contract documents.

- a. Strength: Not less than one test for every 100m³ of concrete placed, with no fewer than one test for each class of concrete placed on any one day.
- b. Slump: A sufficient number of tests must be conducted to establish consistency. It is recommended to test the first 3 loads per mix per day, one for every strength test, and one for every air test.
- c. Air Content: For classes C-XL, C-1 and C-2, every load until consistency is attained, every 3rd load thereafter. An air test must be performed with every strength test.

6.2 OPENING TO TRAFFIC

The pavement may be open to traffic when specimen cylinders conforming to the requirements stated above have attained 20MPa, as per OPSS 350; or cores conforming to the requirements stated above have attained 17MPa.