

Best Management Practices for  
**Municipal Concrete  
Infrastructure**





# Acknowledgements

## Committee Members

---

Tracy Blanchard	City of Orillia
Chris Bradley	County of Peterborough
Peter Bziuk ( <b>Committee Chair</b> )	County of Essex
Sean Frye	Danruss Contracting/Ready-mix
Rico Fung	Cement Association of Canada
Devin Gordon	Miller Group
Neil Johnston	Slip Form Construction
Bart Kanters	Concrete Ontario
Alen Keri	Concrete Ontario
Gerald Kernohan	Dufferin Concrete
Chris McColl	Dufferin Concrete
Matthew Miedema	City of Thunder Bay
Mark Popik	Thurber Engineering
Mick Prieur	Capital Paving
Eric Saunderson ( <b>Technical Editor</b> )	Region of Waterloo
Bradley Schmidt	Dillon Consulting
Bryan Schulz	Canada Building Materials
James Smith	Ontario Good Roads Association
Tim Smith	Lafarge North America
Frank Suppa	City of Vaughan
Peter Waisanen	exp Services

---

Corresponding Member: Doug Hooton, University of Toronto

### Disclaimer

The material presented in this text was carefully researched by the Ontario Good Roads Association (OGRA), Municipal Concrete Liaison Committee. Unfortunately no warranty expressed or implied is made on the accuracy of the contents or their extraction from reference to publications; nor shall the fact of distribution constitute responsibility by OGRA, Concrete Ontario (previously Ready-Mixed Concrete Association of Ontario - RMCAO) and the Cement Association of Canada (CAC), or any researchers or contributing authors for omissions, errors or possible misrepresentations that may result from use of interpretation of the material contained herein. This manual is intended to represent a synopsis of concrete infrastructure best practices. The manual may require updates as new applications mature and you are encouraged to share your best practice by contacting Concrete Ontario or the Cement Association of Canada or the Ontario Good Roads Association.

# Message from the Chair

The evolution of concrete-like structures pre dates the construction of the Roman Coliseum. The continued development of concrete materials and most recent enhancements include air entraining c.1930, fiber reinforcement c. 1970 and super plasticizer c. 1980.

With the addition of steel reinforcement the challenge of constructing sustainable concrete infrastructure has delivered the Confederation Bridge (P.E.I.), the C.N. Tower (Toronto), the Freeport Bridge (Kitchener Waterloo), the Canadian Museum of History (Gatineau), sections of the 400 series highways in Ontario and numerous other bridges and highways across Canada as shown in Figure 1.

The concrete industry takes pride in producing reliable and sustainable infrastructure assets to serve the needs of commuters, commerce and municipal customers. The reliability of those concrete assets is vital to economic growth, movement of goods and employment. Similar to other employment sectors, the concrete industry is at risk of an aging population about to retire. As the workforce takes the exit ramp into their golden years, the institutional knowledge and experience will also leave.

The people are key to the success of the concrete industry. While many of those people are employed with contractors, consulting firms, educational institutions and government offices, some of those same people are contributing authors to this Best Practices Manual. The primary objective of this manual is the continued success of the concrete industry. The transfer of knowledge and best practices starts here.



Figure 1: City Centre Drive, Mississauga (photo provided by Concrete Ontario).



# Table of Contents

<b>Acknowledgements</b> .....	3
<b>Message from the Chair</b> .....	4
<b>Glossary of Terms</b> .....	5
<b>Chapter 1</b>	
Introduction.....	9
<b>Chapter 2 - Sidewalk, Curb &amp; Gutter Evaluation and Inspection</b>	
2.1 Sidewalk Inventory and Assessment.....	10
2.2 Temporary Sidewalk Restoration.....	10
2.3 Sidewalk Replacement.....	11
2.4 Sidewalk Condition Index.....	11
2.5 Curb / Curb and Gutter Replacement.....	12
<b>Chapter 3 - Asset Management and Rigid Pavement Selection</b>	
3.1 Asset Management.....	13
3.2 Economical Assessment.....	13
3.3 Subgrade Soil and Traffic Evaluation.....	14
3.4 Pavement Selection.....	15
3.5 Equivalent Pavement Design.....	15
3.6 Components of a Conventional Concrete Pavement.....	17
3.7 Types of Concrete Pavement.....	18
<b>Chapter 4 - Concrete Bridges</b>	
4.1 Introduction.....	24
4.2 Concrete Bridge Inspection.....	24
4.3 Bridge Rehabilitation.....	26
4.4 New Technologies.....	28
<b>Chapter 5 - Sustainability</b>	
5.1 Cement.....	29
5.2 Long Life Pavement.....	30
5.3 Traffic Delays.....	30
5.4 Heat Island Reduction and Cooling Effects.....	31
5.5 Lighting and Electricity Use.....	31
5.6 CO <sub>2</sub> Sequestering.....	32
5.7 Reduction in Virgin Aggregate Usage.....	32
5.8 Pavement-Vehicle Interaction.....	32
5.9 Two-lift Concrete pavements.....	33
5.10 Thin pavements.....	33
5.11 Diamond Grinding/Grooving.....	34
5.12 Concrete Recycling.....	34
5.13 ECO Certified Plants.....	34
5.14 Enhanced Aesthetics and Societal Benefits.....	35
<b>Chapter 6 - Life-Cycle Cost Analysis (LCCA)</b>	
6.1 Equivalent Pavement Design Example.....	38
6.2 Equivalent Pavement Design - Initial Construction, Maintenance and Rehabilitation Costs.....	40
<b>Chapter 7 - Unshrinkable Fill (U-Fill)</b>	
7.1 Introduction.....	41
7.2 Materials.....	42
7.3 Plastic Properties.....	42
7.4 Harden Properties.....	43
<b>Chapter 8 - Architectural Concrete</b>	
8.1 Types of Architectural Concrete.....	44
8.2 Cast-in-Place Horizontal Surfaces-Decorative Concrete.....	45
8.3 Qualifications and Specifications.....	49
<b>Chapter 9 - Concrete Jointing</b>	
9.1 Construction Joints.....	53
9.2 Contraction Joints.....	54
9.3 Isolation Joints.....	54
9.4 Expansion Joints.....	55
9.5 Joint Sealant.....	56
<b>Chapter 10 - Procurement</b>	
10.1 Plan Purchases and Acquisitions.....	59
10.2 Planned Contracting.....	60
10.3 Contracts.....	61
10.4 Contract Administration.....	62
10.5 Contract Closure.....	63
<b>Chapter 11 - Pre-Construction &amp; Pre-Placement Meetings</b>	
Pre-Construction & Pre-Placement Meetings.....	64
<b>Chapter 12 - Concrete Ordering Procedures</b>	
12.1 Concrete Order Entry.....	65
12.2 Directions to the Jobsite.....	66
12.3 Dispatch Process.....	66
12.4 Specialty Concrete Products.....	66
<b>Chapter 13 - Transportation and Receiving Concrete</b>	
Transportation and Receiving Concrete.....	68
<b>Chapter 14 - Convey, Placing, Consolidating and Finishing Concrete</b>	
Convey, Placing, Consolidating and Finishing Concrete.....	70
<b>Chapter 15 - Concrete Protection and Curing Requirements</b>	
15.1 Concrete Protection.....	73
15.2 Concrete Curing.....	75
<b>Chapter 16 - Measurement, Testing and Acceptance of Concrete</b>	
16.1 Minimum Testing Qualifications of Laboratories and Personnel.....	79
16.2 Normal Plastic (On-site) Concrete Test Methods.....	80
16.3 Standard Frequency of On-site Testing.....	80
16.4 Distribution of Concrete Test Reports.....	81
16.5 Recording and Reporting of Test Reports.....	82
16.6 Evaluation of Concrete Hardened Properties.....	82

# Table of Contents

## Chapter 17 - Project Closeout and Continuous Improvement

17.1	Deficiency Identification and Rectification Work.....	85
17.2	Substantial Completion and Contract Maintenance Period.....	85
17.3	Continuous Improvement and Lessons Learned.....	86
17.4	Contractor and Consultant Performance Evaluation.....	86

## Chapter 18 - Troubleshooting 101

18.1	Plastic Concrete.....	88
18.1.1	Air Loss - Concrete pumping	88
18.1.2	Air loss - Excessive vibration	88
18.1.3	Excessive bleeding	89
18.1.4	Plastic shrinkage cracking	89
18.1.5	Blistering	90
18.1.6	Segregation	90
18.2	Vertical Work	91
18.2.1	Honeycombing	91
18.2.2	Cold Joints	92
18.2.3	Bugholes	92
18.3	Flatwork	93
18.3.1	Low Spots	93
18.3.2	Popouts	93
18.3.3	Uncontrolled drying shrinkage cracks	94
18.3.4	Settlement Cracks	95
18.3.5	Crazing	95
18.3.6	Curling	95
18.3.7	Dusting	96
18.3.8	Scaling	97
18.3.9	Mortar Flaking	98
18.3.10	Faulting	98
18.3.11	Blow-ups	99
18.4	Pavements	100
18.4.1	Segregation	100
18.4.2	Joint Lockup	100
18.4.3	Longitudinal / transverse cracking following placement	101
18.4.4	Low skid resistance	103
18.4.5	Noise Complaints	103
18.5	Common Troubleshooting	110
18.5.1	Low Strength	104
18.5.2	Thermal Cracking	105
18.5.3	Delamination	106
18.5.4	Discolouration	106
18.5.5	Alkali Aggregate Reactivity (Silica or Carbonate)	107
18.5.6	Contamination	108

## Appendix

Appendix A: RMCAO Plant Certification Program.....	109
Appendix B: OGCA Gold Seal Program.....	110
Appendix C: Concrete Test Forms & Reporting - CMATSTM.....	111
Appendix D: Concrete Order Form.....	113
Appendix E: Mix Design Submission Form.....	114
Appendix F: Checklist for Concrete Pre-Construction Conference.....	116
Appendix G: CCIL Concrete Certification Program.....	142
Appendix H: Checklist for Concrete Pumping.....	143
Appendix I: Specialty Concrete Applications.....	147
Appendix J: Summary of CSA Exposure Classes.....	149
Appendix K: Checklist for Concrete Ordering and Scheduling.....	153
Appendix L: Checklist for Concrete Curb and Gutters / Sidewalks.....	158

# Glossary of Terms

**Air Content:** The amount of entrapped or entrained air in a concrete mix; expressed as a percentage of the total volume. Properly air entrained concrete will prevent cracking during freeze-thaw cycles.

**Air Entrainment:** When an admixture is added to a concrete mix design which causes a controlled quantity of very small air bubbles to form in it. This is typically done to increase a concrete's workability along with freeze/thaw resistance.

**Bull-Float:** A tool made up of wood, aluminum or magnesium used to spread and smooth freshly placed concrete.

**Carbonation:** A chemical reaction between the carbon dioxide in the air and the hydration compounds in the cement of the concrete.

**Cold Weather:** Those conditions when the air temperature is at or below 5°C. It is also considered to exist when the air temperature is at or is likely to fall below 5°C within 96 hours after concrete placement.

**Compressive Strength:** The maximum compressive load which concrete can sustain before it fractures.

**Concrete Pavement:** A rigid pavement structure with an exposed concrete surface.

**Consistency:** The ability of a fresh concrete to flow, which can be measured by a slump test.

**Consolidation:** The process of removing entrapped air from freshly placed concrete. Several methods and techniques are available; however the most common method used is vibration.

**Construction Joint:** A joint where two successive concrete placements meet or where new concrete is placed against old concrete.

**Contraction Joint (control joint):** A sawed, grooved, or formed joint in concrete used to control random cracking caused by drying and thermal shrinking of the concrete.

**Curing:** An action taken which maintains favourable temperature and moisture conditions in freshly placed concrete to allow for it to set to its desired strength. The length of curing time varies depending on the size and shape of the concrete section, mix design, cement type, weather, and future exposure conditions. Insufficient curing can lead to premature failure.

**Curing Compound:** A liquid chemical compound applied to the surface of the concrete to prevent loss of moisture during early stages of hydration.

**Cylinder Test:** A lab test which determines the compressive strength of a concrete cylinder; with a height to diameter ratio of 2:1, by compressing it under a hydraulic ram to determine the amount of pressure required to fracture it. This test is usually used to verify that the specified strength of a concrete mix has been achieved.

**Direct Fired Heater:** A style of heater that forces air directly through a flame to heat the air.

**Exposure Class:** The minimum concrete performance is specified based on which exposure class the concrete falls under. This is determined by the applicable exposure conditions, structural, architectural and durability requirements for the concrete.

**Feasibility Study:** An analysis of the ability to complete a project successfully, taking into account legal, economic, technological, scheduling and other factors.

**Flexural Test:** A measure of an unreinforced concrete specimen to resist failure (fracture) in bending. The maximum flexural strength is measured by loading the span of a concrete specimen; with a span length to depth ratio of 3:1, until failure.

**Fresno:** A steel trowel used in finishing the surface of concrete after it has been floated with a wood or magnesium float.

**Hot Weather:** Those conditions when the air temperature is at or above 28°C. It is also considered to exist when the air temperature is at or is likely to rise above 28°C within 24 hours after concrete placement.

**Housing and Heating System:** An enclosure built around concrete with heat applied used to protect the concrete during the curing process.

**Hydration:** The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products.

**Hydronic Heating:** A heating system in which hot water runs through radiant tubing used to maintain curing temperatures or thaw frozen ground.

**In-Direct Fired Heater:** A style of heater that uses a flame contained in a burn chamber which heats an exchanger. Air passes over and around the heat exchanger thus heating the air.

**Permeability:** The property which governs the rate of flow of a fluid through a porous concrete.

**Plastic:** The state at which a freshly mixed concrete is workable and readily mouldable.

**Segregation:** In concrete technology, segregation can be of two types. Firstly the coarse aggregate may separate from the main mass of concrete in its plastic state. Secondly, the grout (cement paste) may separate from

the mix.

**Slump:** A measure of the consistency of freshly mixed concrete. This can be checked with a slump test. If more water is added to a mix design, the slump would increase.

**Tele-belt:** A telescopic belt conveyor mounted on a truck used to place concrete.

**Thermocouple:** A device consisting of two wires of dissimilar metals connected at two points, used to measure temperature in the concrete.

**Tining:** A style of concrete texturing creating grooves in the surface of the concrete commonly used to reduce tire-pavement noise. Grooves can be transverse or longitudinal.



1	Introduction
2	Sitewalk, Cure & Gutter Evaluation and Inspection
3	Asset Management Plan and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 1 - Introduction

The “Best Management Practices for Municipal Concrete Infrastructure (BMP-MCI)” manual has been developed by the Ontario Good Roads Association (OGRA), Municipal Concrete Liaison Committee. The Committee consists of members from various municipalities all over Ontario; consulting firms; contractors; ready-mix concrete suppliers and associations.

It is the intention of this guide to provide a resource for municipal staff, consultants, contractors and ready-mix concrete producers for municipal projects and to have a single resource for information on municipal concrete infrastructure across the province of Ontario. The Committee recognized the need to have a guide that summarizes the best practices across the province in order to provide consistency for contractors, consultants and ready-mix producers. Having everyone on the same page, no matter where they work, should reduce problems and improve communication on municipal infrastructure projects. Every effort has been made to address the known issues facing

our industry today; however, this manual is only a synopsis of best practices available in the market and may not entirely address some of the issues encountered on municipal concrete projects. For further information, participants should continue to work with their local engineering professionals and industry partners to develop solutions for project-specific issues

The manual is setup to walk you through a project from the initial concept stage to the identification of future work, material selection, planning, procurement, delivery, inspection, troubleshooting, and project closeout. Figure 1.1 shows a typical unbonded concrete overlay project in the Region of Waterloo.



Figure 1.1 - Unbonded Concrete Overlay on Spragues Road (provided by Region of Waterloo)





1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA) Basis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation of Concrete
14	Conveying, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 2 - Sidewalk, Curb & Gutter Evaluation and Inspection

Infrastructure planning consists of assessing missing links of sidewalk and curb, infrastructure needs and condition assessments. An annual review is required to document infrastructure condition of assets in accordance with minimum maintenance standards set out in Ontario Regulation 239/02. Municipalities are required to address a sidewalk defect / trip hazard greater than 2 cm within 14 days.

### 2.1 Sidewalk Inventory and Assessment

Inventory and assessment of sidewalks can be undertaken and administered through the use of the municipal staff or outsourced to private agencies through the Request for Proposal (RFP) and procurement process. Inventory and assessment should be conducted on annual basis at the municipality's discretion in the spring of each year (weather permitting) to ensure sidewalk defects can be addressed in a reasonable timeframe.

In accordance with provincial legislation, municipalities are required to address known sidewalk defects and/or tripping hazards within a 14-day period. Therefore, the municipality should document defects, such as vertical joint deflections with electronic photographs denoting the date/time and type of defect found during the 'pre-inspection' process. Additionally, a 'post-inspection' photograph should be taken following restoration of the defect and stored in the municipality's database for future monitoring. Photographs can be provided in image file formats, such as JPEG, unless otherwise directed and/or approved in writing by the municipality.

The information should be made available to whoever is collecting the data for their sole direct use for updating the status of the sidewalk defect repair and maintenance of the sidewalk condition database. If the section of sidewalk is not identified in the

municipality's asset management system, the data collector should add applicable information for inventory purposes and include sidewalk assets for future assessment. Any new sidewalk installed through capital works projects and/or new subdivisions are to be added to the inventory database for future tracking, monitoring and planning purposes.

On an on-going basis, municipal staff and/or consulting firms should be able to provide an annual report on the status of sidewalk assets and develop plans to capture their respective City-wide sidewalk condition data for the entire sidewalk network. The sidewalk assessment should include, but not be limited to, the following detailed information:

- Itemized information on the municipalities selected database;
- Global Positioning System (GPS) location or municipal address;
- Length of sidewalk sections identified by database segments;
- Width of the sidewalk and number of panels;
- Date and time of field inspections or assessments;
- Detailed documentation on sidewalk condition and appearance;
- Number of residential, commercial and industrial driveways;
- Identification of potential restoration (ex. grinding) locations including measurements; and
- Prioritization of any urgent spot repairs and sidewalk removals / replacements.

### 2.2 Temporary Sidewalk Restoration

A thorough inspection is needed to identify and estimate how many defects or joint deflections exist throughout the municipality's sidewalk network. The municipality will need to establish an appropriate level of service for the network and determine what height of deflection is necessary to warrant the various types of repairs.

One method to address trip hazards is to temporarily install asphalt ramps or grind the








edge of the joint to remove the deflection and provide a sloped surface until a permanent repair can be completed. A precision guided grinder or diamond edge saw blade can be used to cut edges and create a tapered surface which can provide a smooth transition between sidewalk panels. The contractor conducting the work can then remove any excess debris that has been cut from the joint deflection and clean the surface to remove any slurry from the grinder or saw. Upon completion, the surface of the sidewalk should be smooth, uniform, and aesthetically pleasing, all while providing a slip-resistant repair for public use following restoration.

## 2.3 Sidewalk Replacement

Generally speaking, the need for sidewalk replacement is mainly identified on an “as required” basis and typically performed by municipalities under annual rehabilitation program. Sections of sidewalk should be identified for replacement based on the overall needs for the network and prioritized based on the parameters required, such as, the geographical location of the defects, severity / number of defects and the frequency of use by area residents and/or businesses. For example, a section of sidewalk adjacent to a school or high pedestrian area should rank higher than a section of

sidewalk with low volume use. Sidewalk repairs that present a hazard to pedestrians (such as trip, slip and fall, etc.) should be promptly addressed and permanently removed / replaced with new concrete sidewalk to

**SIDEWALK DISTRESSES SUMMARY**

DISTRESS TYPE	EXAMPLE	DESCRIPTION	METHOD	RANGE	SEVERITY	EFFECT ON SCI
SPALLING		Cracks extending from the joint with pieces loosened from the fractured area.	Measure the distance from joint or crack to spalled edge	<75mm	Slight	Low
				>75mm	Moderate	Low
				>75mm	Severe	Medium
CRACKING		Cracks in sidewalk slab.	Measure the width of the crack	<3mm	Slight	Low
				3-10mm	Moderate	Medium
				>10mm	Severe	High
PATCHING		Placement of Asphalt i.e. to fix a utility cut or compensate for settling.	Measure the patch thickness	<10mm	Slight	Low
				10-30mm	Moderate	Medium
				>30mm	Severe	High
GRINDING		Removal of Sidewalk Slab Material, i.e. – to correct for settling.	Measure the thickness of grind volume	<10mm	Slight	Low
				10-30mm	Moderate	Medium
				>30mm	Severe	High
SETTLING		Any change in the original orientation of the sidewalk slab	Measure the displacement from the original position	<10mm	Slight	Low
				10-30mm	Moderate	Medium
				>30mm	Severe	High
SCALING		Deterioration of sidewalk surface in with clearly defined outline.	Make a visual observation	Barely noticeable	Slight	None
				Light deterioration	Moderate	Low
				Rough, pitted surface	Severe	Medium
RAVELLING		Weathering of sidewalk surface. Aggregate loss >6 mm	Make a visual observation	Barely noticeable	Slight	Low
				Light deterioration	Moderate	Medium
				Pockmarked, pitted surface	Severe	High

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

alleviate these issues.

## 2.4 Sidewalk Condition Index

One method of evaluating the condition of a section of sidewalk is to assess the defects, severity of repairs required and develop a Sidewalk Condition Index (SCI). As shown in Table 2.1, the SCI can be based on rankings for segments of streets in terms of low, medium or high priority or can be assigned a numerical value for repair prioritization in the network. Each segment or section of sidewalk is assigned a maximum rating of 10 and a specific number is deducted from this value based on the severity and extent of the sidewalk distress. In this particular evaluation process, a higher priority rating should be applied to rank street segments in relation to other sections of the municipality. Based on these rankings, a sidewalk rehabilitation program can be developed for a group of streets with lower ratings. This approach will improve the contractor’s ability to schedule the repairs and provide a cost-effective approach to completing the work.

## 2.5 Curb / Curb and Gutter Replacement

In an effort to meet the expectations of residents and provide adequate drainage on roadways, the municipality

can use or derive their own guidelines from the following examples to create criteria for curb repair or replacement as part of annual road rehabilitation programs or reconstruction projects. Some key deficiencies that can be considered in the planning of curb or curb and gutter repair or replacement work can include, but is not limited to, the following:

- Major stress cracks, 2 or more per driveway entrance (or longer than 500mm each);
- Settlement areas and standing water along the gutter line (greater than 25mm);
- Misalignment of curb lines;
- Tilting or over-turning;
- Missing sections of curb;
- Type of curb (does not comply with current standards); and
- Other defects affecting integrity of the curb (such as, finish) that may affect public safety.

During the preliminary planning stages of a rehabilitation program and/or reconstruction project, a feasibility study should be undertaken to determine the benefit of replacing existing curbing with current standards (i.e. replacing barrier curb with curb and gutter for drainage purposes). The scope of work may vary from project to project based on the type of work required





1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

and overall objectives for the work. It is best practice to replace substandard curb types as part of a road resurfacing project, as shown in Figure 2.1, but it may not be cost-effective given the intended life-expectancy of the road work. Conversely, the curbs may be in good condition although underground services require replacement and it would be practical to replace the curbs during this work.

## Chapter 3 - Asset Management and Rigid Pavement Selection

### 3.1 Asset Management

Similar to sidewalk management programs, municipal roadways are evaluated on a regular basis utilizing network assessment applications within pavement management systems. These computer programs provide a comprehensive approach to manage the existing roadway system and forecast future maintenance and/or rehabilitation needs of the network. These needs are derived from empirical data collected by consulting engineers through controlled surveys, which translate a rating for each parameter of the road condition analysis. Common condition ratings contain three major indices or performance indicators; the Structural Adequacy Index (SAI); Surface Distress Index (SDI); and Ride Comfort Index (RCI). Collectively, these indicators create an overall performance rating and Pavement Quality Index (PQI).

A detailed evaluation of each individual pavement section is analysed using performance prediction models based on the parameters established by the municipality. These models are user defined and can offer valuable feedback on the future deterioration of the pavement's quality. Typically, the performance of the pavement is a direct result of the overall strength of the pavement structure (for example, type, thickness and quality of pavement materials), the frequency / magnitude of vehicular loading and the type of subgrade soil(s). Additional factors, such as environmental conditions (ex. climate,

temperature, drainage, etc.) may also affect the performance of the pavement although, are typically not included at this stage in the evaluation process.

A computer generated deterioration curve predicts the rate of the pavement's weakening and forecasts the "need year" for rehabilitation or maintenance improvements. A minimum acceptable PQI rating is established for various pavement classifications, which influence the identification and prioritization of the network. For example, arterial roadways can be assigned a higher level of service based on the volume of vehicular traffic and trigger rehabilitation or maintenance improvements much earlier than other roadway classifications. Once identified for future improvements, the particular pavement section undergoes a user defined decision process to determine the most applicable road rehabilitation strategy.

### 3.2 Economical Assessment

At this point, an economical assessment and analysis is performed. The economic impact of implementing such strategies must be evaluated to determine the most effective type of rehabilitation based on long-term objectives and the current condition of the roadway. The most effective or optimal strategy is derived utilizing life-cycle economic analysis techniques and the most optimal strategy is typically the sum of the capital cost estimate / effectiveness of each particular type of rehabilitation or maintenance treatment. Each strategy can be assigned a ratio of effectiveness which is a result of the benefit of the work and anticipated cost of construction. This allows particular strategies to be assessed on a relative basis and the system can determine the most suitable strategy based on time of implementation.

Once the economical assessment of the network is complete and the output evaluated, a capital budget assessment and analysis is performed to prioritize the implementation

of annual rehabilitation and preventative maintenance programs. Due to budget restraints, the identified network needs may not be entirely addressed, or delayed, or conversely, accelerated prior to need year due to implications excluded from this engineering exercise. For instance, implications such as new development, growth, social and political needs are factors which may affect this assessment. These aspects are acknowledged throughout the planning process and modifications are carried out to balance these needs with the requirements of the overall network.

Annually, a recommended improvement program is developed and a series of pavement sections are identified for rehabilitation or maintenance through the utilization of pavement management systems. This is only the starting point and additional elements must be considered in order to prepare a practical program for construction. As such, each pavement section is further defined and an overall infrastructure assessment is now performed to confirm the suitability of the strategy. Assessments of such parameters include, but are not limited to, a condition evaluation of sidewalks, curbs, sewers and utilities. Once the inventory of the infrastructure is obtained, a project-level assessment of the scope of work is completed and the project selection process begins.

At this point, road sections will be selected as part of the program review process and a detailed evaluation of the anticipated expenditures will be prepared. A capital budget estimate for each section is completed to quantify the scope of work, strategy and category of project. As noted previously, improvement strategies will vary from crack repair to reconstruction, and if reconstruction is required, a topographic survey / design may be warranted in order to complete the assessment. Furthermore, a separate budget approach and planning process may also be necessary. In the end, a total estimated program cost for each strategy is then re-evaluated to determine the optimal impact

and improvement to the overall network. This exercise will narrow down the project selection process, by determining the most effective approach and will further define the municipality's road rehabilitation and preventative maintenance programs.

### 3.3 Subgrade Soil and Traffic Evaluation

Once the program has been determined, the technical design specifics for each project are accumulated to ensure an adequate pavement design. Geotechnical investigations and non-destructive evaluations such as, Ground Penetrating Radar (GPR) and/or Falling Weight Deflectometer (FWD) data collection can be carried out by qualified consulting engineers to determine the condition of the subgrade and ensure the pavement foundation / drainage system is designed properly. When constructing any pavement, it is important to investigate the subsurface conditions to ensure the pavement is designed appropriately to ensure long-term performance and reduce maintenance. Geotechnical boreholes should be taken between 100-250m along the pavement alignment to determine the soil type(s); soil strength / stiffness; moisture content; gradation; frost susceptibility; water table level; drainage characteristics; and chemical characterization (if necessary) to determine if any contaminants exist in the right-of-way. In addition to the soils information, the municipality should conduct a traffic analysis and determine the current Average Annual Daily Traffic (AADT) volumes. This data can then be used to determine the most appropriate traffic forecasts and Equivalent Single Axel Load (ESAL) to be used in the pavement design. Collectively, the existing subsurface findings and anticipated traffic forecasts are evaluated to determine the proposed thickness design criteria for the pavement.

Subgrade issues such as high plasticity index clays may be able to be addressed by cement stabilization. This practice is known as Cement Modified Soils (CMS). For more details on this

1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

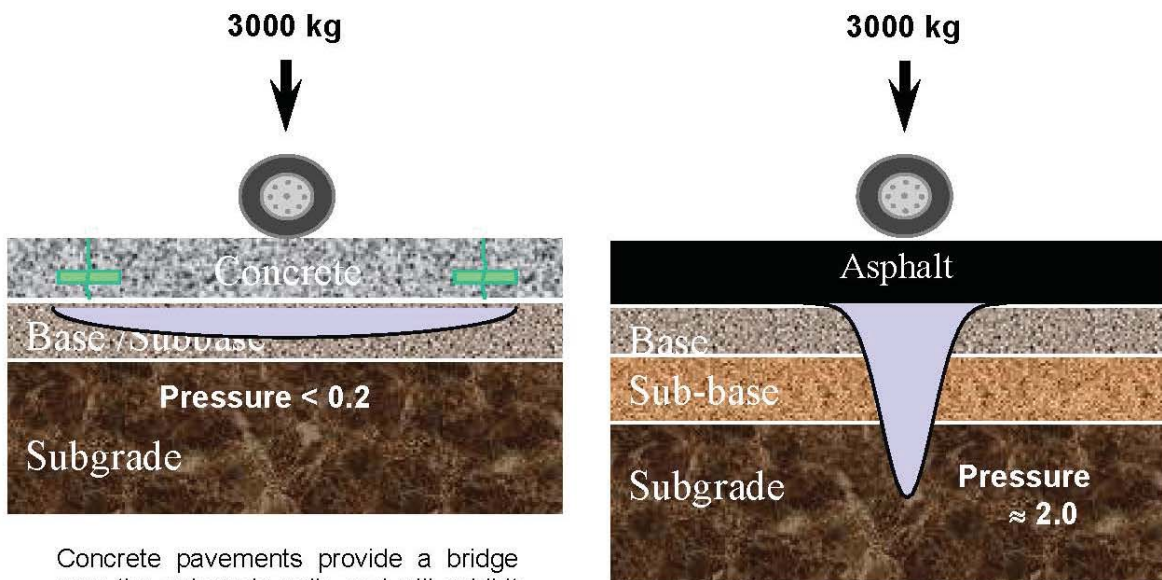
potential solution, see the Guide to Cement Modified Soils document prepared by the Portland Cement Association.

### 3.4 Pavement Selection

Pavements generally fall into two broad categories: flexible pavements and rigid pavements. Figure 3.1 illustrates the way vehicular loads are transferred to the subgrade for the various pavement types. Concrete pavements, also known as a rigid pavement, will absorb most of the load within the pavement structure and evenly distribute the load over a large area. This distribution transmits a small portion of the load into the underlying granular base, sub-base and subgrade. On the other hand, a flexible pavement design such as, asphalt pavements will concentrate the load closer to the point of impact and transmit more of the load to the underlying granular material and subgrade. Therefore, the flexible pavement structure will require the thickness of granular material to be increased to withstand the same loads as an equivalent concrete pavement structure.

### 3.5 Equivalent Pavement Design

In Ontario, rigid and flexible pavements are commonly used for both provincial highways and municipal streets. Each pavement type is designed and constructed based on anticipated traffic forecasts, subsurface soil and environmental conditions. When evaluating which type of pavement structure to choose, concrete or asphalt, it is important to compare equivalent pavement designs; the initial / long-term costs for each alternative and benefits associated with each option. This will ensure the municipality has appropriate information to make a sound decision on the most optimal type of pavement to be used to ensure cost effectiveness and long-term performance. The matrix shown in the following Table 3.1 provides a general comparison for concrete and asphalt equivalent pavement designs for municipal roadways based on various levels of truck traffic and soil conditions. This table is taken from the Methodology for the Development of Equivalent Pavement Structural Design Matrix for Municipal Roads prepared by Applied Research Associates Inc. (ARA).



Concrete pavements provide a bridge over the subgrade soils and will exhibit less pressure on the materials below than asphalt pavements.

Figure 3.1: Typical Load Distribution for Rigid and Flexible Pavement Designs (provided by the CAC).

Table 3.1 – Representative Pavement Designs for Ontario Municipalities

		Average Annual Daily Truck Traffic (AADT) - 25 Year Pavement Design							
		Collector		Minor Arterial		Major Arterial			
		250	500	1,000	1,500	2,500	5,000	10,000	
30 MPa (CBR=5)	PCC	180 mm PCC 200 mm Granular A	190 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	210 mm PCC 200 mm Granular A	230 mm PCC 200 mm Granular A
	HMA	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 400 mm Granular B	40 mm SP 12.5 FC1 90 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC1 100 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC1 110 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 600 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 600 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 600 mm Granular B
40 MPa (CBR=4)	PCC	180 mm PCC 200 mm Granular A	190 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	210 mm PCC 200 mm Granular A
	HMA	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 FC1 80 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 FC1 80 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 FC1 100 mm SP 19 150 mm Granular A 400 mm Granular B	40 mm SP 12.5 FC1 120 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 500 mm Granular B	40 mm SP 12.5 FC2 140 mm SP 19 150 mm Granular A 550 mm Granular B
50 MPa (CBR=5)	PCC	180 mm PCC 200 mm Granular A	190 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A	200 mm PCC 200 mm Granular A
	HMA	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 FC1 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 FC1 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 FC1 100 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 FC1 110 mm SP 19 150 mm Granular A 400 mm Granular B	40 mm SP 12.5 FC1 130 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 FC2 140 mm SP 19 150 mm Granular A 500 mm Granular B
Concrete Slab and Joint Properties		No dowels Slab length = 4 m Tied shoulder/curb *		32M Dowel bars, 300 mm spacing Slab length = 4.5 m Tied shoulder/curb *		32M Dowel bars, 300 mm spacing Slab length = 4.5 m Tied shoulder/curb *		32M Dowel bars, 300 mm spacing Slab length = 4.5 m 0.5 m Widened outside slab or integral curb *	

Notes:

- All materials are based on current OPS Specifications
- Subgrade levels are based on three common subgrade materials in Ontario
  - Low Category (30 MPa) - Low Plasticity Clay Subgrade
  - Medium Category (40 MPa) - Low Plasticity Silt Subgrade
  - High Category (50 MPa) - Sandy Silt Subgrade
- For urban sections, a tied concrete curb or a monolithic slab and curb can be used as a tied shoulder or widened slab respectively.

Reliability Levels

- AADIT 250 to 500 - 75%
- AADIT 1,000 to 1,500 - 80%
- AADIT 2,500 to 5,000 - 90%
- AADIT 7,500 to 10,000 - 95%

1	Introduction
2	Shedwalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Concrete Placement, Finishing and Curing
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

In addition to the initial cost of the design, municipalities should also consider the environmental and sustainability benefits of each type of pavement. The Athena Sustainability Materials Institute has developed the Athena Pavement Life Cycle Assessment (LCA) software which is an LCA-based software package that measures the environmental impact of Canadian and US regional roadway designs. This software is available for free download from the Athena Sustainability Institute website at <http://www.athenasmi.org/>. Refer to Chapter 5 for additional information on the sustainable benefits of concrete pavements.

### 3.6 Components of a Conventional Concrete Pavement

**Longitudinal joint:** Longitudinal joints are used to relieve warping stresses in the concrete pavement and are typically placed between lanes of traffic; construction pours and/or when the width of the concrete pavement exceeds 4.5m (15 ft.). Longitudinal joints are parallel to the direction of traffic and the width should be designed with the pavement markings proposed for the new roadway where possible.

**Transverse joint:** The primary purpose of transverse contraction joints is to control the location of cracking in the concrete

pavement resulting from the tensile and bending stresses in concrete slabs caused by shrinkage of the concrete during the cement hydration process, traffic loading, and the environmental conditions. Transverse joints are perpendicular to the direction of traffic and should be placed in a square pattern with the longitudinal joint. The spacing of transverse contraction or construction joints should be 1 to 1.5 times the width of the longitudinal joint.

**Dowel bars:** Dowel bars are commonly used in concrete pavements 180mm or more to provide additional load transfer across transverse joints when traffic warrants. Typically, dowel bars are 450mm in length; 32-36mm in diameter; spaced 300mm apart along the joint; and manufactured with smooth round steel to allow for horizontal movement between the concrete slabs.

**Tie-bars:** Tie-bars are normally placed lengthwise between pours and/or longitudinal joints to prevent slabs from separating and drifting apart. The bars are ribbed and deformed to ensure the concrete will bond to the steel or protective coating. The size, length and spacing of tie-bars will depend on the thickness of the pavement and grade of steel although, 750mm tie-bars at 600mm spacing is quite common.

**Base and/or sub-base course:** The base is the granular drainage layer directly below the Portland Cement Concrete (PCC) pavement and generally consists of crushed / graded aggregates. As shown in Table 3.1 - Representative Pavement Designs for Ontario Municipalities, a sub-base is not typically required from a pavement design perspective and is often

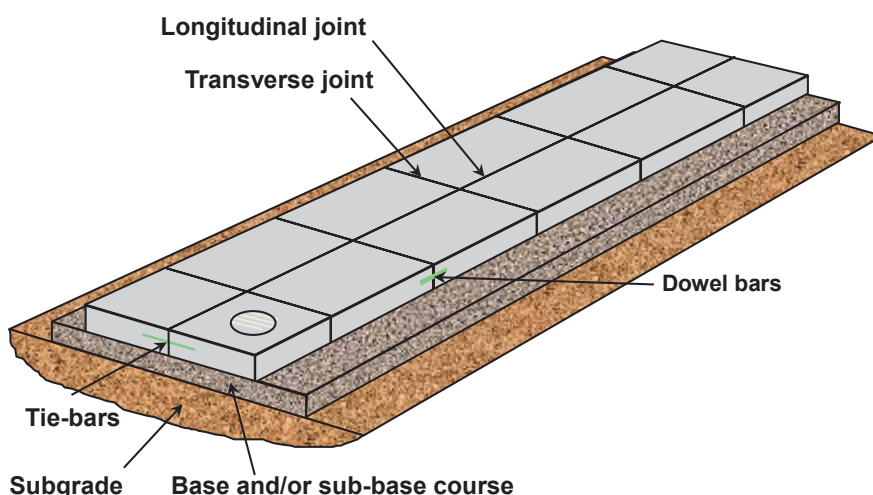


Figure 3.2 - Conventional concrete pavement components (provided by the CAC).

- 1 Introduction
- 2 Signwalk, Curb & Gutter Evaluation and Inspection
- 3 Asset Management Pavement Selection
- 4 Concrete Bridges
- 5 Sustainability
- 6 Life-Cycle Cost (LCC) Analysis
- 7 Unsprinkable Fill (U-Fill)
- 8 Architectural Concrete
- 9 Concrete Jointing
- 10 Procurement
- 11 Pre-Construction Placement Meetings
- 12 Concrete Curing Procedures
- 13 Transportation and Receiving Concrete
- 14 Convey, Placing, and Finishing Concrete
- 15 Concrete Protection and Curing Requirements
- 16 Measurement, Testing and Acceptance of Concrete
- 17 Project Closeout and Continuous Improvement
- 18 Troubleshooting
- Appendix



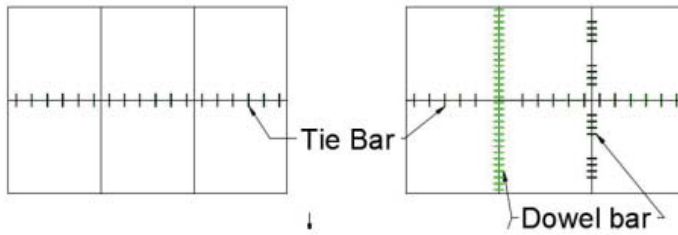


Figure 3.3 – Dowled and undowled Jointed Plain Concrete Pavement (provided by Concrete Ontario).

omitted from the pavement structure.

**Subgrade:** The subgrade soil is the native material found in-situ that supports the pavement structure. Subgrade conditions may vary from fine grained soils such as clay to coarse grained soils such as gravel or cobbles. The thickness of the concrete and granular base layers are based on these subgrade conditions.

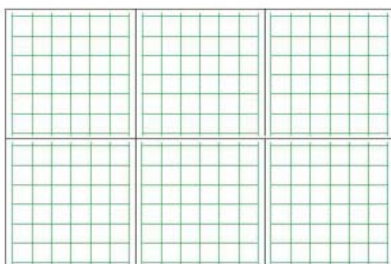
### 3.7 Types of Concrete Pavement

Concrete can provide a durable and long lasting pavement which can be used for new construction, reconstruction or the rehabilitation of deteriorated asphalt / concrete pavements. Listed below are the different types of concrete pavement and rehabilitation treatments available to municipalities:

#### Jointed Plain Concrete Pavement (JPCP):

This is the most common type of rigid pavement in Ontario. The concrete mix typically consists of 32 MPa; air entrainment; a blend of aggregates; and relatively low slump (approximate 20-30mm) for machine

#### JRCP



#### CRCP

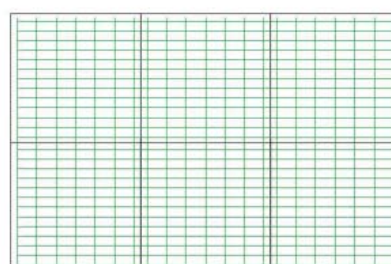


Figure 3.4 Jointed Reinforced Concrete Pavement (JRCP) and Continuously Reinforced Concrete Pavement (CRCP).

placement. JPCP controls cracks by dividing the pavement into individual slabs separated by contraction joints. Slabs are typically one lane wide and spacing typically

ranges between 3.7m (12 ft.) to 4.5m (15 ft.). As shown in Figure 3.3, depending on the design requirements, JPCP may contain dowel bars to improve load transfer between slabs at the transverse joint if the thickness of the concrete exceeds 180mm. Steel reinforcement tie-bars are also used at longitudinal joints to prevent the concrete from separating or drifting apart. JPCP pavements are common for sidewalk, curbs, parking lots, municipal roads and highway pavements applications.

#### Jointed and Continuously Reinforced Concrete Pavement (JRCP and CRCP):

As depicted in Figure 3.4 below, JRCP control cracks by dividing the pavement into individual slabs separated by contraction joints and CRCP uses reinforcing steel rather than contraction joints for crack control. Slab sizes are typically much longer in JRCP than JPCP, typically ranging from 7.5 to 9m (23-30 ft.) in length. The JRCP uses reinforcing steel within each slab to control cracking between the joints.

JRCP can be used in isolated cases where the geometry of the slab makes it impossible to respect the rules for proper

1	Introduction
2	Shrinkage, Curvature, and Cracking Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

contraction joints. If there are panels that you know will crack then having a couple panels with JRCR will ensure the integrity of the rest of the pavement will be maintained without having to reinforce the entire pavement. An example of this would be using a few reinforcing bars at the corners of the catch basins to provide crack mitigation for the re-entrant corners.

CRCP can be used when there are embedment's such as heating lines, conduit, traffic loops, etc.; near the surface of the concrete that may be compromised during saw cutting operations for the contraction joints. Using CRCP in these applications lowers the risk of the embedment's being accidentally cut. Another application would be if longer joint spacing is required than the typical 25 times the slab thickness and maximum 4.5 metre rule recommended by CSA A23.1. CRCP are regularly placed for interior slabs on grade and are used in Montreal's arterial freeways system and some municipal bus stops to minimize future maintenance costs.

### Roller Compacted Concrete (RCC)

**Pavement:** RCC otherwise known as "really cool concrete" was originally developed in British Columbia, Canada for the logging industry but is now being used for residential uses including municipal streets, parking lots and other industrial facilities. RCC is ideal for applications where frequent truck loading / turning is anticipated or as a base in a composite pavement design with an asphalt overlay. For low to medium speed traffic, RCC is adequate from a road smoothness

perspective with an appearance similar to an asphalt base course mix. For higher speed traffic, the surface of the RCC can either be diamond ground (as discussed further in Chapter 5) or overlaid with an asphalt surface to improve the smoothness of the ride.

RCC is a concrete mixture but its composition is not the same as conventional concrete. Typically, RCC mixes have much lower cement content and aggregate gradations similar to an asphalt mix design. Due to the lower cement content, RCC pavements can be a more sustainable solution compared to conventional concrete. RCC is a zero slump concrete and contains a small amount of water, the typical water-cementitious ratio is in the range of 0.32-0.38 w/c. The RCC material is mixed in a pug mill; transported to site in dump truck or ready-mix truck; placed with a conventional or heavy duty asphalt spreader; and compacted with 10 tonne vibratory steel-drum rollers. There are no forms, no steel and no finishing equipment required in this type of concrete pavement application. The material has less shrinkage due to the reduced water content so shrinkage cracks develop at a greater spacing than conventional concrete, typically every 6 to 18 m. For industrial RCC jobs joints are often allowed to randomly crack to provide full depth aggregate interlock for load transfer. When joints are saw cut they are usually put at a range of 6 to 9 metre joint spacing. Figure 3.5 shows the installation of an RCC project at an industrial facility in Ontario.

For additional information on RCC, refer to the Concrete Pavement Technology Center (CP Tech Center), "Guide for Roller-Compacted Concrete Pavements" available on the National Concrete Pavement Technology Center website [cptechcenter.org/](http://cptechcenter.org/)



Figure 3.5 - Roller Compacted Concrete (RCC) for an industrial facility (provided by Concrete Ontario).

### Pervious Concrete:

Pervious concrete is also



known as permeable concrete or no fines concrete. Pervious concrete is a highly porous pavement that allows water to drain through it into a granular storage layer. Typical pavement design for pervious concrete include a thick storage layer of Granular “O” or clear stone placed on the subgrade and the pervious concrete on top. A geotextile is usually used between the subgrade and storage layer when the subgrade has fines which may migrate into the storage layer over time. Pervious concrete has a uniform aggregate gradation (often smaller than conventional concrete) and high void ratio / porosity of 15% to 35%. With this type of permeability, 200 litres or more of storm water can flow through each square metre of pervious concrete per minute.

Pervious concrete is used in parking lot or other flatwork applications and permits water to pass through the concrete slab and stay in the storage layer until it percolates into the underlying soil. This type of concrete pavement reduces the amount of surface water runoff entering the storm sewer systems, allows groundwater sources to recharge and provides site development designers with an opportunity to seek stormwater management credits for Leadership in Energy and Environmental Design (LEED). In situations where the subgrade material is impervious, a drainage system is installed to collect the water which can be reused to water trees, plants and grass when required. Figure 3.6 shows the



Figure 3.6 - Pervious concrete for a sidewalk application (provided by Concrete Ontario).

installation of a pervious concrete sidewalk in Ontario.

For additional information on Pervious Concrete, refer to the Concrete Ontario website at <http://www.rmcao.org/why-concrete/applications/> and the CAC website at <http://www.cement.ca/en/Parking-Lots/Pervious-Concrete.html>

**Interlocking Concrete Pavers (ICP):** Pre-cast concrete paving stones are manufactured for both, permeable or impermeable applications, and can be designed to accommodate a range of loading for a variety of applications including; municipal roadways, parking areas and pedestrian sidewalks / plazas. ICP are provided in a variety of styles / sizes and are typically offered in 75mm (3”) or 100mm (4”) thicknesses. Figure 3.7 is a photo of two different types of ICP installed in a permeable pavement application for monitoring purposes at the Kortright Centre for Conservation in Woodbridge, Ontario. For more information on ICP visit the Interlocking Concrete Pavement Institute’s website at [www.icpi.org](http://www.icpi.org).

**Pre-cast Concrete Pavement:** More recently, pre-cast concrete panels have been used for concrete pavement repair and replacement on heavily travelled roadways where, construction timelines are constrained and traffic must be reinstated in a compressed timeframe. Fully cured pre-cast concrete panels are manufactured off-site, transported

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management: Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Laying, Compacting and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Placement Meetings
12	Concrete Casting Procedures
13	Transportation and Receipt of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



**Figure 3.7 - Interlocking Concrete Pavers (ICP) for a Permeable Pavement Application (provided by Concrete Ontario)**

to site and installed on a precision graded base to match proposed roadway gradients.

The pre-cast concrete panels are connected to the existing concrete pavement with steel dowels during construction and the joints are filled with unshrinkable grout. Figure 3.8 shows the placement of a pre-cast concrete panel on Highway 427 in Toronto, Ontario. For more information on this particular type of concrete pavement repair system, refer to



**Figure 3.8 - Installation of Pre-cast Concrete Panel on Highway 427 (C/o super-slab.com).**

The Fort Miller Co. Inc. website at [www.super-slab.com](http://www.super-slab.com).

**Concrete Overlays:** Concrete pavements can be used to resurface or overlay deteriorated asphalt, composite and existing concrete pavements. There are two main types of pavement rehabilitation techniques; bonded and unbonded concrete overlays. Bonded overlays utilize the strength of the existing pavement and the design takes into consideration the combined thickness of the new pavement structure. On the other hand, unbonded concrete overlays are a new pavement constructed independently on a stable base and existing pavement.

Bonded overlay options require the existing pavement structure be in good to fair structural condition. The concrete overlay eliminates surface distresses in the existing pavement and the new overlay / underlying pavement act as a monolithic structure. Unbonded overlay options add structural capacity to the existing pavement system and do not require bonding to the existing pavement. Unbonded overlays can be placed on poor or even deteriorated

pavements providing the structure has uniform support. As shown in Figure 3.9, both bonded and unbonded overlays can be installed on existing asphalt, composite or concrete pavements. For additional information on concrete overlays, refer to the National Concrete Pavement Technology Center (CP Tech Center) - Guide for Concrete Overlays.

**Concrete Pavement Applications:** The

following provides a general list of best practice applications for concrete pavements and appurtenances:

Applications where stresses from heavy to moderate vehicular loads are expected or deteriorated asphalt is present such as:

- Bus bays and bus lanes: fully loaded school bus or transit bus;
- Alleys: refuse disposal vehicles and commercial delivery vehicles;
- Highways: Local, collector roadways, arterial roadways and freeways;
- Commercial parking lots, plazas and malls;
- Commercial or industrial distribution centers truck loading docks and trailer storage areas;
- Intersections including designated turn lanes or dedicated bus lanes; and
- Port, Intermodal facilities and container terminals.

Locations where higher light reflectivity would be beneficial such as:

- Intersections
- Pathways
- Parking lots
- School zones

Locations where less service interruption is required or long term reliability is required such as:

- Noise barrier walls
- Storm water pipes across highways
- Catch basins and access chambers
- Bridges and culverts
- Freeways
- Loading docks
- Business areas
- Hospital entrances
- Emergency access/egress at fire stations and hospitals

Locations for stormwater management should be taken into consideration:

- Pervious concrete sidewalk or pathway
- Pervious parking lots
- Pervious tree pits
- Boulevards

Locations where lateral restraint is required:

- Curbs
- Abutment walls
- Wing walls
- Barrier walls

References:

Applied Research Associates (ARA), "Methodology for the Development of Equivalent Pavement Structural Design Matrix for Municipal Roadways", (2015).

Cement Association of Canada (CAC), description of concrete pavement provided on association website, [www.cement.ca/en/highways](http://www.cement.ca/en/highways)

Federal Highway Administration (FHWA), "Technical Advisory T5040.30 Concrete Pavement Joints" (1990). <https://www.fhwa.dot.gov/pavement/t504030.cfm>

National Concrete Pavement Technology Center (CP Tech Center), "Guide for Roller-Compacted Concrete Pavements" (2010).

National Concrete Pavement Technology Center (CP Tech Center), "Guide for Concrete Overlays, Third Edition", (2014). <http://www.cptechcenter.org/research/research-initiatives/overlays/>

Pavement Interactive website, [www.pavementinteractive.org/article/pcc-pavement/](http://www.pavementinteractive.org/article/pcc-pavement/)

Concrete Ontario (RMCAO) website, <http://www.rmcao.org/why-concrete/applications/>

The Fort Miller Co., Inc. website, [www.super-slab.com](http://www.super-slab.com)

1	Introduction
2	Sidewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Costs (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Pavement Meetings
12	Concrete Overlay Procedures
13	Transportation Concrete
14	Convey, Grading, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



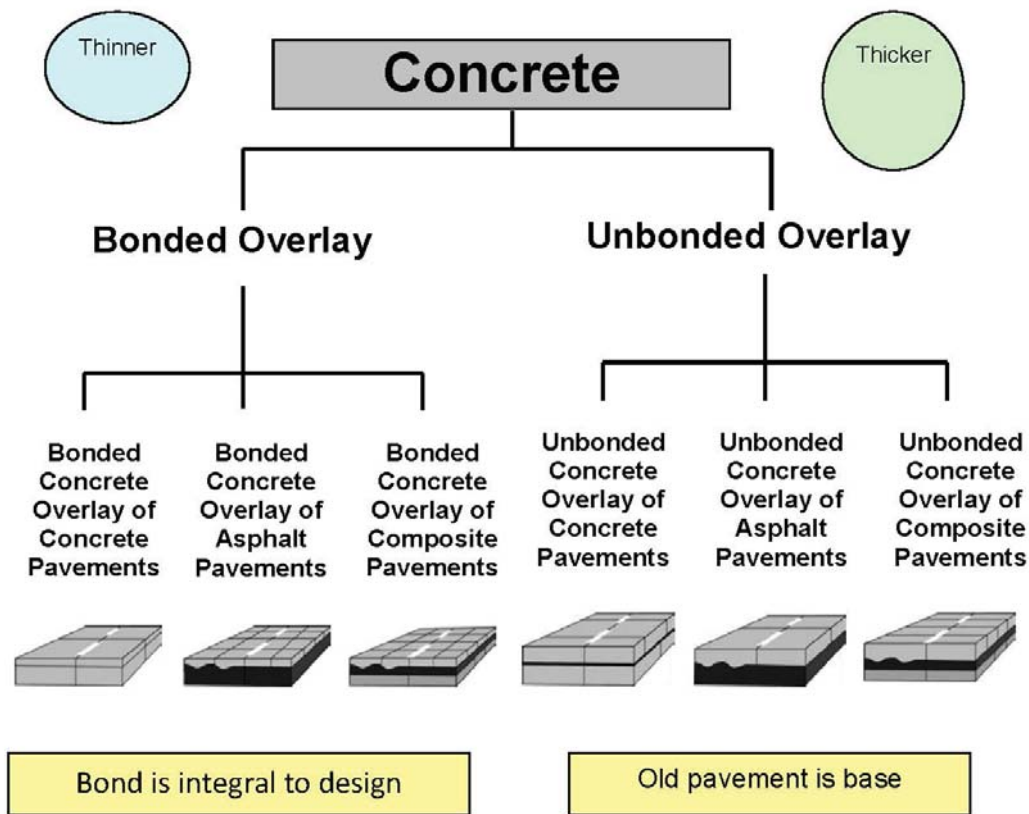


Figure 3.9 - Concrete overlay options (provided by CP Tech Center).

1	Introduction
2	Stipewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC) Analysis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Pavement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 4 - Concrete Bridges

### 4.1 Introduction

Municipalities are the largest bridge infrastructure owners in Ontario. The majority of bridges in current municipal inventories were constructed between 1950 and 1980 and are approaching time for major rehabilitation



Figure 4.1 - Puce River Bridge at County Road 22, County of Essex

or replacement. Structures constructed prior to 1970's are more susceptible to deterioration from chloride penetration and freeze-thaw cycle effects due to the use of non-air entrained concrete; minimal concrete cover for reinforcing steel; exposed concrete bridge decks; and/or a lack of waterproofing.

In the Province of Ontario, bridge owners are mandated by law to assess and maintain their infrastructure under the Public Transportation and Highway Improvement Act, Ontario Regulation 104/97 (O. Reg 104/97), Standards for Bridges. In accordance with the O. Reg 104/97, "The structural integrity, safety and condition of every bridge shall be determined through the performance of at least one inspection in every second calendar year under the direction of a professional engineer and in accordance with 'the Ontario Structure Inspection Manual; and

"Every bridge shall be kept safe and in good repair..."

The purpose of this chapter is to provide some guidance for the inspection and maintenance of concrete bridges such as shown in Figure 4.1. This chapter is intended to provide some highlights on key issues associated with concrete bridges that should be considered and provide municipalities with some direction to obtain more detailed resources for further study. This chapter does not replace the requirement of having a licensed structural engineer be a part of the investigation and design process. In addition, the design and construction of new concrete bridges is beyond the scope of this document although, it should be noted that concrete remains to be the most versatile and common material used in most new bridge construction projects.

All resources noted in this chapter are available from the Ministry of Transportation, Ontario (MTO) website:

[www.mto.gov.on.ca/english/](http://www.mto.gov.on.ca/english/)

[publications/mto-research-library-online-catalogue.shtml](http://www.mto.gov.on.ca/english/publications/mto-research-library-online-catalogue.shtml)

### 4.2 Concrete Bridge Inspection

Regular inspections as illustrated in Figure 4.2, are important to identify repairs and provide opportunity to create long-term plans for maintenance based on their existing



Figure 4.2 - Inspection of concrete frame bridge



1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Curing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

condition, thereby reducing the risk of failures. The Ontario Structure Inspection Manual (OSIM) prepared by the MTO provides guidance for engineers and municipalities regarding bridge inspection.

In accordance with the Act, the following structures shall be inspected every two years (biennially): bridges, culverts, and tunnels with spans greater than 3.0m; retaining walls; and moveable bridges. An exception can be made for retaining walls and culverts ranging between 3.1m to 6m in span length, the inspection interval can be increased to four years providing the structure is considered to be in good condition; and that the condition is not anticipated to change significantly before the next inspection.

As part of the inspection, the following components of a concrete bridge should be assessed for both their material condition and overall performance: bridge barriers and approach guiderails; asphalt surface (if any) and top of the bridge deck; underside of a bridge deck and beams / girders; support bearings; abutments, piers and retaining walls; streetlights and signs; and slopes, embankments, drainage systems and/or adjacent water courses. When inspecting, it's important to determine the overall condition and consider the global performance of the structure. Attention should be paid to signs of movement which could be an indication of a potential instability of the structure, such as wide cracks in the bridge substructure, sliding of footings and rotation of concrete walls in open frame bridges.

The Bridge Condition Index (BCI) rating is a planning tool that helps owners schedule maintenance and upkeep of their bridge inventory. A BCI value for a bridge can be calculated as the ratio of the sum of the current value of the various components to the total replacement value of the structure. The current value can be determined based on condition data obtained from the OSIM inspection and the anticipated industry costs for these components. The BCI is not used

to rate or indicate the safety of a bridge but is meant to help an owner prioritize capital expenditures and plan maintenance / rehabilitation work.

To assist in the planning process, it best practice that municipalities consider a Bridge Management System (BMS) for both, quantitative-based and qualitative-based bridge data collection. An example of a quantitative-based BMS is the OGRA Municipal DataWorks (MDW) program. For additional information, refer to MDW website at <http://www.municipaldataworks.ca/>

The OSIM inspection may provide follow-up recommendations based on condition such as, additional inspections required; comprehensive structural evaluations and/or load posting; maintenance, repairs and rehabilitation. Structures over 30 years old with critical components in poor condition such as shown in Figure 4.3, should have an Enhanced OSIM inspection completed every six years. An Enhanced OSIM Inspection is a visual inspection to be completed at a



Figure 4.3 - Below-deck inspection and steel corrosion deficiency

distance no greater than an 'arm's length' from the bridge components and may require specialized equipment for access such as, the use of a ladder, scaffolding, bridge master / elevated work platform and/or boat / barge.

If an emergency situation exists where a structural component contributing to overall stability of the structure has failed, or is in imminent danger of failure, or public safety is in any way at risk, a detailed visual inspection should be carried out immediately and consideration should be taken for closing all or part of the structure until the extent of the damage / risk has been confirmed. Problems that may cause an emergency situation to develop are: an accident or vehicle collision with a structure; spring run-off or major flooding; an earthquake; loose concrete in an overhead structure; and advanced deterioration creating the potential for structure instability (i.e. concrete cracking or spalling below support bearings).

Through the OSIM inspection process, a structure may be identified by the engineer for further evaluation. Such studies may consist of structural load evaluations and bridge deck condition surveys (BDCS). The inspector and/or structural engineer will make recommendations based on the observed condition of each bridge component. Various levels of condition surveys can be taken and may include, more detailed visual inspections; concrete delamination surveys; half-cell potential surveys to estimate the level of corrosion in the structure (black steel only); concrete coring and testing (ex. strength, air voids and/or chloride penetration); and partial asphalt removals / deck assessments.

This information can assist the engineer as to the state when making decisions for renewal of the structure and provide repair quantity information for estimating the cost of a particular rehabilitation approach.

An example of a repair can be seen in Figure 4.4.

### 4.3 Bridge Rehabilitation

In general, municipalities should perform regular bridge maintenance to sustain / extend the life of existing structure and prevent more costly repairs or rehabilitation



Figure 4.4 - Bearing seat spalling and temporary support installation

treatments. Today's bridges are designed to last 75+ years but frequent maintenance and an appropriate rehabilitation program is required to maintain structures in sound working condition. Bridges will require a number of rehabilitation projects over their lifetime depending on the type of bridge, usage and quality of the maintenance program. For example, bridge decks typically last 50+ years and major rehabilitation programs last 25+ years.

The following provides some guidance on the expected life-spans for various rehabilitation treatments and techniques noted in the MTO Structural Financial Analysis Manual. When considering various treatments or techniques, the remaining life of the structure should be determined and a life-cycle cost / benefit analysis should be considered when determining the most appropriate renewal or rehabilitation option for a bridge.

- Mill and pave surface course asphalt (15 years);
- Concrete patch repair, replacement of waterproofing and asphalt (30 years);
- Concrete overlay (30 years) as seen in Figure 4.5, applicable to:
  - o Normal concrete
  - o Latex modified concrete

1	Introduction
2	Shedwalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Placement Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



Figure 4.5 - Placement of concrete deck overlay 0

### Silica fume concrete

- Cathodic protection (15 to 30 years);
- Deck, sidewalk and parapet wall replacement (50 years);
- Replace seals (5 to 15 years);
- Replace expansion joints (15 to 30 years); and
- Eliminate expansion joints (50 years);
  - o Semi-integral abutments
  - o Link slabs at piers

The best management practice guideline for the rehabilitation of concrete bridges in Ontario is the MTO Structure Rehabilitation Manual. This resource covers many requirements for the rehabilitation of bridge including those identified for BDCS. The following provides a brief introduction on the most common considerations when rehabilitating concrete structures.

**Concrete Repairs:** best practice for the repair of spalled or deteriorated concrete is to repair “like” with “like” or, in other words, repair normal or ready-mix concrete with normal concrete whenever possible. For overhead and vertical repairs, form and pump concrete is recommended. Shotcrete (specifically, bagged silica fume shotcrete) can provide an alternative for overhead repairs however form and pump concrete, if completed correctly, is expected to provide better durability.

Another alternative includes proprietary (bagged) cementitious products which are useful for small or shallow repairs. Careful

consideration should be given to using proprietary products for large repairs as the durability of these products is typically considered secondary to ready-mix concrete. These products can be placed by trowel, form and place, or form and pump depending on the manufacturer. It is highly recommended that the requirements of the manufacturer are followed to ensure the utmost quality of the final product.

There are several methods available for repairing cracks. It is most important to determine the cause of the cracking such that an appropriate material can be utilized. For instance, a polyurethane injection is often recommended where there are active cracks that are opening and closing. For non-active cracks where the structural integrity needs to be restored, epoxy injection is preferred. Removal of the surrounding concrete and patch repairing is yet another option if the cause of the initial crack is determined to be no longer present.

**Expansion Joint Removal:** Leaking expansion joints are one of the main causes for premature deterioration of a structure. Where possible, a review of the possibility for the removal of expansion joints should be undertaken in conjunction with a life-cycle cost analysis of potential rehabilitations design options. Pier expansion joints can sometimes be replaced with a semi-continuous concrete deck or by using a flexible link slab that is designed to crack in a controlled manner in-lieu of a typical movement joint. Semi-integral abutment retrofits as seen in Figure 4.6 eliminate the joint at the girder ends and transfer the expansion movement to the ends of the approach slabs where salt-laden runoff does less damage.

For additional information, refer to the MTO resource “Retrofitting of Existing Bridges with Joints to Semi-Integral Bridges”. In addition, there are several journal papers available online regarding link slab design.



Specifying Concrete for Rehabilitation: Ontario Provincial Standard Specification (OPSS) 928 and 930 describe the standard requirements for concrete removals, repair and the placement of concrete overlays. For concrete repairs the provincial version of OPSS 930 provides a designer with the most current or state-of-the-art requirements and is the recommended resource at the time of this publication. For full depth concrete component replacement or construction, OPSS 904 is the most relevant specification. OPSS 932 should be used as the basis for crack repairs. OPSS 931 or MTO Standard Special Provision 931S01 can be considered as the basis for specifying shotcrete.

#### 4.4 New Technologies

When conducting bridge inspections, Ground Penetrating Radar (GPR), in conjunction with a BDCS can be used to establish concrete cover in bridge decks and is able to identify both top and bottom reinforcement cover measurements with good accuracy.

Self-consolidating ready-mix concrete is gaining popularity for concrete repairs due to its high flowability and self-leveling qualities which make it especially effective where there is high reinforcing steel congestion or shallow repair depths.

Glass Fibre Reinforced Polymer (GFRP) reinforcement is gaining popularity for bridge rehabilitations as an economical and durable option for new or rehabilitated cast-in-place concrete barriers and parapet walls. GFRP may also be a suitable alternative in bridge decks to reduce the weight of reinforcement where existing substructure support is unknown.

Where additional strength or durability is desired for a structure the use of FRP (glass or carbon) wrapping can be employed. Examples of this include wrapping of concrete girders where shear or bending strength is inadequate and pier columns for added confinement and durability.

Concrete sealers and surface applied corrosion inhibitors provide some additional durability for concrete surfaces that are exposed to salt splash such as curbs, sidewalks and barriers or parapet walls. Typically concrete sealers need to be reapplied after a number of years to remain effective.



Figure 4.6 - Semi-integral joint and abutment retrofit

#### References:

Ontario Ministry of Transportation, Downsview Bridge Office. "Structural Financial Analysis Manual" (1993). <https://www.library.mto.gov.on.ca/>

Ontario Ministry of Transportation, St. Catharines Bridge Office. "Retrofitting of Existing Bridges with Joints to Semi-Integral Bridges" (2004). <https://www.library.mto.gov.on.ca/>

Ontario Ministry of Transportation, St. Catharines Bridge Office. "Structure Rehabilitation Manual" (2007). <https://www.library.mto.gov.on.ca/>

Ontario Ministry of Transportation, St. Catharines Bridge Office. "Structure Inspection Manual (OSIM)" (2008). <https://www.library.mto.gov.on.ca/>

Province of Ontario, Public Transportation and Highway Improvement Act, O. Reg. 104/97: "Standards for Bridges" (2006). <https://www.ontario.ca/laws/regulation/970104/v2>

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



## Chapter 5 - Sustainability

The pressures for accountability on climate change issues are becoming a higher priority to most governments. Governments are a driver for change and it is important they adopt new practises in order to facilitate a sustainable approach to municipal concrete construction. When selecting materials for a project, it is important to ascertain how the material will function from a safety, financial and serviceability perspective as well as the impact on society and the environment.

Our youth are more aware now of their impact on the globe than ever before. It has even been suggested that in order to retain 'millennial' generation staff, it is important that organizations and agencies have a comprehensive policy on climate change. Millennials (also known as Generation "Y") are known to stay with companies they feel provide a positive impact on the globe (Dr. Karyn Gordon RMCAO Annual Conference 2013).

There are many new programs available to determine how "Green" your practises are in the industry. One of the local products provided by the Ministry of Transportation Ontario (MTO) is the "GreenPave" ranking system. The GreenPave system looks at various criteria and applies a point system to rank the pavement. The more points generated, the greater the "sustainability" of the pavement.

Another program available on the market is the Athena Institute's LCA Impact Estimator for Highways. The Athena software is a more comprehensive system where environmental effect of the road and construction equipment is input into the program. The software calculates for the specified design project the total Fossil Fuel Consumption (MJ); Global Warming Potential (kg CO<sub>2</sub> eq); Acidification Potential (moles of H<sup>+</sup> eq); HH Criteria (kg PM10 eq); Eutrophication Potential (kg N eq); Ozone Depletion Potential (kg CFC-11 eq); and Smog Potential (kg O<sub>3</sub> eq).

The Athena software looks at a 'Cradle-to-Grave' or a 'Cradle-to-Cradle' scenarios which estimate the total impact of the proposed design. It is important during the evaluation of sustainable options that the total life of the structure is analyzed. Some designs may look good based on initial construction cost, but if they require frequent repairs or the environmental impact of the option in more damaging than initial construction approach will not provide a clear picture. Only by evaluating the total life-cycle of the structure will the analysis be meaningful.



### 5.1 Cement

Concrete is the most widely used man-made material in the world; the only natural product used more is water. Cement is the glue that binds together the concrete and hence is an integral part to achieving a quality concrete. Due to the carbon dioxide (CO<sub>2</sub>) release during the manufacturing process of cement, it has been given a reputation for not being a sustainable product, as well as being very harmful to the environment. Although this argument may have been valid in the past, today most cement plants in Canada are very conscience of their environmental impact and go to great lengths to further reduce the release of CO<sub>2</sub> into the atmosphere. For example, some producers are investigating ways to capture their CO<sub>2</sub> output and using it to produce other products. One producer in Ontario is capturing their CO<sub>2</sub> and other emissions from their cement plant and is using it as feedstock for algae which is grown in ponds. This algae is then dried and can be used as a bio-fuel.

Another initiative by the cement producers is Contempra cement and/or PLC (Portland-Limestone Cement). Contempra is a cement

product where up to 15% of the limestone is held back from the kiln and then added to the clinker after the firing process. This reduces the CO2 impact of the cement by approximately 10%. Contempra is identified in the Canadian Standards Association, CSA A23.1, "Concrete Materials and Methods of Concrete Construction / Test methods and Standard Practices for Concrete" as PLC cement. Type GUL cement is commonly shown on mix designs from producers although, PLC is readily available in the Ontario market. PLC cement has been used in Europe with good success for a number of



years and has been approved by the MTO / City of Toronto. For additional information on PLC cement, refer to the CAC website at <http://www.cement.ca/contempra/>.

## 5.2 Long Life Pavement

Concrete, when properly designed and constructed, is known to have a very long service life. Products that do not need to be repaired frequently are usually very sustainable. The City of Winnipeg, Manitoba has the oldest exposed concrete roads in Canada. Alexander Avenue was constructed in 1903 and is still in use at the date of this report. The oldest concrete road in North America is Ontario Street in Toronto, which was constructed in 1890. The concrete is still in place, although, an asphalt overlay is now covering the concrete.

It is important when designing pavements to ensure the proper design is used with sufficient thickness to ensure it will last to the desired service life, but not too thick that it is economically unfeasible. Depending on the application of the pavement and design parameters required, asphalt or

concrete can be selected as the material of construction. Concrete Ontario has been involved in educating Municipalities on potentially using concrete as an asphalt alternative and provides a Pavement Design Assistance Program (PDAP) to assist in making an informative decision for the new/existing pavement. PDAP provides an alternate concrete pavement design which includes a life cycle cost analysis using CANPav™. It is a very helpful tool in ensuring that both materials, asphalt and concrete, are considered when constructing a new pavement or rehabbing an existing one.



For more information please visit [www.pdap.ca](http://www.pdap.ca).

## 5.3 Traffic Delays

As commuters sit in traffic as a result of construction related delays, their vehicles are idling and pollutants are released to the atmosphere. Sustainable solutions look to reduce traffic delays over the long term. "Santero et al. (2011a) hypothesis' that traffic delays may be a more significant contributor to a pavements environment impact than the entire construction, material and equipment." (CP Tech Center 2012). Once again it is important to understand the maintenance requirements over a long term period.

One example is the intersection of Courtneypark Drive and Kennedy Road in the City of Mississauga, Ontario. (Figure 5.1) The intersection has a very high volume of truck traffic and one left-turn lane was experiencing 75-100 mm of asphalt rutting every 2 years. The City decided to try a concrete pavement for the lane. The two lanes were closed at 10 am in order to start removal of the asphalt and at 3 pm the concrete placement

1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsustainable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Curing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Close-out and Continuous Improvement
18	Troubleshooting
	Appendix



**Figure 5.1 – Asphalt rutting and concrete left-turn lane installation in Mississauga (provided by Concrete Ontario).**

started. Using the maturity testing methods to determine the strength of the concrete in-situ, it was determined that the minimum strength of 20 MPa was achieved and the road could have been opened to traffic by 1 am. Since the design thickness was based on a 100 year design life, there will be minimal maintenance and repairs required in the future for this specific turning lane.

#### 5.4 Heat Island Reduction and Cooling Effects

Concrete has a high solar reflectance compared to other construction products due to the inherent light colour of material (although, it should be noted that colour alone is not the only indicator of solar reflectance). The natural colour of concrete can be made even lighter with the use of white coloured pigments (such as, titanium dioxide photocatalytic) or ground granulated blast furnace slag (slag cement).

Solar reflectance is important since it contributes to the creation of the urban heat island effect where surface temperatures are found to be higher than surrounding rural areas. As urban areas increase in temperature, there is a greater increase in smog formation, as well as, a greater need

for energy usage for cooling of buildings. For every 0.6 °C increase in summertime temperature the estimated increase in peak utility load is 1.5-2.0% for medium and large cities (United States Environmental Protection Agency - EPA, 2003).

#### 5.5 Lighting and Electricity Use

Concrete pavements offer the best surface for lighting purposes due to the high reflectance and luminance qualities of the Portland cement. Luminance is the measurement of light used in street light design to determine the intensity of the surface brightness. A lighter coloured concrete pavement, parking lot or walkway will require less light fixtures or luminaries than a darker coloured surface such as asphalt. Studies have shown that the luminance of concrete is approximately 1.5 times greater than asphalt and concrete provides improved uniformity (or maximum to minimum ratios in the levels of light) over the surface. This distinction is based on the specularly of the pavement and associated scaling factor associated with determining the overall “lightness” of the surface. High reflectance leads to greater visibility and improved safety for the users of the pavement. Concrete pavements will not only



provide a savings on the initial capital costs for electrical streetlight installations but will also provide long-term saving saves on the electrical consumption over the life of the pavement, parking lot or pedestrian walkway.

### 5.6 CO<sub>2</sub> Sequestering

As concrete ages, there is a natural reaction with the concrete and CO<sub>2</sub> in the environment. The concrete sequesters CO<sub>2</sub> which helps offset some of the CO<sub>2</sub> released during the manufacturing of the cement. Any concrete surface exposed to air will carbonate which will sequester CO<sub>2</sub> into the concrete. During the service life the pavement, the top portion (millimetres) of the exposed surface will carbonate. At the end of pavements service life, the concrete can be crushed and any surface of the crushed aggregate exposed to the air will carbonate as well.

### 5.7 Reduction in Virgin Aggregate Usage

Concrete pavements distribute stresses over a wide area; consequently they do not require strong base layers to carry the load from vehicles. Concrete pavements are less sensitive to subgrade resilient modulus than other pavement types, therefore many are designed for a worst case scenario. By designing concrete pavements assuming weak subgrade, during spring conditions, there is no need to increase base layers to improve the pavement strength. Concrete pavements require good drainage and a uniform subgrade to control frost heave. If these conditions are met, concrete pavements do not require thick subbase layers. This can significantly reduce the cost of the pavement and amount of virgin

aggregate that needs to be used on a project.

### 5.8 Pavement-Vehicle Interaction

While vehicles are travelling on a roadway there are many forces at work. The engine is turning the tires, the wind is resisting the forward movement and the tires are interacting with the pavement. Road smoothness plays a role in the ability of the tires to move on the pavement, but the stiffness of the pavement also has an effect. Concrete roads are intentionally textured and tined in order to provide additional skid resistance, while this affects the roughness test reading, the area that is actually being driven on is a smooth surface. The other component for pavement-vehicle interaction is the stiffness of the pavement which correlates to rolling-resistance. As shown in Figure 5.2, when the pavement stiffness is reduced, the tires “sink”\ into the pavement and the net effect for the vehicle is a slight uphill climb.

In the early 2000’s, Taylor and Patten at the National Research Council (NRC) of Canada published several papers that show with stiffer pavements there is potential for up to 6.9% fuel savings for full tractor-trailers travelling at 60 km/hr. Since this original study was published, additional studies were completed from Swedish Lund University, 2007; VTI (Swedish National Road and Transport Research Institute), 2009, 2010, 2013; University of Texas Arlington, 2010; Massachusetts Institute of Technology, 2012

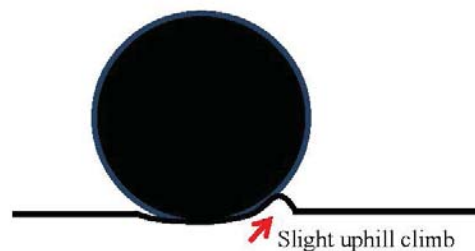


Figure 5.2 – Pavement stiffness and vehicle interaction (provided by Mick Prieur).

1	Introduction
2	Shelwalk, Curf & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Handling and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC) Analysis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Pavement Meetings
12	Concrete Construction Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

& 2013; UK- Transport Research Laboratory, 2007; Japan -Nippon Expressway Research Institute, 2010; and Florida International University, 2013. In all of these studies, it was shown that concrete roads improve rolling resistance and can save fuel consumption. While up to 7% fuel savings may not seem like a lot, the total savings can be substantial due to the high volume of vehicles and trucks travelling our roadways.

The Cement Association of Canada did a case study and presents the range of potential fuel savings and reductions in emissions that could be achieved for a 183 km section of Hwy 401 from London to Toronto based on the NRC 2002/2006 studies and MTO traffic data from 2005. From the study, a comparison was performed for a rigid pavement and a flexible pavement. The study assumed a bulk diesel fuel price of \$0.87/litre between January and June, 2006 and a heavy truck efficiency of 43 litres/100km. If only the heavy trucks were considered for a rigid pavement compared to a flexible pavement the potential annual fuel savings and emissions reduction would be: emissions reduction would be as shown in Table 5.1 below.

For detailed calculations on Pavement-Vehicle interaction fuel savings and other environmental impacts, the Athena Institute Impact Estimator for Highways (discussed in Chapter 3) is readily available for utilization.

Sustainable Impacts due to Pavement-Vehicle Interaction Rigid vs. Flexible Pavement (2006 Dollars)	Minimum Savings	Average Savings	Maximum Savings
Fuel Savings (litres)	14,551,000	70,026,000	125,502,000
Dollar Savings (\$)	12,687,000	61,056,000	109,425,000
CO <sub>2</sub> Equivalent Reductions (Tonnes)	40,131	193,132	346,133
NO <sub>x</sub> Reductions (Tonnes)	454.2	2185.9	3917.5
SO <sub>2</sub> Reductions (Tonnes)	57.4	276.3	495.2

Table 5.1 – Comparison of Pavement-Vehicle Interaction (Reference: Concrete Highways: The Greener Alternative by CAC)

## 5.9 Two-lift Concrete pavements

Similar to asphalt, concrete can be placed in multiple lifts in order to reduce the quantity of high quality aggregates required for the design. Prior to January 2012 there have been eleven two lift pavement projects in the United States. In 2012/13, the Illinois Tollway reconstructed I-88 using wet-on-wet (Two lift concrete) pavement. The bottom lift was designed to use high amounts of recycled material including; fractionated reclaimed asphalt pavement as a coarse aggregate, recycled concrete aggregate and a high percent replacement of supplementary cementing materials. The thinner top lift used a higher cement content and a high quality aggregate for improved skid resistance. The bottom lift is not the riding surface and will be protected from the elements thus, a lower quality concrete mix can be used to optimize cost and the sustainable benefits of the pavement.

## 5.10 Thin pavements

A researcher from Chile, South America has developed a patented concrete pavement design system known as TCPave that will allow for thinner pavements than normal, compared to the American Association of State Highway and Transportation Officials (AASHTO) 1993/98 designs. The designs are currently being investigated and assessed by the University of Illinois. The TCPave system utilizes smaller concrete panel sizes in order

to reduce curling of the slab and minimize the amount of tensile stresses in the concrete. In some cases, pavements between 100 -150 mm have been used to carry medium to heavy truck volumes of traffic. Since the concrete is thinner than conventional pavements, there is a potential for substantial savings on initial construction costs as well as the added sustainable benefits. This system has been around since 2007 and over 2.5 million m<sup>2</sup> has been placed in South America although, the design concept is still under evaluation in North America and further research is required. For additional information, refer to the TCPavements website at [www.tcpavements.com](http://www.tcpavements.com)

### 5.11 Diamond Grinding/Grooving

Diamond Grinding/Grooving is a repair technique used for concrete to improve the ride quality, noise and skid resistance. For concrete pavements, it may be helpful to initially design the pavement slightly thicker than required to accommodate future repairs. Diamond grinding removes the top 5-10 mm of the concrete surface to provide longitudinal grooves as shown in Figure 5.3. Diamond grinding will correct some surface defect issues such as, ride comfort, joint faulting and noise issues.

Figure 5.3 - Diamond grinding surface texture

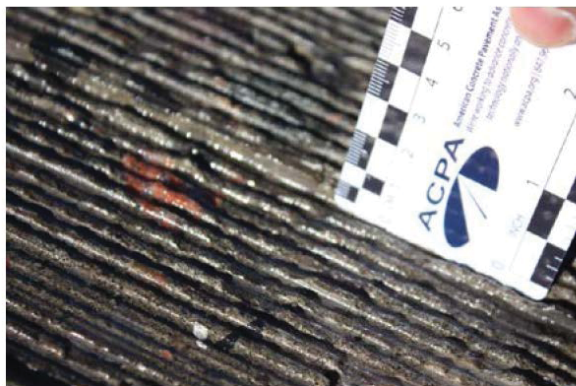


Figure 5.3 – Diamond grinding surface texture (provided by ACPA)

Alternatively, diamond grooving does not remove the surface. Diamond grooving cuts thin grooves into the pavement to improve the macro-texture of the pavement. Grooving is a good method to improve the skid resistance of the concrete on high speed roadways.

In the Street Smart report prepared by Applied Research Associates (ARA), the first diamond grinding operation is recommended at year 25 for concrete pavements with traffic between 7,500-10,000 AADTT. For lower volume roads the texturing can be extended beyond 25 years. By only having to remove 5-10 mm of your pavement surface every 25 years, the sustainable benefits are enhanced compared to a rehabilitation overlay project. For additional information, refer to the Street Smart report at [http://www.cement.ca/images/content/streetsmartara\\_report\\_feb%202012.pdf](http://www.cement.ca/images/content/streetsmartara_report_feb%202012.pdf)

### 5.12 Concrete Recycling

Concrete is 100% recyclable and can be reused for other purposes at the end of the structures service life. For concrete pavements, sidewalks, curbs and buildings; the concrete can be brought back to a local facility for crushing and processing into new recycled aggregates. OPSS 1010 allows recycled concrete aggregates in Granular

A only and the University of Waterloo, led by Susan Tighe, is performing research on Granular B with good success. Additional research performed by the University of Waterloo suggests that up to 30% of RCA does not impact the service life of the pavement or other concrete infrastructure assets.

### 5.13 ECO Certified Plants

In order to be a member of the Ready-mixed Concrete Association of Ontario (RMCAO), otherwise known as Concrete

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Placing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Construction Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

Ontario, all ready-mixed plants must be certified by an independent consulting engineer. As part of that process, the engineer must ensure the plant is capable of meeting the Ministry of Environment and Climate Change (MOECC) Ontario requirements for air and noise pollution, water taking and water discharge. The process also allows members to be granted further acknowledgement for exemplary controls through the ECO Gold certification program. By being an ECO Gold facility the member has exceeded the MOECC requirements. For additional information, refer to the Concrete Ontario website at <http://www.rmcao.org/certification/rmcao-production-facilities/>

#### 5.14 Enhanced Aesthetics and Societal Benefits

The sustainability of concrete can have positive impacts on society and designers should consider enhanced concrete treatments to improve the public realm / built environment. One of the benefits of concrete is its ability to be molded and conformed to a vast array of shapes and sizes. Concrete can

also be coloured, textured and/or impressed with a variety of finishes to further enhance its aesthetics. Landscape, streetscape and urban designers apply a wide variety of concrete treatments to enhance their projects; create a sense of place; and make the built environment more appealing for the public. For additional information, refer to Chapter 8 -



Architectural Concrete.

References:

National Concrete Pavement Technology Center, "Sustainable Concrete Pavements: A Manual of Practice" (2012).

US Environmental Protection Agency, "Cooling Summertime Temperatures: Strategies to Reduce Urban Heat Islands" (2003).

Athena Sustainable Materials Institute, "Impact Estimator for Highways" (2015).

Swedish Lund University, Lengrenn C.A., Faldner L., "Fuel Cost Considerations Regarding Truck Rolling Resistance on Different Pavement Types" (2010).

VTI (Swedish National Road and Transport Research Institute), Hultqvist B., "Measurement of Fuel Consumption on Asphalt and Concrete Pavements North of Uppsala" (2009).

University of Texas Arlington, Ardekani S.A., Sumitsawan P., "Effect of Pavement Type on Fuel Consumption and Emissions in City Driving" (2010)

Massachusetts Institute of Technology, Akbarian M., Ulm, F., "Model Based Pavement-Vehicle Interaction Simulation for Life Cycle Assessment of Pavements" (2012)

UK-Transportation Research Library, Benbow E., laquinta J, Lodge R., Wright A., "Investigation of the Effects of Pavement Stiffness on Fuel Consumption" (2007)

Japan-Nippon Expressway Research Institute, Yoshimoto T., Kazato T., Hayakawa I., "Effect of Pavement Type on Rolling Resistance and Fuel Consumption of Heavy-Duty Vehicles" (2010).

Florida International University, Bienvenu M., Jiao X., "Comparison of Fuel Consumption on Rigid Versus Flexible Pavements Along I-95 in Florida" (2013).

National Research Council Canada, Taylor G.W., Patten J.D., "Effects of Pavement Structure on Vehicle Fuel Consumption, Phase III" (2006).

Stark R.E., "Road Surface's Reflectance Influences Lighting Design, Lighting Design + Application" (1986).

Rosenfeld, A.H. et al., "Painting the Town White - and Green, MIT Technology Review" (1997).

1	Introduction
2	Sidewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Shrinkage, Curbs & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Concrete, Placing, and Finishing
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 6 - Life-Cycle Cost Analysis (LCCA)

The modern municipal roadway network generally consists of platforms constructed with concrete and/or asphalt. On occasion, a platform with brick pavers or a combination of one material overlaid on a different material may be encountered. The focus of this chapter will consider conventional concrete and asphalt pavements only, and the purpose of assessing the life-cycle costs to conduct an economic comparison or “best value” evaluation of each alternative.

The phrase “pay it now or pay it later” provides the impetus to assess pavement design alternatives or strategies in greater detail in order to make an educated decision before investing capital expenditures on new roadway improvements. It is in the best interest of the municipality to determine the overall goals of the project (ex. short or long-term rehabilitation objectives), conduct a LCCA and select the most optimal pavement design strategy based on the best value for money (VFM). The VFM concept considers not only the minimum purchase price (initial capital expense) but also the maximum efficiency and effectiveness of each alternative.

In order to complete a LCCA, an understanding of the general terminology is required prior to proceeding:

**Analysis Period:** The analysis period is the duration of time considered as part of the economic evaluation. The duration period must be long enough to analyse the maintenance requirements of each alternative and include at least one (1) major rehabilitation event. For example, a 50-year duration period will include several maintenance and rehabilitation (M&R) milestones for concrete and asphalt pavements.

**Initial Cost of Construction:** The initial cost of construction is the total capital expense required to plan, design and construct the

new pavement platform including, removal of the existing pavement, excavation, granular base materials, shoulders, curbs and/or any other related item associated with the roadwork. Additional costs for underground infrastructure upgrades such as, drainage improvements and utility work may be omitted from the analysis.

**Maintenance Costs:** The maintenance costs are the future costs anticipated to maintain the pavement platform at a reasonable level of service in accordance with minimum maintenance standards set out in Ontario Regulation 239/02. For example, maintenance for a concrete pavement may include but is not limited to; concrete panel replacement, joint maintenance, crack sealing and diamond-grinding to improve the skid-resistance of the surface.

**Salvage/Residual Value:** The salvage and/or residual value is the expected value of the pavement at the end of the analysis period. If the pavement is anticipated to be replaced in its entirety at the end of the analysis period, the salvage value may include the recycling of materials that will be removed and reused. Generally speaking, it is prudent to assume the salvage value will be minimal in this scenario unless there is a specific use and intent by the municipality. Conversely, the residual value should be included in LCCA if the pavement is still in service and is intended to be used after the analysis period.

**Present Worth:** The present worth or present value is the total cost of expenditures in the future discounted to present-day dollars. Essentially, this concept recognizes that certain costs or benefits will occur in different time periods and converts these values into comparable amounts. This concept recognizes the fact that money in today-dollars has the ability to earn interest over time (known as the time / value of money), and the notion that economic assessments are required to evaluate financial decision-making options over various time periods.



1	Introduction
2	Shelwalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

**Interest Discount Rate:** The rate at which current funds are discounted to a future year value. Typically expressed as a percentage figure for an annual rate, the discount rate represents the interest money is anticipated to earn over the analysis period. A reasonable interest rate at which money can be invested in bonds or used for debentures is the appropriate discount rate to use in these economic evaluations.

With the intention of bringing future costs to the present value and adding the present worth of capital investment, the following formula is derived for LCCA:  
 Life Cycle Cost Analysis (LCCA) = Initial construction cost + maintenance costs - salvage value

$$LCC = A + E_1 (PWF_1) + \dots + E_k (PWF_k) - S (PWF_n)$$

where;

- LCC = Life Cycle Costs (present worth of the expenditures over the pavement's life)
- A = initial cost of construction
- $E_k$  = maintenance cost in year k
- $PWF_i$  = present worth factor =  $(1 / (1+r))^i$  (where, r = discount rate, i = year of repair)
- n = analysis period
- S = salvage value

## 6.1 Equivalent Pavement Design Example

For this example, a 50-year analysis period for the construction and maintenance of 1 km of 4-lane roadway was considered for comparable concrete and asphalt pavement designs. The existing subgrade is assumed to be in the medium category (low plasticity / silt = 40 MPa and/or CBR=4) and the Annual Average Daily Truck Traffic (AADT) is 2,500 vehicles. For these design conditions, the proposed concrete pavement section consists of 200 mm of concrete; and 200 mm Granular "A" base. The proposed asphalt pavement section consists of 140 mm of hot-mix asphalt (HMA); 150 mm of Granular "A" base; and 450 mm of Granular "B" sub-base. The resulting data from this analysis is summarized in Tables 6.1 and 6.2. For additional information on pavement design comparisons, refer to 3.4 Pavement Selection, Table 3.2 - Equivalent Pavement Structure Design Matrix for Municipal Roadways.

The sum of the data in Table 6.3 provides a present worth value of the proposed concrete pavement to be: \$980,100 (Initial construction cost) + \$136,916 (maintenance costs - salvage value) = \$1,117,016 (LCCA). Some of the maintenance treatments included in this analysis is as follows;

Years After Construction	Present Worth Factor (PWF <sub>i</sub> )	M/R Cost	Net Present Worth (PWF <sub>i</sub> x Cost)
12	.5568	\$37,500	\$20,881
25	.2953	\$150,000	\$44,295
40	.1420	\$225,000	\$31,960

Table 6.1 - Concrete Pavement Maintenance/Rehabilitation (M/R) cost

Years After Construction	Present Worth Factor (PWF <sub>i</sub> )	M/R Cost	Net Present Worth (PWF <sub>i</sub> x Cost)
10	.6139	\$26,250	\$16,115
20	.3769	\$173,880	\$65,534
35	.1813	\$177,120	\$32,110
48	.0961	\$173,880	\$16,717

Table 6.2 - Asphalt Pavement Maintenance/Rehabilitation (M/R) cost

1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Plan Development and Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCC) Analysis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Curing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

**Joint Resealing:** Presently, there are two philosophies on the requirement for joint sealing. The first school of thought suggests that the joints should not be sealed due to ongoing maintenance needs, the other school suggests otherwise and recommends sealing the joints. There are advantages and disadvantages to both options. The idea behind not sealing the joints is that joint sealants typically last 10-15 years at which point the sealant should be removed and replaced with new joint sealing compounds. By putting in the sealant the municipality is recognizing that additional maintenance activities are required over the life of the pavement albeit, incompressible particles will not enter the joint and cause the concrete to chip in seasonal freeze / thaw conditions. With no sealant in the joints, incompressible materials can enter the joint, especially during maintenance operations in the winter months. If the incompressible material is not removed, the individual concrete panels may lock up and expand in the summer months when the panels move due to the summer heat. If joint sealant is not used then sweeping,

blowing and/or vacuuming of the joints is recommended to ensure longevity of the saw cut over the life of the pavement.

With joint sealing, after the concrete receives the initial saw cut to relieve shrinkage stresses during the curing period, a wider saw cut is sawn. The joint should then be cleaned, backer rod installed and then the sealant material. The sealant material helps reduce the amount of water that infiltrates into the sub-base at the joint and prevents incompressible materials from entering the joint. The main disadvantage is the sealants typically last less than 10 years, at that time the joint has to be cut wider and new sealant installed. Successive saw cutting will create wider joints over time that may lead to potential noise complaints. Both methods have worked successfully for various municipalities in Ontario. It is the municipality's option to determine which maintenance activity is best suited over the life of the pavement. The same approach applies for asphalt pavements, crack sealing for roadways prevent and slow down

**Initial Pavement Structure**

Pavement layer	Description of pavement layer, Amount (Quantity)	Amount	Quantity per km	Price per unit of quantity	Cost
Surface	200 mm PCC pavement, 32M dowels (m <sup>2</sup> )	200	15000	\$ 49.50	\$ 742,500
Base	Granular A, mm (t)	200	7200	\$ 18.00	\$ 129,600
Excavation	Earth excavation (m <sup>3</sup> )	400	6000	\$ 18.00	\$ 108,000
<b>Total Initial Cost</b>					<b>\$ 980,100</b>

**Urban Pavement Maintenance and Rehabilitation Action Plan**

Years after initial construction	Description of pavement layer, Amount (Quantity)	Amount	Quantity	Price per unit of quantity	Cost	Net present worth
12	Partial depth PCC repair, % area (m <sup>2</sup> )	2	300	\$ 125.00	\$ 37,500	\$ 20,881
12	Reseal joints, % Length (m)	25	833	\$ 10.00	\$ 8,333	\$ 4,640
25	Partial depth PCC repair, % area (m <sup>2</sup> )	5	750	\$ 125.00	\$ 93,750	\$ 27,685
25	Full depth PCC repair, % area (m <sup>2</sup> )	10	1500	\$ 100.00	\$ 150,000	\$ 44,295
25	Reseal joints, % Length (m)	25	833	\$ 10.00	\$ 8,333	\$ 2,461
40	Partial depth PCC repair, % area (m <sup>2</sup> )	5	750	\$ 125.00	\$ 93,750	\$ 13,317
40	Full depth PCC repair, % area (m <sup>2</sup> )	15	2250	\$ 100.00	\$ 225,000	\$ 31,960
40	Reseal joints, % Length (m)	25	833	\$ 10.00	\$ 8,333	\$ 1,184
50	Residual Value				\$ 109,028	\$ 9,508
<b>Total M&amp;R Cost</b>					<b>\$ 515,972</b>	<b>\$ 136,916</b>

Table 6.3 - Initial and long-term maintenance costs for a concrete pavement with 2,500 AADTT and 40MPa subgrade (provided by CAC – Street Smart Report, ARA).

deterioration although, new joints are formed and crack sealing must be reapplied regularly. For thinner concrete pavements, the movement of the joint becomes quite limited and the width of the saw cuts can be reduced due to the size of panels / joint spacing. As a result, joint sealing is not normally required for these projects.

Partial and Full Depth Repair: Partial depth concrete repair is a maintenance technique used to repair either joint spalling or surface imperfections. A partial depth repair typically consists of removing approximately 75 mm of the concrete around the repair area and replacing the surface with new concrete or a specialized patch material. Full depth repairs are completed in order to repair panels that have been damaged during service, such as cracking, ravelling and / or faulting at joints. Fast track concrete can be used in order to accelerate curing period and reopen the roadway to traffic. The repair is similar to a utility cut repair where, it is best to replace

an entire panel instead of cutting out small section. Small repairs are prone to cracking unless the length to width ratio greater than 1.5. For example, if a panel is to be cut 600 mm wide then the length of the panel to be saw cut cannot be greater than 900 mm. If the panels are not “square” or under the 1.5 ratio, then the panel will normally crack mid-panel and cracking may transfer to adjacent concrete panels.

### Comparative Asphalt Design:

Following the same life cycle cost analysis method, the initial construction costs of the asphalt cross-section and the maintenance requirements over a 50 year period are as follows:

Table 6.4 - Initial and long-term maintenance costs for an asphalt pavement with 2,500 AADTT and 40MPa subgrade (provided by CAC - Street Smart Report, ARA).

Initial Pavement Structure						
Pavement layer	Description of pavement layer, Amount (Quantity)	Amount	Quantity per km	Price per unit of quantity	Cost	
Surface	Superpave 12.5FC1, mm (t)	40	1,512	\$ 115.00	\$ 173,880	
Binder	Superpave 19, mm (t)	100	3,690	\$ 96.00	\$ 354,240	
Base	Granular A, mm (t)	150	5,400	\$ 18.00	\$ 97,200	
Subbase	Granular B, mm (t)	400	12,000	\$ 15.00	\$ 180,000	
Excavation	Earth excavation (m <sup>3</sup> )	690	10,350	\$ 18.00	\$ 186,300	
<b>Total Initial Cost</b>					<b>\$ 991,620</b>	

Urban Pavement Maintenance and Rehabilitation Action Plan						
Years after initial construction	Description of pavement layer, Amount (Quantity)	Amount	Quantity	Price per unit of quantity	Cost	Net present worth
5	Rout and seal, m/km (m)	200	200	\$ 5.00	\$ 1,000	\$ 784
10	Rout and seal, m/km (m)	500	500	\$ 5.00	\$ 2,500	\$ 1,535
10	Spot repairs, mill 40 mm/patch 40 mm, % area (m <sup>2</sup> )	5	750	\$ 35.00	\$ 26,250	\$ 16,115
20	Mill HMA, mm (t)	40	1500	\$ 15.00	\$ 22,500	\$ 8,480
20	Resurface with Superpave 12.5FC1, mm (t)	40	1512	\$ 115.00	\$ 173,880	\$ 65,534
25	Spot repairs, mill 40 mm/patch 40 mm, % area (m <sup>2</sup> )	1000	1000	\$ 35.00	\$ 35,000	\$ 10,336
30	Spot repairs, mill 40 mm/patch 40 mm, % area (m <sup>2</sup> )	10	1500	\$ 35.00	\$ 52,500	\$ 12,147
35	Mill HMA, mm (t)	90	3375	\$ 15.00	\$ 50,625	\$ 9,178
35	Resurface with Superpave 19, mm (t)	50	1845	\$ 96.00	\$ 177,120	\$ 32,110
35	Resurface with Superpave 12.5FC1, mm (t)	40	1512	\$ 115.00	\$ 173,880	\$ 31,523
40	Rout and seal, m/km (m)	1500	1500	\$ 5.00	\$ 7,500	\$ 1,065
45	Spot repairs, mill 40 mm/patch 40 mm, % area (m <sup>2</sup> )	10	1500	\$ 35.00	\$ 52,500	\$ 5,843
48	Mill HMA, mm (t)	40	1500	\$ 15.00	\$ 22,500	\$ 2,163
48	Full depth asphalt base repair, % area (m <sup>2</sup> )	5	750	\$ 45.00	\$ 33,750	\$ 3,245
48	Resurface with Superpave 12.5FC1, mm (t)	40	1512	\$ 115.00	\$ 173,880	\$ 16,717
50	Residual value				\$ 191,775	\$ 16,723
<b>Total M&amp;R Cost</b>					<b>\$ 813,610</b>	<b>\$ 200,051</b>

Table 6.4 - Initial and long-term maintenance costs for an asphalt pavement with 2,500 AADTT and 40MPa subgrade (provided by CAC – Street Smart Report, ARA).

- 1 Introduction
- 2 Sitework, Curbs & Gutter Evaluation and Inspection
- 3 Asset Management / Pavement Selection
- 4 Concrete Bridges
- 5 Sustainability
- 6 Life Cycle Costs (LCC)
- 7 Unsprinkable Fill (U-Fill)
- 8 Architectural Concrete
- 9 Concrete Jointing
- 10 Procurement
- 11 Construction / Placement Meetings
- 12 Concrete Construction Procedures
- 13 Transportation of Concrete
- 14 Conveying, Handling, and Finishing Concrete
- 15 Concrete Protection and Curing Requirements
- 16 Measurement, Testing and Acceptance of Concrete
- 17 Project Closeout and Continuous Improvement
- 18 Troubleshooting
- Appendix



1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Pavement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

The sum of the data in Table 6.4 provides a present worth value of the proposed asphalt pavement to be: \$991,620 (Initial construction cost) + \$200,051 (maintenance costs - salvage value) = \$1,191,671 (LCCA)

The decision to construct and maintain the proposed concrete pavement results in a savings of \$74,655.

#### References:

Concrete Ontario (RMCAO), Pavement Design Assistance Program (PDAP), "Concrete Pavement Proposal - King Street North, Region of Waterloo" (2015).

U.S. Department of Transportation Federal Highway Administration Pavements LCCA <http://www.fhwa.dot.gov/pavement/recycling/98042/20.cfm>

## Chapter 7 - Unshrinkable Fill (U-Fill)

### 7.1 Introduction

Every year in cities and towns across Ontario, existing roadways are excavated and trenched at times to repair or install new utilities. When the repair or installation is complete, the pavement must be restored and reopened to vehicular traffic. Over the years, inadequate performance of these restored utility trenches has shortened the life of the pavement; resulted in settlements / further repairs; and a large annual outlay of public funds for maintenance activities to provide an acceptable level of service to the travelling public.

This chapter describes a flowable backfill material called U-Fill and how it should be used in place of compacted granular as a viable backfill material to restore excavations for the installation of storm and sanitary sewers; maintenance manholes; catch basins and ditch inlets; valve chambers for watermains; and other utilities. The use of U-Fill eliminates future settlement of the trench material, restores the riding quality and prolongs the service life of the pavement.

Based on the low strength of the material, U-Fill can be removed with hand tools and provides easy access to the utilities if / when repairs or reinstallations are required in the future.

U-Fill is a controlled, low strength, self-compacted, backfill material (or CLSM - Controlled Low-Strength Materials) used in utility cuts and trenches as shown in Figure 7.1. Similar to concrete, U-Fill is manufactured using cement, water, fine and/or coarse aggregates. In addition, it is an extremely low-strength concrete with a maximum strength usually specified, rather than a minimum strength as for normal concrete. The minimum 24-hour compressive strength should be 0.07 MPa with a maximum compressive strength of 0.7 MPa at 28 days. The density of the material is controlled such that no compaction is required to achieve an adequate bearing capacity, as would be the case if granular materials were used for backfilling purposes. Bearing capacity is a common criterion used for measuring the ability of a soil to withstand or support a load, and soils in excess of 0.3 MPa to 0.7 MPa would represent a well-compacted fill.



Figure 7.1 – Utility cut restoration with U-Fill (provided by CAC).

1	Introduction
2	Shrinkage, Curing, and Evaluation and Inspection
3	Asset Management Planning and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## 7.2 Materials

U-Fill, also known as flowable fill, usually consists of water, cement, fine and/or coarse aggregates, but may also contain fly ash or slag or air entrainment admixtures. Special attention should be taken when fly ash or slag is used, as it may result in slower development of early strength and the eventual development of strengths in excess of that required. Selection of materials should be based on availability, cost, specific application, and the necessary characteristics of the mixture, including flowability, strength, excavatability of earth, and density.

**Cement:** Cement is the bonding agent for concrete and U-Fill, provides cohesion in the mixture and ultimate strength for the material. For most applications, Type GU or GUL cement conforming to CSA A3001 is normally specified.

**Admixtures:** The inclusion of air entrainment in U-Fill mixtures can improve the workability of the material; reduce shrinkage; result in little or no bleeding; provide minimal segregation; lower unit weights; and control strength development. For air content greater than 6%, it may increase segregation of the mix. Water content can be reduced as much as 50% when using air-entraining admixtures. The use of these materials may require modifications to typical U-Fill mixtures. To prevent segregation when utilizing high air contents, the mixtures need to be proportioned with sufficient fines to promote cohesion.

**Water:** Water typically used in concrete mixtures is acceptable for use in U-Fill mixtures.

**Aggregates:** The type, grading, and shape of aggregates can affect the physical properties of the mixture, such as flowability and compressive strength. Aggregates complying with CSA A23.1 are generally used, because concrete producers have these materials in stock. Granular materials with lower-

quality properties than concrete aggregates, including recycled concrete aggregates up to 25% replacement are a potential source of CLSM materials and should be considered in U-Fill mixtures although, variations of the physical properties in the aggregates will have a significant effect on the mixture's performance. Aggregates that have been used successfully include:

- Pea gravel with sand;
- 19 mm (3/4") minus aggregate with sand;
- Native sandy soils, with more than 10% passing a 75 µm (No. 200) sieve; and
- Quarry waste products, generally 10 mm (3/8") minus aggregates.

**Fly ash:** Coal-combustion fly ash is sometimes used to improve flowability in concrete and U-Fill mixtures. High fly ash content mixtures result in low-density CLSM when compared with mixtures with high aggregate contents. Under these circumstances, it is best practice to conduct trial mixtures to determine whether the mixture will meet the specified requirements.

## 7.3 Plastic Properties

**Flowability:** High flowability is achieved when there is no noticeable segregation observed in the mixture and the U-Fill material is at least 200 mm (8 in.) in diameter with the slump cone test. Flowability ranges can be expressed as follows:

- Low flowability: less than 150 mm (6 in.);
- Normal flowability: 150 to 200 mm (6 to 8 in.); and
- High flowability: greater than 200 mm (8 in.).

**Set Time:** Setting time is the approximate period of time required for U-Fill to consolidate from a plastic state to a hardened state with sufficient strength to support the weight of a person. This time is greatly influenced by the amount and rate of bleed water released from the mixture. When excess water leaves the mixture, solid particles realign, provide greater contact and



the mixture becomes rigid. Hardening time is greatly dependent on the type and quantity of cementitious material in the U-Fill. Final set time can be as short as one (1) hour, but generally takes three (3) to five (5) hours under normal conditions. Normal factors affecting the hardening time are:

- Type and quantity of cementitious material;
- Permeability and degree of saturation of surrounding soil that is in contact with U-Fill;
- Moisture content of U-Fill;
- Proportioning of U-Fill;
- Mixture and ambient temperature;
- Humidity; and
- Depth of trench / cut.

#### 7.4 Harden Properties

**Strength:** Unconfined compressive strength is a measure of the load-carrying ability of U-Fill. The compressive strength of 0.3 to 0.7 MPa equates to an allowable bearing capacity of a well-compacted soil. It is the primary objective for U-Fill installations to provide adequate bearing support while maintaining low level strengths to ensure future excavation (if necessary) can be accommodated at a later date. Some mixtures that are acceptable at early ages continue to gain strength with time, making future excavation with hand tools difficult to complete.

**Density:** Wet density of an U-Fill, in place, is in the range of 1,840 to 2,320 kg/m<sup>3</sup>, which is greater than most compacted materials. The dry density of the mixture can be expected to be substantially less than that of the wet density due to water loss. Lower unit weights can be achieved by using lightweight aggregates, high entrained-air contents, and foaming agents.

**Settlement:** Earth fills can settle and consolidate even when compaction requirements have been met during construction. In contrast, U-Fill does not shrink after installation and settlement will not occur after hardening, providing the mixture properties have been met.

Measurements taken months after the placement of a large U-Fill installations have shown good performance with no shrinkage or settlements observed.

**Codes and Standards:** Canadian Standards Association (CSA) A23.1-14 Concrete Materials and Methods of Concrete Construction, clause 8.11 regarding Controlled Low-Strength Materials (CLSM) provides guidance for the U-Fill, performance requirements relating to compressive strength, and recommended methods of construction. Additional information regarding U-Fill can also be found in OPSS 1359.

References:

Canadian Standards Association; A23.1-14 Concrete Materials and Methods of Concrete Construction

American Concrete Institute; ACI 229-R13 Report on Controlled Low-Strength Materials

Ontario Provincial Standard Specifications; OPSS 1359, "Material Specification For Unshrinkable Backfill". (2006)

1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Shrinkage, Curvature, and Evaluation and Inspection
3	Asset Management Planning and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Construction Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 8 - Architectural Concrete

Concrete is one of the most versatile and widely used construction materials in the world. One special subset is called architectural concrete, which refers to a substance that provides an aesthetic finish and structural capabilities in one. This material is made to be seen. Canadian Standards Association (CSA) A23.1-14, defines architectural concrete as concrete that is exposed to view as an interior or exterior surface. Whether creating broad expanses or minute details, concrete permanently captures the chosen look. Achieving an architectural or decorative appearance usually requires something different to be done to the concrete to make it stand out. Whether that involves special forms, special finishing techniques, or special ingredients, the variety of effects is almost endless and open to the designer’s imagination.

Architectural concrete can be defined as concrete which is exposed as an interior finish or exterior surface in a public space or municipal right-of-way; contributes to the visual character of the space or structure; and is designated in the contract documents as architectural concrete.

### 8.1 Types of Architectural Concrete

There are many ways in which concrete can be formed; however, they generally fall into one of two main categories: concrete that is cast where it will remain, and concrete that is cast elsewhere and transported to site for installation. Within these two categories, the most common methods of concrete construction are cast-in-place and precast. These techniques are described briefly below, and are further explained in surface and basic techniques.

**Cast-in-Place Vertical:** In this method of concrete construction, formwork is erected on-site and the concrete is typically placed via ready-mixed concrete where, the material is batched at a local concrete plant and trucked

to the site in an agitator truck. The most common surface of a cast-in-place concrete is patterned form-tie holes and a smooth surface finish. For vertical structures such as foundations and retaining walls, this method can accommodate countless types of finishes such as, textures created by various forming methods and revealed after the concrete has been cast (ex. patterned form liners).  
**Cast-in-Place Horizontal:** also known as decorative concrete, in this method of construction, the concrete is placed into forms and then the surface is textured and / or coloured with a variety of techniques to provide a decorative finish. Some techniques used for cast-in-place concrete flatworks include; texturing in alternating directions (using brooms, trowels or other hand tools); exposed aggregate finishes using retardants to slow the hardening process; sand blasting or shot blasting to provide a coarse surface; stamping; acid etching and staining.

**Precast:** In this method of concrete construction, formwork is erected off-site, usually in a controlled factory setting such as a precast concrete plant. Typically, these structural members or panels are used as exterior cladding for buildings as previously shown in Figure 8.1 and other structures such as, bridge abutments shown in Figure 8.2. This method is quite common when a consistency of colour, texture and finish is required to acquire a desired appearance. Precast panels are often viewed as a cost-effective approach due to the amount of time saved during installation. In addition, precast concrete can provide a particularly artful appearance and creative form for any surface.

**Tilt-up:** In this method of precast concrete, a cast-in-place concrete floor slab is usually used as formwork for the cladding/wall of the building. Once the floor slab has cured, formwork is erected to form the edges of the wall slabs, which are then cast horizontally on the floor slab, sometimes in stacks on top of each other. Once cured, they are hoisted and tilted into place.

This method of construction requires substantial manoeuvring space for the lifting equipment and proper planning.

**Applied:** Applied concrete is not as common now as it used to be. It is often recognizable at a zoo, skate park, or pool, or one of the spaceship-like buildings from the 1960s. The application of shotcrete, using a pneumatic sprayer is one way that curvilinear shapes are achieved.

## 8.2

### Cast-in-Place Horizontal Surfaces-Decorative Concrete

**Coloured Concrete:** Concrete is a product known to be mouldable into many shapes and is well known to have many different colours as is illustrated in Figure 8.3. Coloured concrete is produced through the use of iron oxide pigments in the mix and have been used in concrete to provide earth-tone elements for over 50 years. The pigments are either mined from the ground or manufactured in chemical plants around the world. Pigments

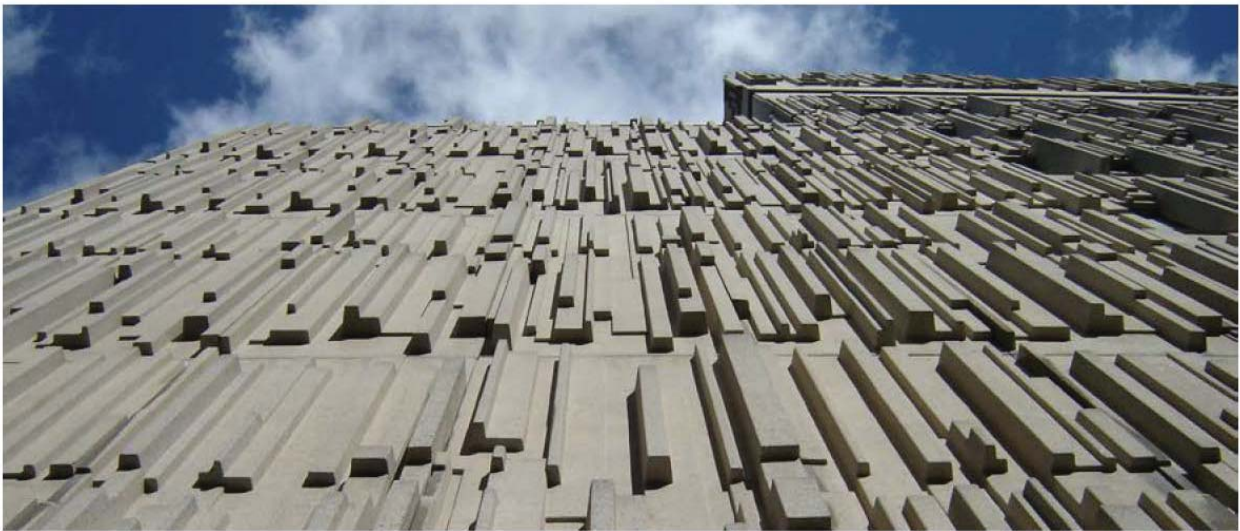


Figure 8.1 – Exterior Claddings in University of Toronto (provided by CAC)



Figure 8.2 – Architectural precast concrete bridge abutment, City of Kitchener (provided by Region of Waterloo).



1	Introduction
2	Sitewalk, Curf & Gutter Evaluation and Inspection
3	Asset Management Plan Development Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Curing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

are available from suppliers in either powder, liquid and granular forms. Iron oxide pigment particles are ten times smaller than cement and cover the cement particle when mixed in concrete to create a coloured concrete appearance.

This is the primary reason the quantity of color is typically based on the weight of the cement content or a percentage of the overall mix. The supplier and / or contractor should control the amount of water added to the concrete to ensure the mix provides a consistent colour throughout the entire project. If additional water is added during construction then the proportions of the mix will change resulting in the colour fading or becoming lighter in appearance.

Concrete inherently is a natural coloured material and consistency depends on many factors from batch to batch. These factors include but are not limited to; the temperature of the mix; moisture content of the aggregates; the source of the cement; types of supplementary cementing materials; and the accuracy in

which any pigment has been added. Pigment can be added to the concrete mix integrally in the mixing process or can be applied to the surface after the concrete has set.

White Portland Cement is an ingredient in the production of coloured concrete. It can also be used on its own and allow for a broad spectrum of colours from bright whites to pastels or saturated colors. Mix designs for white or coloured concrete are formulated with respect to the following ingredients.



Figure 8.3 - Decorative patio and pool entry with exposed aggregate surface using coloured beaded glass (provided by Concrete Ontario)

paying particular attention to the resultant effect on color; (1) type and color of cement; (2) type and quantity of pigment; (3) type and quantity of chemical admixtures; (4) type, gradation, color, and cleanliness of fine and coarse aggregates; (5) type and quantity of supplementary cementing materials such as, slag, fly-ash, dark or white silica fume; and (6) consistent water to cementing materials ratio (w/cm ratio).

**Exposed Aggregate:** A textured surface can be constructed to provide colour changes and surface finishes such as, impressed brick or stone. Another simple way to change the texture is to provide an exposed aggregate finish with a surface retardant to slow down the setting process. This

technique can be applied using a variety of decorative aggregates (ex. black granite); vary in size; and the depth of penetration can be controlled based on desired amount of aggregate exposed. For example, the concrete on the left in Figure 8.4 has been constructed with a light etch or micro-exposed aggregate finish to expose the sand grains in the mix only. This technique provides texture surface but is still comfortable for bare feet or bicycle traffic. Right beside is the same colour of concrete only stamped with a subtle stone surface. By simply changing the texture of the concrete, the finished product gives the impression that a different colour of concrete has been used.

In Figure 8.5, is a concrete surface with



Figure 8.4 – Decorative coloured concrete with etched and stamped finishes (provided by Concrete Ontario).



Figure 8.5 – Decorative coloured concrete with exposed, stamped and broom finishes (provided by Concrete Ontario).

1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Laying, Finishing and Curing of Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Plan Development Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Recreational Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

a medium-exposed aggregate finish and flagstone stamped surface and broom finished on the left respectively. This surface treatment removes the concrete paste just enough to expose the top of the coarse aggregate. On the right is a traditional (full depth) exposed aggregate surface and conventional broomed surface commonly used to finish sidewalks or walkways. The traditional (full depth) exposed aggregate removes more paste from the surface; reveals more aggregate colours in the mixture and provides a rougher surface appearance. When texturing and colour are combined, a beautiful concrete walkway can be created as shown in Figure 8.6.

Shown subsequently in Figure 8.7 is another technique municipal designers may want to consider for their decorative concrete applications. Similar to the examples above, the treatment involves texturing the surface with micro-exposed aggregate finishes although, jointing is imprinted into the concrete with plastic stencils to develop a brick paving stone pattern. The styles of patterns are limitless to the designer’s imagination as the stencils can be manufactured with computer programs to suit a particular design objective.

**Stamped (or Impressed) Concrete:** Stamped concrete, or sometimes called impressed concrete or patterned concrete, is a method of concrete construction that provides a finished surface that resembles other materials such as, slate, flagstone, brick, hardwood, cobbles, etc.

Stamped concrete offers a wide array of options to municipalities when creating a desired look for new streetscapes, sidewalks, parking lots, parks and other public spaces. Stamped concrete has the ability to provide a cost-effective surface treatment without compromising on appearance. There are hundreds of stamped concrete patterns available in the market, such patterns include; random or repetitive interlocking stones, tiles, fieldstone, flagstone and other natural stone finishes. The concrete mats used to create these finishes vary in size and can offer an array of jointing designs or seamless stone-like finishes. When applied with coloured release agents and concrete sealers, the municipality can enhance the appearance of the surface and create a two-tone finish similar to natural stone, in Figure 8.8 or interlocking pavers.

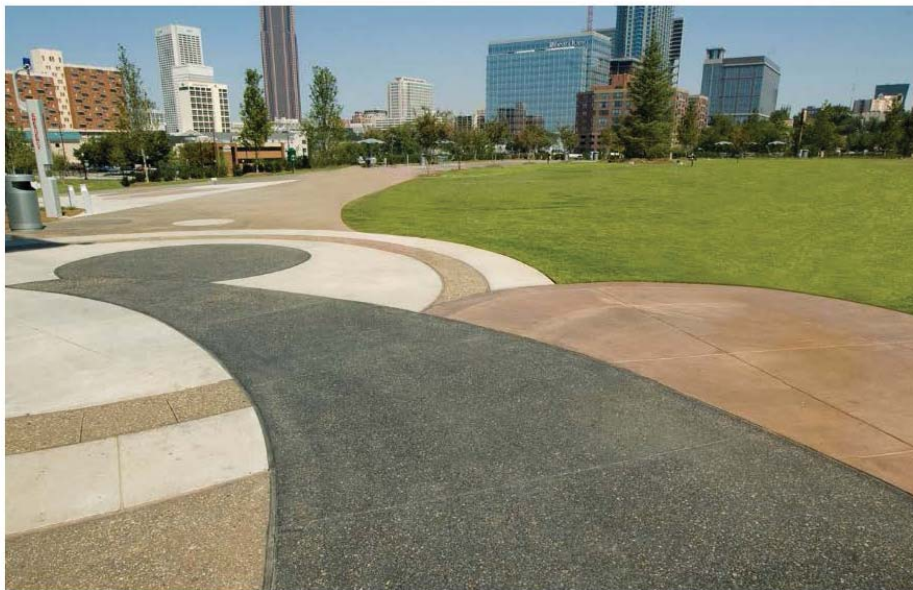


Figure 8.6 – Decorative concrete walkways with a combination of coloured and exposed finishes (provided by Concrete Ontario).



For examples on stamped concrete finishes and / or products, refer to the following supplier websites for additional information; Brickform - <http://www.brickform.com/Textures/About-Our-Textures/>; and Proline

**Tools** - [http://www.prolinestamps.com/concrete\\_stamps.aspx?id=1](http://www.prolinestamps.com/concrete_stamps.aspx?id=1)

Figure 8.8 - Decorative coloured concrete with stamped stone finish (provided by Concrete Ontario)

### 8.3 Qualifications and Specifications

It is best practice to include in the contact documents, a special provision outlining the municipality’s quality expectations for architectural or decorative concrete, the monitoring / controlling procedures during placement and subsequent acceptance requirements. The contract should define the qualifications required by the general contractor and the municipal representative who will evaluate the concrete for compliance with the specifications. In order to mitigate any misunderstandings, it is imperative that the specifications are clear to the contractor and the municipal representative is readily available to guide and approve the performance of the work.

The following is a general list of items that can be considered in the contract documents to control the quality of decorative concrete work. These items include but are not limited to; jointing patterns and advising the contractor that the representative will approve all chalk lines prior to saw cutting; contractor’s opportunity to patch and repair damaged and / or nonconforming sections of decorative concrete; color variations between concrete placements and the contractor’s responsibility to control / verify mix designs; contractor’s opportunity to review and recommend changes to the concrete mixture to improve performance; and trial batches or mock-ups required for representative review / approval prior to concrete placement.

**Mock-ups:** The mock-up can be a separate standalone item in the contract or built-in to the unit cost of the architectural or decorative concrete items providing the description of work is clearly identified for contractor’s bidding on the work. It is in the best interest of all parties that a mock-up of the proposed work is conducted to ensure the contractor and municipal representative have agreed on a sample of the architectural/decorative concrete work prior to proceeding with larger placements.

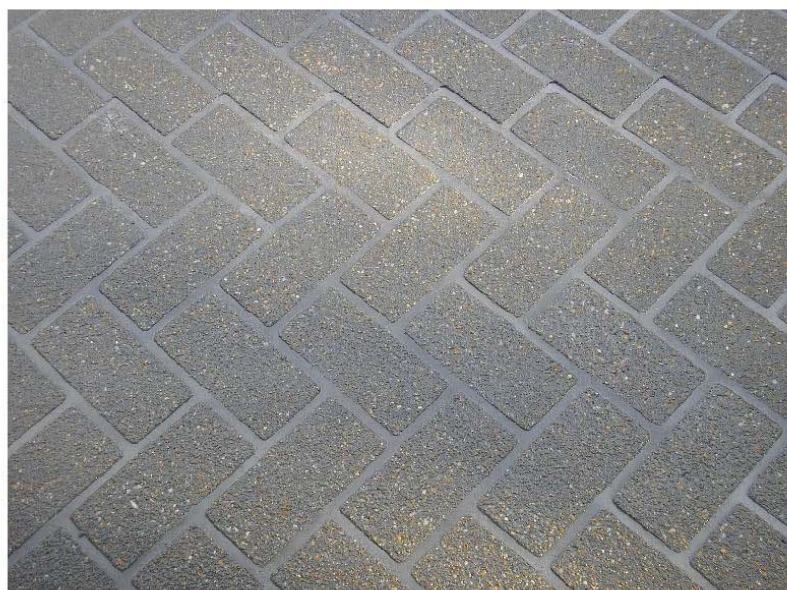


Figure 8.7 – Decorative coloured concrete with micro etched and brick stencil finish (provided by Concrete Ontario).

1	Introduction
2	Shelwalk, Curf & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Control Procedures
13	Transportation of Concrete
14	Convey, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

It is recommended the concrete specifications have a defined scope of work for the mock-up installation and approval thereof.

Enclosed are some tips for ensuring a positive outcome from the mock-up:

- Construct the mock-up as close reasonably possible to the actual work in every detail;
- Include multiple sections of a mock-up to represent various aspects of the project if required. The mock-ups may be expensive but it will identify the preferred quality of work and alleviate any schedule delays resulting from disputes and / or replacing the work;
- When multiple lifts of concrete are required in the design, pour at least the second lift that is going to be exposed on the surface.
- Use the same amount of rebar in the mock-up as in the real structure to represent the actual congestion;
- Placing methods must be the same. If you use a pump during construction, then use a pump for the mock-up;
- Do it more than once. A couple of practice sessions are helpful to ensure a consistent product;
- Determine the curing methods, cleaning methods, and weather protection, if required, and decide who is responsible for maintaining the protection throughout the duration of the job;

- Size of the mock-up should represent repair and patching of concrete if required;
  - Consider specifications that permit the municipality to request additional mock-ups if necessary. This will be difficult for the contractor to bid thus, the number of mock-ups possibly required should be specified;
  - Place the mock-up somewhere it can remain until the job is complete and accepted at final completion; and
  - Provide acceptance, direction, objections, or rejection in writing to the contractor.
- The Canadian Standards Association (CSA), Concrete Materials and Methods of Concrete Construction (A23.1-14) has provisions on Architectural Concrete. For additional information, refer to Clause 8.3 for information on “Reference samples”; “Mock-up Field Samples”; “Formwork for Special Architectural Finishes”; “Placing of Architectural Cast-in-Place Concrete”; and “Special Finishes”.

References:

The Concrete Network, Understanding Coloured Concrete. [http://www.concretenetwork.com/chris\\_sullivan/colored\\_concrete.htm](http://www.concretenetwork.com/chris_sullivan/colored_concrete.htm)



Figure 8.8 – Decorative coloured concrete with stamped stone finish (provided by Concrete Ontario)

Canadian Precast / Prestressed Concrete Institute's Technical Brochure, "Architectural Precast Concrete" (2009). [http://www.cpci.ca/en/resources/technical\\_publications/](http://www.cpci.ca/en/resources/technical_publications/)

The Canadian Standards Association (CSA), "Concrete Materials and Methods of Concrete Construction, A23.1-14" (2014). - <http://shop.csa.ca/en/canada/concrete/a231-14a232-14/inv/27012102014>

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Laying, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 9 - Concrete Jointing

Joints are used in concrete pavement to control the location and geometry of the transverse and longitudinal cracks. These cracks develop due to stresses in the concrete caused by shrinkage during the curing period; inconsistent temperature and moisture differences; and traffic loading applied to the surface. Concrete moves for a variety of reasons and if the concrete is restrained in any way cracking may occur. A pavement can move on the base shrinking towards the centre of the panel, there are frictional forces generated between the soil and the concrete. The friction prevents full contraction of the panel and if the resistance force is greater than the tensile capacity of the concrete, the concrete will crack. Restraint is also caused by appurtenances such as, catch basins, light poles, maintenance holes or other appurtenances embedded in the concrete. The primary causes for concrete movement are drying shrinkage and thermal expansion / contraction.

Concrete requires water / cementitious ratios (w/cm) between 0.28 and 0.32. The current Canadian edition of Design and Control of Concrete Mixtures states this ratio excludes evaporable water, the water to Portland cement ratio (by mass) should be approximately 0.22 to 0.25 in order to completely hydrate the cementitious particles in the mixture. In order to place the concrete, typical w/cm ratios are between 0.70 and 0.40. For sidewalks and curb applications, the w/cm ratio specified is a maximum 0.45 and bridge decks are a maximum 0.40. Roller Compacted Concrete (RCC) has a lower w/cm ratio of 0.38 or lower (which reduces shrinkage cracking). The primary difference in the w/cm ratio is the water required to make the concrete more flowable at the desired slump, this term is called “the water of convenience”.

With the latest technologies in concrete water reducers, it is possible to have a

wide variety of slumps at any given w/cm ratio. As the concrete hydrates the water of convenience will bleed out of the concrete which will then lose volume. The loss of volume is a phenomenon called drying shrinkage in the concrete. Low shrinkage concrete is defined by the Canadian Standards Association (CSA) A23.1, Clause 8.8.2 as concrete that has shrinkage not greater than 0.04% at 28 days when using 75 x 75 mm prisms, or 0.035% when using 100 x 100 mm prisms in accordance with CSA A23.2-21C. Conventional concrete has typical drying shrinkage values between 0.035% and 0.070%.

In order to allow for drying shrinkage, joints must be placed in the concrete at predetermined intervals or random cracking will occur which will not be as aesthetically pleasing as a controlled joint. For example, assume a pavement is 4.5 m in length with an average shrinkage of 0.06%, then the concrete will shrink 2.7 mm and jointing should be installed to control any shrinkage cracking. In addition, the American Concrete Pavement Association (ACPA) provides a “Joint and Sealant Movement Estimator” App free for downloading at <http://apps.acpa.org/applibrary/JointMovement/>.

For municipal applications, concrete is placed for exterior applications that are subject to the elements. When the concrete is heated or cooled there is a corresponding change in volume of the material. The amount of change is determined by the concrete’s Coefficient of Thermal Expansion (CTE). Figure 9.1 shown below represents the average CTE for various types of aggregates. For a typical limestone concrete mix, the average CTE is  $7.8 \times 10^{-6}$  m/m/°C. For the same 4.5 m concrete section noted above, the length of the pavement will now vary by 0.7 mm due to thermal expansion / contraction for temperatures ranging between -10 to 10 °C. This is not a significant change when compared to the shrinkage that occurs during curing although, this expansion / contraction may cause the concrete to chip

if the joints are filled with incompressible materials.

To accommodate these movements there are four types of jointing techniques that are commonly used:

(1) construction joints; (2) contraction joints; (3) isolation joints; and (4) expansion joints. For these types of jointing applications, the joints can be sealed or not sealed depending on the municipality's preference.

Concrete jointing is an important consideration in the design and longevity of the pavement. As shown in Figure 9.2, there are three critical cases for stress in the pavement; interior load, corner load and edge load. Interior loads are in the middle of the panel and they are usually the lowest stress condition. Corner loads are at the corner of the panels and edge loads are at the limit of the concrete where there is no load transfer between adjacent panels. Edge loads are usually the highest stress condition and designers should take this into

consideration when determining the limit of the concrete pavement.

For sidewalks and curbs, the edge loads are the most predominate load condition whereas, interior loads are the most predominant load condition for concrete pavements. It is important to understand the difference since interior loads can change to edge loads if the joints in a concrete pavement separate, become wider and the load transfer between panels is reduced. The transition from edge load to interior load is determined by the radius of relative stiffness of the concrete pavement which is beyond the limits of this manual.

### 9.1 Construction Joints

Constuction joints occur for two primary reasons; the concrete work has continued from a previous concrete pour or delays have been experienced on a project and the pour had to be completed due to time constraints between placement. Depending

Primary Aggregate Class	Average CTE (/°F x 10 <sup>-6</sup> )	Standard Deviation (s) (/°F x 10 <sup>-6</sup> )	Average CTE (/°C x 10 <sup>-6</sup> )	Standard Deviation (s) (/°C x 10 <sup>-6</sup> )	Sample Count <sup>1</sup>
Andesite	4.32	0.42	7.78	0.75	52
Basalt	4.33	0.43	7.80	0.77	141
Chert	6.01	0.42	10.83	0.75	106
Diabase	4.64	0.52	8.35	0.94	91
Dolomite	4.95	0.40	8.92	0.73	433
Gabbro	4.44	0.42	8.00	0.75	8
Gneiss	4.87	0.08	8.77	0.15	3
Granite	4.72	0.40	8.50	0.71	331
Limestone	4.34	0.52	7.80	0.94	813
Quartzite	5.19	0.50	9.34	0.90	131
Rhyolite	3.84	0.82	6.91	1.47	7
Sandstone	5.32	0.52	9.58	0.94	84
Schist	4.43	0.39	7.98	0.70	30
Siltstone	5.02	0.31	9.03	0.56	21
<b>Total Sample Count</b>					<b>2,251</b>

1. A total of 2,991 CTE values are available in LTPP Standard Data Release 25.0 (January 2011); 628 CTE values were not used due to aggregate class not defined or only one sample available for the primary aggregate type, and 112 CTE outlier values were also not included in the table.

**Figure 9.1 - Coefficients of thermal expansion of concrete aggregates (Hein, D. and Sullivan, S.)**

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management - Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sidewalk Curing and Evaluation and Inspection
3	Asset Management Plan Development and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

on the application, construction joints are typically formed with a smooth vertical face when there is new concrete placed beside old concrete. The following is a list of best practice methods that can be considered for various applications and are illustrated in Figure 9.3:

**Butt Joint with Expansion Joint Material:**

This method is the most common construction joint for concrete sidewalk applications and is used to isolate appurtenances such as, maintenance hole frames or poles, and is placed for separation between consecutive sidewalk pours. This

joint does not allow load transfer between the panels and the slabs will act independently when loading is applied. This is acceptable for light load conditions or when there is potential for cracking and the limit of cracking should be contained within a panel. Under this scenario, load transfer is not needed if the panel is designed for edge load conditions.

**Butt Joint with Expansion Joint Material and Dowel Bars:**

This method is used in concrete pavements where one panel is likely to crack due to appurtenances in the concrete but load transfer is required across

the joint and /or it is necessary to prevent faulting (lifting) of the joint. This method includes an expansion joint material which provides separation and prevents the crack from propagating to the adjacent panel. The steel dowel will prevent vertical movement of the joint and provide load transfer between the panels to ensure a smooth surface. In this case, an edge condition design is not required as the panels are acting homogeneously.

Butt Joint with Tie-bars or Dowels: This method is used is commonly used in slip-form concrete paving when it is not necessary to isolate the panels. Tie-bars are typically placed

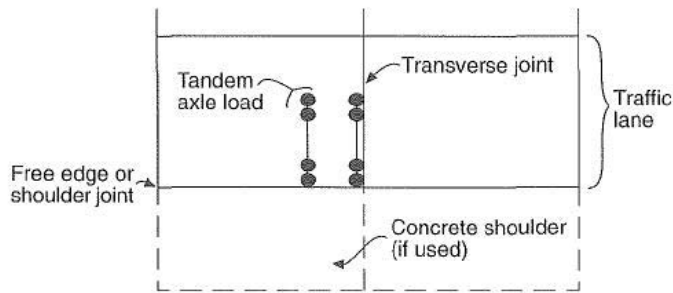


Figure 9.2 - Load conditions for stress in a concrete pavement (CPCA w/ CAC)

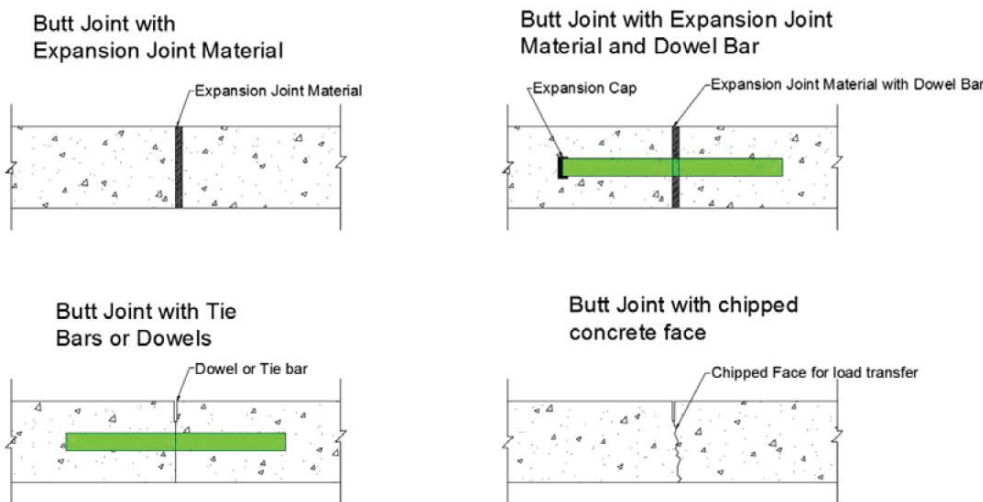


Figure 9.3 - Various jointing details for concrete sidewalks and pavements (OPSD552.020).



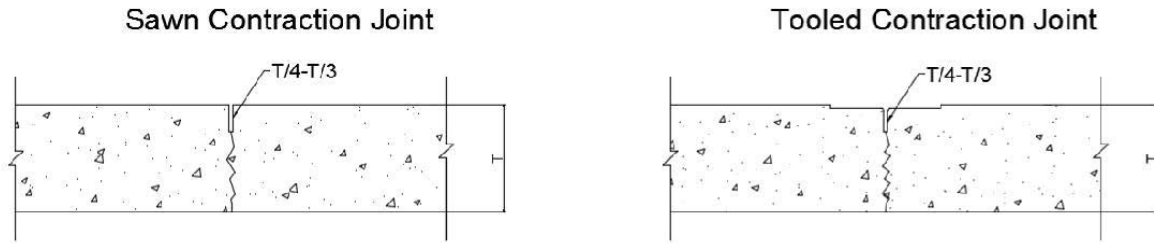


Figure 9.4 - Various jointing details for concrete sidewalks (OPSD552.020).

transversely to the direction travel and placed between pours to connect the slabs. Dowel bars are placed longitudinally at construction joints but should only be used for pavements greater than 180 mm thick.

#### Butt Joint with Chipped Concrete Face:

This method is used in lieu of dowels for pavements less than 180 mm thick. Since dowels are not practical for this application, the joint is manually chipped to provide a rough surface and cleaned to enhance the bond of the new concrete. This method promotes aggregate interlock between the pours and encourages the panels to act as one. It is important that the chipped face does not undercut the existing concrete as it will be difficult to fill the void and potential reduce the effective thickness of the pavement.

### 9.2 Contraction Joints

Contraction joints are joints that are either sawn into the pavement or tooled in using a grooving tool. Contraction joints are installed to a depth of 1/4 to 1/3 of the slab thickness ( $T/4$  or  $T/3$ ). Some municipalities prefer sawn joints to reduce bumps for wheelchairs and accessibility purposes. In accordance with Canadian Standard Association (CSA) A23.1, the spacing of contraction joints should be approximately 25 times the slab thickness and should not exceed 4.5 m. The concrete panels should be as square as possible with the length to wide ratio not exceeding 1:1.5 (note: If you have an Open Graded Drainage Layer (OGDL) under the concrete it is recommended to use

a maximum ratio of 1:1.2). Sawn contraction joints should be cut between 8 and 24 hours after placement depending on the environmental conditions (eg. temperature, wind, etc). Early entry saws can be used to reduce the cut time to approximately 4 hours after placement. When the pavement or sidewalk is not isolated from the curb through the use of expansion joint material, then sawcuts in the curb should be aligned with the adjacent slab to control the location of cracking.

### 9.3 Isolation Joints

Isolation joints are needed around embedded appurtenances or ironworks in the concrete. Embedded ironworks in the concrete may restrain the concrete when movement occurs and cause the concrete to crack. There are three examples provided in Figure 9.5 below. Panel 1 has a lamp post in the bottom left corner which will be fixed when the panel moves towards the centre of the panel. Therefore, the concrete at the top right corner has to move farther to accommodate the fixed point when shrinkage occurs in the concrete. In Panel 2, there is no restraint and the panel will have the ability to shrink towards the centre of the panel. Lastly, the lamp post is located in the centre of Panel 3 which is the preferred location as the panel will shrink towards the centre. Most of the drying shrinkage occurs in the first month of placement and cracking may be observed within a couple months of concrete placement.

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

Another reason for cracking in the concrete results from the thermal expansion of the concrete and steel embedments. The CTE for steel is approximately  $12 \times 10^{-6} \text{ m/m/}^\circ\text{C}$ . When the steel and the concrete are heated by the sun, both materials will expand in the same space and cracking may occur if they are not isolated correctly. In Figure 9.6, the maintenance hole frame and cover does not need to be isolated for drying shrinkage although, needs to be isolated due to the thermal expansion of the two materials. If the concrete was installed on a base with minimal friction then the concrete could expand without cracking.

For additional information on isolation joints and construction details for telescoping maintenance holes, catch basins, etc., refer

to the "Design and Construction of Joints for Concrete Streets" guideline provided on the ACPA website at [www.acpa.org](http://www.acpa.org).

### 9.4 Expansion Joints

Expansion joints are used to isolate concrete panels that are anticipated to move differently than adjacent concrete sections. For sidewalk and curb applications, expansion joints can be placed between the sidewalk and the curb and sections of sidewalks that are perpendicular to each other. The curb and sidewalk are different thicknesses and widths therefore, the concrete is anticipated to expand at different rates. For sidewalks, most of the expansion is in the longitudinal direction and misalignment or cracking may occur if perpendicular sections are not isolated from

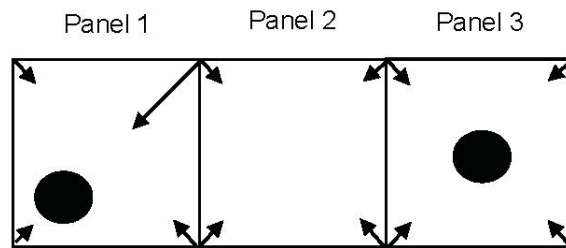


Figure 9.5 - Embedment jointing for concrete pavement (provided by Mick Prieur).

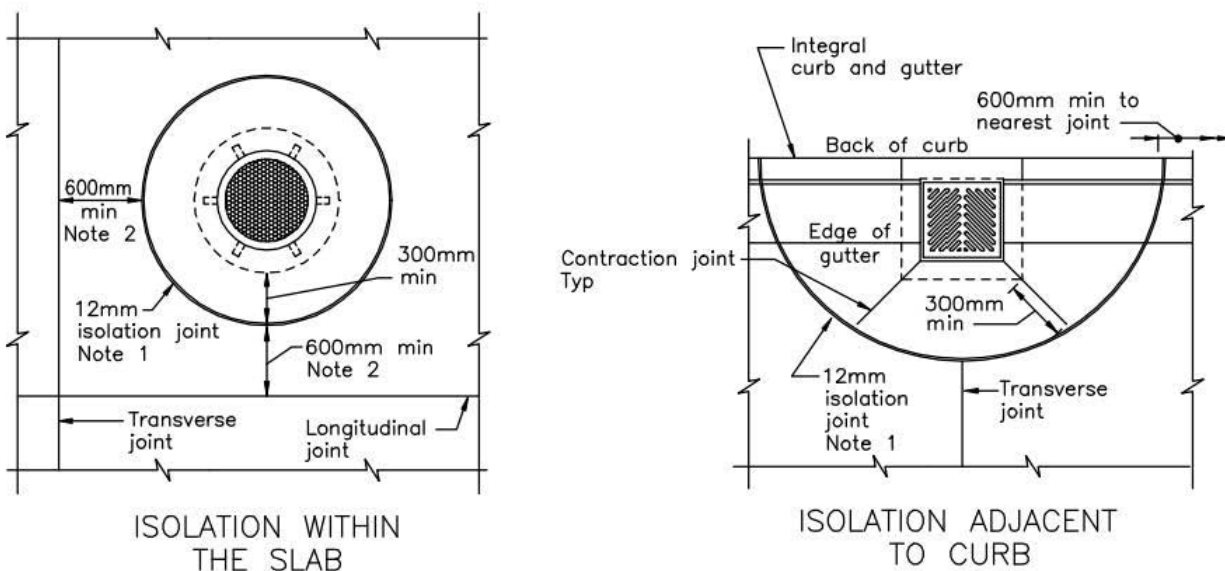


Figure 9.6 - Typical details for common embedments in concrete pavement (OPSD 551.032)

each other. Expansion joints are also used at approaches to bridge structures. If a concrete pavement was constructed adjacent to a bridge approach, expansion in the concrete pavement would apply stress on the bridge abutments if proper expansion joints were not constructed.

Similar to expansion joints, it is best practice to construct expansion joints the full thickness of the slab with fiber board or other expansion joint material such as, rubber or foam. If the joints are not constructed the full depth of the slab, then sections of the sidewalk or pavement are still connected and expansion may cause the concrete to crack as

shown in Figure 9.7. Expansion joints should be carefully planned during the design stage of a concrete pavement project. If there are too many expansion joints in a pavement, the pavement may move and cause the contraction joints to separate and widen. When the contraction joints widen excessively then there will be loss of load transfer at the contraction joints. (Figure 9.8)

### 9.5 Joint Sealant

Joint sealing or no sealing is a very hot topic with numerous experts sitting on both sides of the dividing line. As pavement designers are aware, water can have a damaging effect



Figure 9.7 - Joint failure due to expansion (provided by County of Essex)

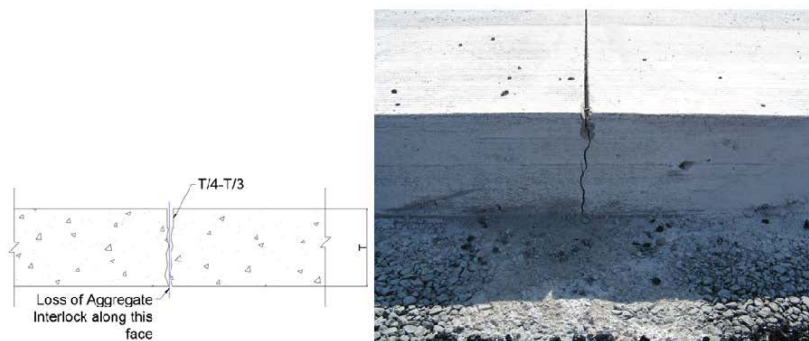


Figure 9.8 - Contraction joint with loss of load transfer between panels (provided by County of Essex)

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1 Introduction		
2 Sikemalk Curt & Gutter Evaluation and Inspection	on the performace of the pavement if water enters the base and doesn't drain properly.	Cement Association of Canada (CAC), Kosmatka, Steven H.; Kerkhoff, B.; Panarese, William C.; MacLeod, Norman F.; and McGrath, R.J. "Design and Control of Concrete Mixtures, 8th Canadian Edition" (2011).
3 Asset Management Pavement Selection	The pro-sealing group states that joints need to be sealed to keep the water out and to limit the amount of incompressible materials entering the joints. The primary problem with sealing is that if it is done incorrectly it can trap water which may become a large problem. Typically, joint sealants last approximately 10-15 years before failures occurs and the sealant requires replacement or maintennce. Each maintenance cycle requires the joint to be sawn wider which can contribute to increased noise of the pavement.	Canadian Portland Cement Association (CPCA). "Thickness Design for Concrete Highway and Street Pavement Canadian Edition/Metric" (EB209.03P)
4 Concrete Bridges		Canadian Standards Association (CSA). "Concrete Materials and Methods of Concrete Construction / Test Methods and Standard Practices for Concrete - A23.1/2" (2014).
5 Sustainability		Hein, D. and Sullivan, S. Transportation Association of Canada. "Concrete Coefficient of Thermal Expansion (CTE) and Its Significance in Mechanistic-Empirical Pavement Design" (2012).
6 Life-Cycle Cost (LCC)		Ontario Provincial Standards and Specifications, OPSD 310.010 (2005).
7 Unsprinkable Fill (U-Fill)	The no-seal group suggests the joints should be designed with closer spacing to reduce the amount of movement in the joint and minimize the amount of incompressible materials entering the joint. In addition, if the pavement is designed with good drainage then water entering the joint and / or base should not be an issue. The main concern with no sealant is incompressibles entering the joint which may lead to concrete chipping and potential blow-outs of the joint during expansion / contraction. To address these concerns, routine cleaning of the joints is recommended to remove incompressible material such as aggregates. Additionally, it would be best practice to seal granular shoulders to minimize the migration of aggregates that may travel along the surface and enter the joint.	Ontario Provincial Standards and Specifications, OPSD 551.032 (2008).
8 Architectural Concrete		Ontario Provincial Standards and Specifications, OPSD 552.020 (2008).
9 Concrete Jointing		
10 Procurement		
11 Pre- Construction Pavement Meetings		
12 Concrete Construction Procedures		
13 Transportation and Receiving Concrete		
14 Convey, Placing, and Finishing Concrete	Both approaches have performed well on pavements in Ontario with good success. For additional information regarding joint sealant, refer to the following website which has been dedicated to this topic <a href="http://www.sealnoseal.org">www.sealnoseal.org</a> . In addition, jointing design information can be found at the ACPA website at <a href="http://www.wikipave.org">www.wikipave.org</a>	
15 Concrete Protection and Curing Requirements		
16 Measurement, Testing and Acceptance of Concrete		
17 Project Closeout and Continuous Improvement	References:	
18 Troubleshooting	American Concrete Paving Association ACPA, Design and Construction of Joints for Concrete Streets, 1992.	
Appendix		Best Management Practices for Municipal Concrete Infrastructure

## Chapter 10 - Procurement

This chapter provides a guideline for municipal concrete designers and contract administrators during the procurement phase of a project and preparation of contract documents. The procurement phase can be defined as the process of which the acquisition of products, services or results are obtained from an outside external source. It is in the best interest of government agencies that projects are procured appropriately in order to ensure good value for the work in terms of cost, time, quality and scope of work.

The initial step in the municipal procurement process is to identify the purchasing needs of the agency and establish a strategy to satisfy these requirements. This strategy typically includes a series of steps and can be categorized in the following five process groups. These groups can be summarized as follows; Plan Purchases and Acquisitions; Planned Contracting; Contracts; Contract Administration; and Contract Closure.

### 10.1 Plan Purchases and Acquisitions

This process identifies which needs can be met by purchasing or acquiring products, services or results from outside of the agency. This process typically includes considerations of how, what and when to acquire products, services or results. During this process, the agency may seek services and support from subject matter experts or specialists in disciplines such as engineering, contracting, financing, purchasing and law.

The Plan Purchases and Acquisitions process includes reviewing the risks when determining whether to perform the work with in-house resources or soliciting the work from outside of the organization. This process generally involves the agency determining whether to 'make-or-buy' a product or service under conditions when specific resources or specialized skills may not be available. It is good practice to make use of economic evaluation tools and techniques such as,

estimating and cost-benefit analysis during this decision making process. Through the economic evaluation process, the agency should identify potential risks and the impact of making such procurement related decisions.

Depending on the complexity of a particular project, such as a skate-park seen in Figure 10.1 or reconstruction of a concrete bridge for example, the procurement schedule should be considered as part of the overall work plan for the project. The preferred timing of the reconstruction work may dictate the schedule for procurement and the agency's ability to meet key milestones dates, including; advertising timelines; bidding period; closing / opening of bids; acceptance period; recommendation for award; and execution of the contract documents. The procurement schedule can significantly influence this process and the development of a Procurement Management Plan may assist agencies in administering the procurement phase of a project.

Items to be considered as part of a Procurement Management Plan include;

- Products, services or results to be procured with justification statements and anticipated timelines;
  - Procurement related costs, evaluation of purchasing options and selection methodology;
  - Risks associated with procurement management and potential mitigation strategies;
- Standardized procurement templates or documents to be used (e.g. Request for Quotation - RFQ);
- General instructions for bidders such as, contract schedules and work breakdown structure (WBS);
  - Procurement coordination with other agency projects (if required);
  - Identification of potential bidders and possible bidding constraints, for example, current industry conditions, competing projects and contractor availability for specialized work (ex. concrete pavement construction);

1	Introduction
2	Shrinkage, Cracks & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Procurement Procedures
13	Transportation of Concrete
14	Conveying, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sitewalk, Curf & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



Figure 10.1: Concrete skate-park in the City of Port Colborne (provided by Concrete Ontario)



- Concrete Ontario third party certification of the concrete plant and delivery vehicles as per the requirements of OPSS 1350.MUNI.
- Development of a bidder's list, notification process and industry liaison strategy;
- Contract approval process, deliverables and deadlines; and
- Criteria for vender performance evaluations.

## 10.2 Planned Contracting

Provided that the agency determines to solicit the work from outside of the organization, the Planned Contracting process prepares the documents required to facilitate the bid submissions from General Contractors and the subsequent selection / approval process. The Planned Contracting process obtains responses from the concrete industry, such as tendered bids or proposals from Contractors interested in performing the work. The bids and/or proposals are received by the agency and evaluated to ensure the submissions meet the requirements of the contract documents. Many factors can be considered when evaluating submissions, such as, cost; contractual compliance; list of suppliers / subcontractors; past performance; references; and bonds / insurance.

### **Pre-Qualification of General Contractors:**

Depending on the type of concrete project planned by the agency, designers / contract administrators may consider pre-qualifying general contractors prior to the bidding process to ensure potential bidders are capable of delivering the project; conducting the work; and meet the minimum requirements in the contract documents. The primary benefits of pre-qualification process include; reduced time between closing and award of a contract; ensuring consistent delivery of high-quality construction projects; and making the best use of agency / contractor resources.

The pre-qualification process is typically open to the public where potential bidders are invited to express their interest by

submitting a detailed submission for review and consideration by the agency. Potential bidders are required to provide detailed information pertaining to, but not limited to, information about the general contractor; project management experience and qualifications of supervisory staff; insurance / bonding capabilities; company financial statements; past work history; the value of work completed; project references; and performance reports / ratings.

After the closing date for pre-qualified bid submissions, the proposals may be forwarded to a multi-discipline review Committee consisting of agency staff, external consultants and/or subject matter experts (ex. Structural Engineers retained on a concrete bridge construction project). The review Committee will assess, evaluate and rate each proposal based on a set criteria defined for the project. Once completed, general contractors will be shortlisted; a summary of the results / recommendation will be prepared for the agency's approval body, such as Council; and the list of qualified contractors will provide a bid as part of the second stage of the procurement process.

## 10.3 Contracts

The municipal procurement process often involves Purchasing Contracts between a buyer and seller, or government agency and general contractor. A mutual agreement, promise and/or contract is developed to bind this relationship that defines the terms and obligations of each party. For example, the seller or general contractor shall provide the product, service or result for a set price over a certain period of time, and the buyer or agency shall provide a monetary payment for work performed in accordance with the conditions of the contract.

One of the primary requirements for a contract to be enforceable is the condition that all parties accept the terms of the legal agreement. This is commonly achieved through signature and seal of party

1	Introduction
2	Shelwalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Shearwalk, Curb & Gutter Evaluation and Inspection
3	Asset Management, Payment Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC) Analysis
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Contracting Procedures
13	Transportation and Concrete
14	Conveying, Placing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

agreements, but in some jurisdictions, the acceptance of contracts have evolved to include e-tendering processes and various forms of electronic bid submissions. Regardless of the format of an agreement, a contract is a legally binding relationship subject to remedy of the courts and arbitration.

If any, one (or more), of the following elements is not present in an agreement then the contract is not formed and the agreement is not enforceable by law. These essential elements include; offer and acceptance of the terms / conditions of the contract; mutual intent to complete the contract work and requirements; financial consideration or something of monetary value is exchanged between the parties; capacity of the persons contracting with each other is clear; and the intended outcome of the contract is for lawful purposes.

In Canadian Contract law, the agency's request for bidders on a project constitutes as an offer and 'Contract A' is formed when the offer is accepted upon submission of each bid / bid deposit from general contractors. 'Contract B' is formed when the agency awards the bid submission or tender to the successful bidder. This concept has recently been adopted by the courts to ensure fairness for both, the agency / owner and bidders during the procurement process. In essence, this concept protects the right of both parties and instills confidence that bid submissions are valid / irrevocable; and that general contractors can expect an equal opportunity to successfully bid on the work.

**Contract Types:** There are several types of contracts that agencies may want to consider during the procurement phase of a project. Expectations on a project can vary and the type of contract should be selected to best suit the expected outcome of the work, based on the parameters of the project. The agency should consider the anticipated dynamics of each contract; the type of relationship formed with the general contractor; the

various methods of payment; the preferred timelines for completion; and the level of risk / responsibility associated with the work.

It is the responsibility of the agency to tailor the Contract to the specific needs of the project and clearly define the roles of the agency and General Contractor. Where possible, the terms and conditions should identify risks, which party is responsible for the risk and potential mitigation strategies to manage the risk. The type of Contract that bears the most amount of the risk will typically cost agency more to complete. Alternatively, the Contractor may better suited to manage or mitigate the risk and in turn, the agency may find the cost of the project to be more economical.

The type of Contracts can be generally categorized into three main groups, these groups include;

**Fixed price (either Lump Sum or Unit Price):** Compensation is based on a predetermined value for the scope of work and may include incentives for meeting or exceeding selected project objectives such as, defined timelines for Contract completion through performance bonuses / liquidated damages (ex. bonus / penalty clauses);

**Cost reimbursable (or Cost plus):** This type of Contract reduces the risk endured by the Contractor as the agency compensates the Contractor for actual work performed plus a set fee for profit, both parties are held accountable for completing and funding the project; and

**Time and Material (T&M):** Similar to cost plus arrangements except the Contractor's risk is limited as the value of the Contract is open ended as the scope of work is undefined and the full value of the work has not been determined at the time of Contract award.

## 10.4 Contract Administration

On a conventional concrete construction project, the agency's role in managing the work includes ensuring the General Contractor complies with the terms and conditions of the Contract, as well as documenting and agreeing on any changes that may arise during the implementation of the work. Contract Administration can be defined as the process of managing the delivery of Contract work for the purposes of optimizing financial and operational performance, while monitoring and controlling the agency's level of risk.

The Contract Administration process may include the management of many different processes (often at multiple levels of complexity). Some examples include, but are not limited to; monitoring and controlling the project schedule; financial tracking / reporting of work performed; documenting and evaluating on the Contractor's performance; administering quality control; and integrating change control procedures. It is important to note that Contracts can be amended at any time by mutual consent of all parties involved, through the change control process identified in the conditions of Contract.

**Change Control:** An efficient Change Control process should be clear to all parties at the onset of the project. The process should be fair and flexibility although, provide the agency with the ability to control scope of work changes on a Contract. If the process is too onerous, valuable changes may be overlooked or lead to uncontrolled scope creep and reconfiguration of the Contract objectives. If the process is too lenient, then changes to the Contract may be implemented with insufficient thought and consideration of the potential consequences.

Generally speaking, the Contract Documents may include the following steps and/or requirements as part of the change control process. These steps include; the rationale

for the change; the basis for approval; level of authority protocols; the person or group that authorizes the change; tools / templates to be used; procedures / requirements for supporting documents; and links to other Contract management procedures.

Depending on the complexity of the concrete project, the Change Control process could involve other monitoring and controlling procedures, for example, schedule and cost performance forecasting utilizing tools such as Earned Value Management. Regardless of the project, the key to change control success is to have a well-defined and documented process that allows agency's to monitor the progress of project. Changes to a Contract may often reflect lessons to be learned and agencies may benefit from the transfer of knowledge on future projects.

## 10.5 Contract Closure

At the completion of the project, the agency will be required to close-out the Contract and provide a formal notice to the General Contractor that the requirements of the Contract have been completed; the Contractor is no longer responsible for the work performed; and that all outstanding matters have been reconciled. The Contract Closure procedure should be defined in the general conditions of Contract, often in the form of a signed completion certificate and/or letter documented in the project file for future reference.

For more information on the Contract Closure procedures / processes, please refer to Chapter 17: Project Closeout.

### References:

City of Calgary, Prequalification for Construction Prime Contractor - <http://www.calgary.ca/CA/fs/Pages/Bid-and-Vendor-Information/Prequalification-for-Construction-Prime-Contractor.aspx>

1	Introduction
2	Sidewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

Project Management Docs, Procurement Management Plan Template - <http://www.projectmanagementdocs.com/project-planning-templates/procurement-management-plan.html#axzz42bpzjd9>

Project Management, Contract Management Guide - <http://zo-d.com/blog/archives/taking-the-pmp-exam/taking-the-pmp-exam-appendix-b-contract-types.html>

Public Works and Government Services Canada, Contractor Performance Evaluation Report Form (CPERF) - <http://www.tpsgc-pwgsc.gc.ca/app-acq/forms/2913-eng.html>

The ePMbook, Scope & Change Control - <http://www.epmbook.com/scope.htm>

University of Waterloo, Contract Law, Engineering Law and Professional Liability (Case Studies): Changes to the Professional Engineers Act (2010) -<https://ece.uwaterloo.ca/~dwharder/PPE/Contracts/>; and [https://ece.uwaterloo.ca/~dwharder/PPE/Part\\_B\\_cases/](https://ece.uwaterloo.ca/~dwharder/PPE/Part_B_cases/)

Wikipedia, Contract A, Contract Management and Procurement - [https://en.wikipedia.org/wiki/Contract\\_A](https://en.wikipedia.org/wiki/Contract_A); [https://en.wikipedia.org/wiki/Contract\\_management](https://en.wikipedia.org/wiki/Contract_management); and <https://en.wikipedia.org/wiki/Procurement>

## Chapter 11 - Pre-Construction & Pre-Placement Meetings

Depending upon the size and scope of the project, a pre-placement meeting as seen in Figure 11.1 should be held regardless of its formality. Having a set of plans for the contractor is advisable, this allows the contractor to plan the work accordingly, determine the size of crew, pour schedule, construction staging and equipment requirements.

Parties present for a pre-placement meeting can vary depending on the size and complexity of the concrete pour; for example, miscellaneous sidewalk pours across a large area are often facilitated in the format of a pre-construction meeting with the municipality to discuss items such as, special requirements of the contract; schedule / hours of work; traffic control; access for adjacent property owners / businesses; and other related matters. Large pours, such as the pour for a concrete pavement project or bridge structure should be held weeks prior to the actual pour, with all invested parties (supplier, contractor, consultant, engineering firm, owner, local municipality representative, etc.) present to ensure the work is well planned and coordinated.

In advance of the meeting, it would be beneficial to develop a Concrete Placement Plan and include topics such as, the type of concrete; rate of hydration; haul route; discharge rate; placement techniques; finish of the concrete; discharge locations permitted; clean-out areas; road closures, traffic control or detours; testing procedures; remedial measures if potential problems occur (ex. during inclement weather) and any other concerns that an invested party may have regarding the work. For additional information, refer to Appendix F, "Checklist for Concrete Pre-Construction Meeting".

In some cases, it is advisable to specify a pre-placement trial batch or test section in order to ensure the contractor can meet the requirements of the contract, textured finishes, colour, placement rate, etc. During this time, it is best practice to obtain samples of the concrete and conduct material testing for compressive strength; flexural strength; air void; and / or rapid chloride permeability to ensure the concrete mix can meet the specifications after placement.

Ultimately, it will be up to the contractor to alleviate any concerns from the municipality and / or owner's engineering consultant. Concerns may include, but are not limited to; determining the method of concrete construction; quality of concrete mixtures; possible discharge locations and rates. The role of the supplier will be to assure the contractor that the desired discharge rate can be met during construction to ensure contractor is productive. The contractor and supplier will have to work together to determine the most appropriate discharge / delivery rate and stay in constant communication while the work proceeds to address any problems should they arise.



Figure 11.1: Concrete pave-in demonstration and meeting (provided by Region of Waterloo).

1	Introduction
2	Sidewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Concrete Placement Meetings
12	Concrete Operation Procedures
13	Transportation of Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Plan and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Procurement Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 12 - Concrete Ordering Procedures

While general contractors and concrete suppliers all have unique procedures for the processing and handling of concrete orders for their construction projects, it is important that the minimum ordering requirements are identified and addressed by both stakeholders.

It is strongly recommended that a formal quotation is provided by the concrete supplier and a purchase order is issued / used by the general contractor for ordering the concrete. These documents should specify the anticipated quantity of concrete; class of concrete mix being ordered; and identify the unique mix number. If performance mixes are required, the mix specifications should be submitted on Ontario Provincial Standard Form (OPSF) 1350-1 in OPSS Muni.1350 at least 2 weeks prior to delivery of the concrete, the mix code provided on OPSF 1350-1 should be used to order the concrete during construction.

General contractors should place orders for concrete directly with the appropriate order entry / dispatch personnel. Concrete sales and management personnel may assist by facilitating communications between company dispatch personnel and the customer. Although, confirmation of the order and time of delivery should be the responsibility of the order entry / dispatch personnel to ensure correct supply requirements are provided to the contractor. The concrete supplier should explain the preferred method for receiving orders. Most orders are received by telephone, over a dedicated line, or directly into the order entry / dispatch office. Some company's receive orders by fax and most recently by email.

### 12.1 Concrete Order Entry

As orders are received, they are recorded on the appropriate order entry form or entered directly into the concrete supplier's dispatch software. It is recommended that

each concrete company use a checklist for ordering and scheduling ready-mixed concrete. A sample is provided in Appendix K and was developed by the National Ready-mix Concrete Association (NRMCA) and American Society of Concrete Contractors (ASCC) in the United States and modified by Concrete Ontario for use on Canadian projects.

The recommended minimum information required for entering an order is:

- Name and address of the customer;
- Individual placing the order and contact information (preferably a mobile phone number);
- Date and time the order was received;
- Customer number - all customers, except pre-paid and cash-on-delivery (COD) customers, should be assigned a customer number by the concrete supplier accounting department;
- Product and quantity desired. This should include the mix number and any additional requirements such as fibres, colour, etc.;
- Type of order - Is the order confirmed? Contractor will call later, weather permitting, etc.;
- Purpose or use of the concrete and method of placement;
- Address of the delivery and detailed directions or access to the site;
- Requested date and time of delivery;
- Frequency of concrete delivery required for larger pours / multiple loads;
- Special site conditions when on-site. Clean-out locations; personal protective equipment (PPE); construction gate access, etc.;
- Confirm the type of placement via pumping, bucket transfers, standard chutes, etc.;
- Any special requests such as, minimum truck size, conveyor belt, concrete pumps, ice, etc.; and
- Appropriate filed staff receiving the order, general contractor or sub-contractor, etc..

All orders should be verified with OPSF 1350-1 and Purchase Order or Concrete Order Form, where applicable. A sample Concrete Order Form is provided in Appendix D. In addition,



the general contractor should identify who has authority to change the type of mixture; add supplements or make other requests to the order; and the acceptable method of verification (either verbal over the phone, via email, updated purchase order number, etc.).

## 12.2 Directions to the Jobsite

Once the concrete order has been placed, the concrete supplier should be provided with clear and understandable site information in order to properly dispatch the concrete trucks to the jobsite. The person placing the order should also provide additional information, such as:

- Street entrance location with assigned gate numbers when there are multiple entrances;
- Layout of the proposed structures and buildings indicating the appropriate names of the structures (i.e. West Bridge Pier # 1, westbound curb & gutter, lane one / northbound pavement, etc.);
- Layout of proposed concrete pumping locations;
- Location for concrete truck washout areas; and
- Location for proper site egress.

## 12.3 Dispatch Process

When the concrete supplier is developing their delivery cycle, they must consider many factors, including but not limited to, unique dispatching systems; total number of trucks available in their fleet; the number and locations of concrete plants that could supply the project; and the frequency and production demands of additional concrete customers while the work is taking place. In some instances, this process is now automated but the majority of suppliers still dispatch the concrete via radios to the driver. The concrete supplier must consider all these factors when attempting to balance their delivery cycle and ensure the concrete can be delivered to the jobsite when necessary.

It is best practice that all concrete customers, whether it is a municipality or contractor working on a municipal project, to contact suppliers in advance of the work taking place and submit their orders with a minimum of 24 hours' notice. For specialty concrete applications and products, this pre-ordering period are likely extended to ensure appropriate materials are in-place and available. If such limitations are required then the supplier should advise municipality / contractor during both, the quotation stage and during the pre-construction meeting. For example, requirements for ice to cool the temperature of the concrete may require more than 24 hours' notice.

The general contractor is responsible for supplying the dispatcher with the requested concrete quantity, type of work and anticipated delivery rates. It is the responsibility of the concrete dispatcher to integrate these requests into their daily production schedules and to load trucks in an orderly fashion as seen in Figure 12.1. As a result, the concrete dispatcher may request a large volume or high delivery rate for concrete projects to be scheduled during off-peak load times. In these circumstances, there may be a need to schedule the pour during the evening or weekend to accommodate such demanding projects. Like many aspects of the project, early communication of these requirements between the parties is critical to ensure the success of the project.

## 12.4 Specialty Concrete Products

Canadian Standards Association (CSA) A23.1 requires that all concrete products used in the production of ready-mixed concrete be added by the concrete supplier. To meet this specification, early communication of additional products required is necessary to ensure the concrete supplier can have the necessary quantity of material on hand for the project. Such products may include but are not limited to, colour pigments; fibres; corrosion inhibitors; non-chloride based accelerators; specialty aggregates; ice; etc.

1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Procedures
13	Transportation of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Specialty Concrete Products and Evaluation and Inspection
3	Asset Management Plan and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Production Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

Specialty concrete products raise the issue of whether the material should be added at the plant versus adding the material on-site. Where possible, the preferred location for the addition of these materials is at the concrete supplier's plant. The plant will provide greater controls through the use of automated dispensing systems and reduce likelihood of potential errors when added on-site. This does not mean that the addition of material on-site should be eliminated entirely as there may be instances where the addition of raw materials is either warranted or preferred from a concrete performance standpoint. For example, a load of concrete could contain low air entrainment and the supplier may be allowed to increase the quantity of admixture on-site to ensure the concrete meets the specified requirements.



FIGURE 12.1: Concrete truck loading at plant

It is the responsibility of the ready-mixed concrete supplier to inform the contractor if the temperature of the concrete mixture is approaching the maximum threshold for the project. The ready-mixed concrete supplier and contractor should ensure that all provisions are taken into consideration to ensure the concrete is kept cool during the curing period. This may be difficult for speciality mixes such as, coloured concrete, where conventional (white) curing compounds cannot be used. Under these circumstances, cool water and light mists can be applied through the use of sprinklers.

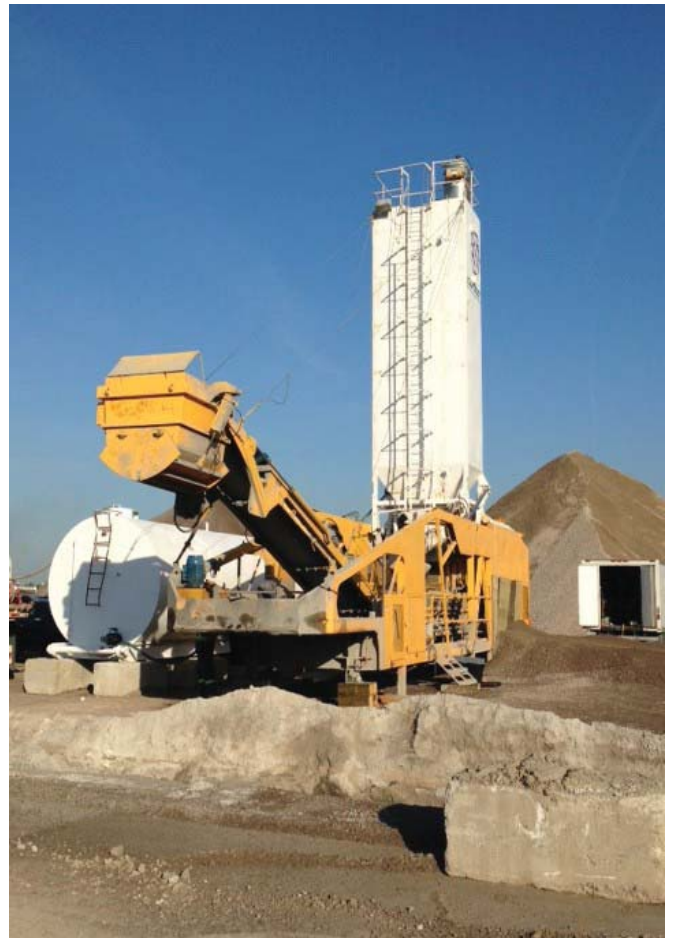


Figure 12.2: Portable concrete plant and truck loading area

## Chapter 13 - Transportation and Receiving Concrete

The majority of concrete delivered to a site is provided via a ready-mix truck, or a volumetric concrete mixer as shown in Figure 13.1. For large highway projects or roller compacted concrete projects, dump trucks may be used for delivery providing travel distances are suitable and the material can be delivered with a reasonable timeframe. For any transportation method, trucks are considered heavy vehicles and operators must adhere to local traffic by-laws; designated trucking routes; and maximum load restrictions (ex. bridge structures requiring repair).



Figure 13.1: Concrete ready-mix truck (left) and volumetric mixer (right)  
[Provided by Concrete Ontario]

Planning of the work in advance will allow invested parties to choose the most appropriate method of handling the delivery of the concrete to the jobsite. Due to the nature of concrete, the hydration process will occur as soon as the ingredients in the concrete have been charged and the water / cement have been combined. The initial setting of the concrete will occur within 30 minutes although, this time period can be prolonged if the concrete is continuously mixed and agitated in a ready-mix truck. However, the concrete should be fully discharged within a 2 hour period from the initial charging of the material. OPSS 1350.07.07 states that the discharge of concrete should be within

90 minutes of initial charging for ready-mix trucks and 30 minutes for dump trucks on a concrete pavement project.

Upon reaching the site, it is best practice that the concrete contractor and / or the material testing consultant confirm that the load of concrete has been batched correctly and is specifically intended for the site, especially if there is more than one concrete trade present on the project. Once the concrete has been delivered, the contractor may have to consider different methodologies for further transportation of the material on-site and will need to incorporate this approach in the concrete placement plan. As shown in Figure

13.2, the placement of concrete may involve a paving train. The placement will be fairly straightforward if a pour can be done simply by off-loading the concrete from the ready-mix truck via chutes to its desired position. Conversely, the placement process may require the use of pumps; conveyers; tele-belts; concrete buggies; wheel barrows, etc. to transport the material to the desired location. These operations may impact productivity and the supplier / contractor should be fully aware of these requirements prior to placement. Once the logistics are known, the contractor and supplier can work together to develop an action plan to ensure the pour is conducted successfully.

1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Laying, Compacting and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Casting Procedures
13	Transportation and Acceptance of Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



Figure 13.2: Concrete paving operation and dump truck (provided by County of Essex.)

The supplier will determine the best course of transportation for the concrete pour upon examining the type of project; the quantity of concrete required; the geographical location; detouring routes; access to the site; and pouring schedule. The preferred method chosen must be able to accommodate the capacity of work planned in order to avoid any cold joints during construction, if a delay occurs unexpectedly. Once the concrete arrives on-site, the material must be transported by the contractor the location of placement as expeditiously as possible without compromising segregation or any loss of the mixture.

References:

Cement Association of Canada (CAC), Kosmatka, Steven H.; Kerkhoff, B.; Panarese, William C.; MacLeod, Norman F.; and McGrath, R.J. "Design and Control of Concrete Mixtures, 8th Canadian Edition" (2011).

## Chapter 14 - Convey, Placing, Consolidating and Finishing Concrete

After the pre-planning, ordering and transportation of the concrete has occurred successfully, it is then the responsibility of the contractor to take the concrete from the delivery truck to its final placement position.



Figure 14.1: Concrete base and formwork preparation (provided by Mick Prieur)

Before the concrete has arrived on site, the base that the concrete will be placed upon needs to be checked for grade; any undulations; compaction; standing water;



Figure 14.2: Concrete bridge deck (provided by County of Essex)

and moisture content. As illustrated in Figure 14.1, the contractor must ensure the formwork has been installed correctly; meets the desired alignment, layout; and is properly supported to maintain the desired shape during construction. Additionally, if the concrete requires steel reinforcing; internal embedments for load distribution; electrical conduit, or plumbing, then these applications must also be placed and confirmed prior to the arrival of the concrete. These quick checks will allow the contractor to install the concrete with fewer delays once the material has arrival on-site.

The sequence on how the concrete pour will progress must be determined. Large pours will require construction, contraction and / or expansion joints at pre-determined locations. In these circumstances, it would be beneficial to place the concrete in long / narrow sections to allow enough room for the discharge

truck to travel beside the pour between the longitudinal joints. The size of the placement crew will vary with the nature of the concrete pour and type of application. For example, small sidewalk pours can be performed with as little as 4 workers whereas; a large pour for a bridge deck or pavement as shown in Figure 14.2, may require several crews to complete the work.

The application of moving the concrete from the point of delivery to its placement location can be achieved by multiple possibilities, including; crane and bucket; pumping; tele-belt; conveyer belt; chute discharge; concrete buggy; skid-steer or back-hoe bucket; wheel barrow; and other hand tools. These can be utilized, as long as, the methodology doesn't disrupt the even distribution of the concrete



1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Planning and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

properties and the process of pouring can be done as expeditiously as possible without degrading the desired mix composition and strength of the concrete. When discharging, always be aware of the conditions surrounding the site. Booms, pumps, conveyors and even ready-mix concrete trucks may come in contact with overhead lines. It is important to make sure the pathway for equipment is clear of overhead lines or appropriate means should be taken to alter the discharge location and avoid the hazard.

Upon initial placement of the concrete, the material is worked into place and agitated through a variety of means to achieve proper consolidation. Internal vibrators are common for cast in-place vertical pours greater than 200mm in thickness and /or around areas with a significant amount of reinforcing steel. For slabs on grade, sidewalks, parking lots or pavements, a mechanical screed or laser screed can be used to place the concrete and agitate the surface, this allows for both grade control and consolidation of the pour. For additional information on laser screeds, refer to the Somero Enterprises website at <http://www.somero.com/>

The placement and spreading of concrete should be conducted to minimize any possible segregation of the concrete mix. Large pours using pumps and buckets should be done in layers, with each layer being agitated



Figure 14.3: Vibratory screed concrete pour (provided by County of Essex)

and consolidated as the work proceeds. Over-loading an area and attempting to achieve proper grade of the concrete by dragging a vibrator across the surface is not recommended, since this method of placement may lead to segregation and weakening of the concrete. An alternative is a vibratory screed as shown in Figure 14.3. Open tooth rakes should be discouraged because they can cause segregation of the concrete by “grabbing” and displacing larger aggregate. In addition, all strike off tools should be checked for trueness prior to being applied to the surface of the concrete.

After the initial placement, consolidation and striking off the concrete the desired finish can be initiated. The desired finish of the surface is typically related to the intended appearance and function of the concrete. For example, factory floors typically require a smooth-finish with minimal undulations whereas, an exterior concrete sidewalk application will have a broom-finish texture to provide better traction for walking pedestrians. This finishing process would likely include the following steps; placement, consolidation and screeding of the concrete; bull-floating the concrete; hand-floating the concrete edges and areas where the bull-float could not reach; incorporating expansion joints to the desired sidewalk spacing; providing a broom- finish to the concrete; edging the concrete with finishing tools; and applying concrete curing techniques.

Additionally, the type of concrete also determines the type of equipment and tools used to finish the concrete. Concrete that contains air entrainment should never be finished with a steel trowel or hand tool. The use of this tool will seal the surface of the concrete and facilitate the formation of surface irregularities that will likely become a deficiency. Figure 14.4 shows the bad practice of applying additional water to the concrete surface as this increases the water to cement ratio on the surface and impacts the durability of the concrete.





Figure 14.4: Concrete finishing bad practice (provided by Concrete Ontario)

Upon initial set-up, or when the concrete has achieved enough strength to not be marred, the application of tooled contraction joints should be initiated. The early introduction of contraction joints will minimize the formation and risk of random cracking. If tooled jointing is not specified, then it is imperative to finish the concrete surface; cure the concrete slowly and apply saw cut contraction joints when the concrete has hardened sufficiently to avoid chipping at the joints. For additional information, the America Concrete Institute (ACI) offers a Certification Program for Concrete Flatwork Technician and Flatwork Finisher. Contained within the course, many more applications; problem solving and planning for most flatwork applications are covered. In addition, Ontario Provincial Standard Specification (OPSS) documents for specific concrete applications contain detailed placement techniques and methodologies.

All finishing techniques and desired finishes should be known well in advance to actually pouring the concrete. Different concrete applications require different finishing techniques. For example, industrial floor applications require the surface to be smooth and contractors commonly use a Fresno, and either a walk-behind trowel machines or ride-on trowels machines. Pervious concrete requires a rotating cylinder to provide both strike off and consolidation of the concrete;

structural walls with continuous rebar require a rougher surface for the next pour of concrete to ensure a mechanical bond.

The finishes for concrete pavements should be a texture surface to improve vehicular traction and skid resistance. The initial texturing should be performed with a longitudinal burlap drag to produce a uniform textured surface. The burlap should be kept clean in a damp condition, free from tears and encrusted mortar. Concrete pavements should also receive a final tining texture using equipment manufactured to produce longitudinal or transverse tines (3mm wide on 16mm centres with a tine depth of 4mm). Once complete, the surface of the concrete shall be free of any displaced aggregate particles and localized projections.

#### References:

America Concrete Institute (ACI) Craftsman Workbook Publication CP-10(10), ACI Certification Concrete Flatwork Technician and Flatwork Finisher. ACI Certification Programs Committee, American Concrete Institute, Farmington Hills, Michigan, 2012.

Cement Association of Canada (CAC), Kosmatka, Steven H.; Kerkhoff, B.; Panarese, William C.; MacLeod, Norman F.; and McGrath, R.J. "Design and Control of Concrete Mixtures, 8th Canadian Edition" (2011).

National Ready-mixed Concrete Association. Pervious Concrete Contractor Certification. National Ready-mixed Concrete Association, Publication 2PPCRT, Silver Spring, MD, August 2010.

Ontario Provincial Standard Specifications. Material Specifications for Concrete - Materials and Production. OPSS Metric, OPSS Muni 350, 353, 356, 904 and 1350. Most recent publication.

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation Concrete
14	Concrete Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Shrinkage, Curing, Evaluation and Inspection
3	Asset Management Plan Development
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, Finishing and Curing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 15 - Concrete Protection and Curing Requirements

After placement and finishing of the concrete, the final stage of the concrete construction process begins. In this last stage, contractors install curing protection systems and maintain an optimal environment for the concrete resulting in a finished concrete product that has achieved the desired strength and durability for its intended use.

### 15.1 Concrete Protection

In the planning stages of the work, the contractor selects a protection system for the worst weather conditions that may be anticipated at the site during the concrete pour. Previous weather records, future weather forecasts, and current site conditions are a few factors that should be taken into consideration. Through proper planning, the contractor will have the appropriate protection measures on-site and readily available on the day of the pour in case of inclement weather or excessive temperatures. Weather and temperature are important factors to consider when selecting the most appropriate protection system.

When the temperature falls outside the normal range for curing concrete (above 28°C or below 5°C), a protection system is required to control conditions during construction and ensure the concrete correctly performs. Hot weather conditions exist when the temperature rises above 28°C. When this occurs, the heat from the ambient air plus the heat generated from the hydration process results in a shortened reaction time for the cement. This in turn leads to cracking in the concrete and an overall lower strength in the final product.

To monitor temperature, the contractor can install thermocouple wires and digital temperature indicator(s). The thermocouple wires are embedded during placement of the material near the surface of the concrete. The thermocouple should have an accuracy of  $\pm 1^\circ\text{C}$  and capable of recording / displaying the temperature of the concrete mixture. The contractor / municipality can monitor the reading during the curing period and document the readings for future reference or evaluation following construction.

Typically, a hot weather protection system will consist of one or a combination of the following; sun shades; wind breaks; water / fog spray; wet burlap (Figure 15.1); and / or moisture vapour barrier. Each system has different benefits and the preferred approach should be based on the conditions and temperature at the jobsite.

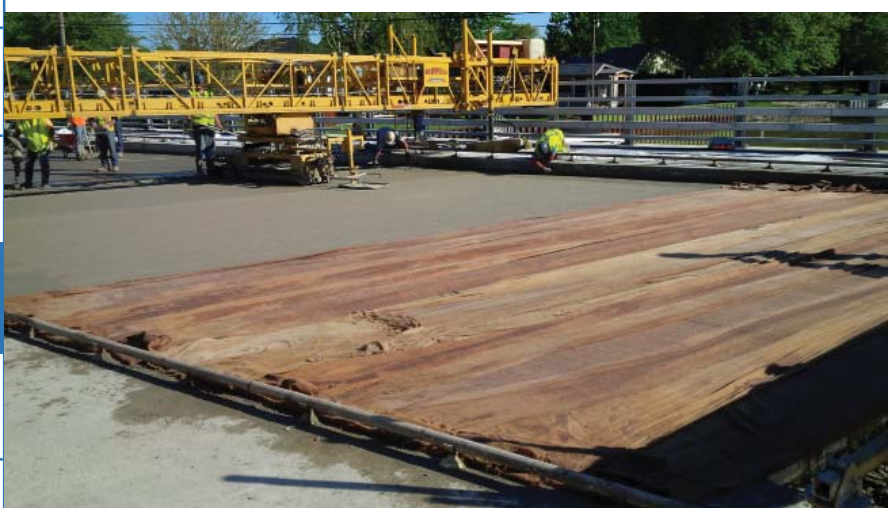


Figure 15.1: Concrete curing with wet burlap during hot weather conditions (provided by County of Essex)

Cold weather conditions present a different type of problems. When the temperature falls below 5°C, the hydration of the cement is slowed down significantly and leaves the concrete susceptible to freeze / thaw conditions, which may cause serious damage to the concrete. The strength of the concrete can be significantly

**TABLE 3**  
**Minimum Cold Weather Protective Measures**

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

**Table 15.1 – Cold weather protection measures for various temperatures – OPSS 904**

reduced by up to 50% if the concrete is frozen before reaching a minimum of 3.5 MPa, and the concrete should be at least 20 MPa prior to the exposure of multiple freeze / thaw cycles.

Typically, a cold weather protection system will consist of one of the following: moisture vapour barrier; moisture vapour barrier with insulation; insulated formwork; and / or full enclosures with heat (ex. 'Housing and Heating'). The type of protection selected in cold weather will depend on the outside temperature and the thickness of the concrete being placed. Ontario Provincial Standard Specification (OPSS) 904, Table 3 (Table 15.1)

provides an outline of the different types of protection that are required for different thicknesses of concrete at different air temperatures.

All pathways where the cold weather can enter the protected area should be covered. Pay close attention to corners and edges as these areas are the most susceptible to heat loss. For example, reinforcement bars that protrude through the forms and extend outside the protected area should be covered. In some instances, additional layers of insulating protection may be required to ensure the concrete cures correctly.



1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Plan/Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



Figure 15.2: Unsecured protection system (provided by Concrete Ontario)

may be required to provide a constant temperature range within the preferred limits.

In either hot weather or cold weather conditions, the protection measure installed should be properly anchored and tightly secured around the concrete, unlike shown in Figure 15.2. High wind can be detrimental to the protection system and cause unwanted airflow into the protected area or loss of the entire protection system.

Through proper selection, implementation, and maintenance of the

protection system, the concrete has the opportunity to gain strength at a normal rate and help prevent early damage by unfavourable weather conditions.

When using a housing and heating system, caution should be taken to ensure the proper selection of the heat source and ventilation. Typically, there are three types of heaters used in cold weather concrete, these include; (1) direct fired; (2) indirect fired; and (3) hydronic systems. The type of heat source selected is dependent on the closure set-up. For example, direct-fired heaters are suitable for enclosures where the concrete is not exposed to the heater or exhaust directly. Conversely, an indirect heat method is preferred in areas where the heat source is in close proximity to the concrete. This approach should avoid carbonation and the development of a soft-dusty surface on the fresh concrete. The third option, hydronic systems, can be used to provide heat through the circulation of glycol or hot water in a closed system of pipes.

## 15.2 Concrete Curing

The concrete curing process starts immediately following the placing and finishing operations. During this process, the goal is to maintain the optimal moisture content and temperature of the concrete for an appropriate period of time. This will allow the concrete to obtain the strength and durability that is needed for its desired use.

The left and centre photographs in Figure 15.3 are examples of improper application of curing compound on concrete sidewalk. The photograph on the left shows uneven placement of the curing compound on a section of sidewalk. The photograph in the middle shows a section of sidewalk poured with no curing compound or alternate curing method provided in an appropriate timeframe. The last photograph on the right shows an improved application of curing compound although, additional effort should be applied to ensure the compound is completely uniform

As the concrete continues to cure, the temperature differential between the concrete and exterior air must be monitored. The difference in temperature should be less than 20°C between the centre of the concrete component and the surface. If large fluctuations in the temperature are observed, then modifications to the protection system



Figure 15.3 – (Left / middle) Insufficient curing examples and (right) adequate curing compound application (provided by Concrete Ontario).

across the entire surface. When complete, the surface should be consistently covered with white curing compound, unlike the minor spots of grey are observed in this application. A second pass of the curing compound at 90 degrees to the first spray was needed to eliminate this inconsistency.

When using curing compounds, proper application of the compound is key to the success of the curing process. Curing compounds must be applied in a uniform manner across the entire surface of the concrete. There should be an even thickness / colour throughout and the compound must be free of breaks. In addition, the curing compound must be placed on the concrete within an appropriate timeframe. Most manufacturers recommend the curing compound should be applied when the water on the surface disappears from the horizontal surface of the concrete. OPSS 904 requires the curing compound to be placed immediately following the finishing operation and states a second application of curing compound should be applied within 30 to 60 minutes after the first application.

Taking proper care when applying the curing compound in this step will help mitigate potential problems on the surface of the concrete after it has cured. In most cases, concrete placement takes place when the weather conditions are moderate, making the curing process easily managed by the contractor or municipality. The application of curing compound or covering the concrete with vapour barrier / wet burlap are common types of curing measures used under these conditions. However, additional curing measures may be required when the temperature begins to rise above or fall below the normal temperature range for cold or hot weather concrete.

The time period and temperature restrictions that are to be followed during the curing process should be noted in the contract specifications. Table 15.2, presents the allowable curing times in accordance with CSA A23.1 - Table 19.

Best practices for curing concrete in hot weather include:

- Moisture applied immediately following the finishing operation. The first few hours after

1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Plan Development Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

finishing the concrete are crucial in keeping the surface moist in hot weather conditions;

- Apply moisture in a continuous manner instead of in a wet - dry cycle. Applying moisture continuously will avoid premature surface cracking;
- Avoid pooling water, use fogging sprays or soaker hoses;
- Apply a moisture retaining curing compound, if accepted by the municipality; and
- Upon completion of the initial curing period, the concrete should be allowed to dry out slowly. This will help prevent surface cracking or crazing

Best practices for curing concrete in cold weather include:

- Avoid using overly wet curing methods as this may result in premature defects in the surface of the concrete;
- Allow for longer curing period than normal weather conditions (ex. a minimum of 7 days of curing should be provided for vertical formwork applications);
- Leave the forms in place for the duration of the curing period or as long as possible. Even

with heated enclosures, forms provide a way to distribute the heat evenly and help prevent drying;

- At sites where the concrete will be exposed to freeze / thaw conditions and road salt, a general rule of thumb is to provide at least 28 days of curing time and another 28 days prior to any freeze / thaw cycle and /or road salt application. In some cases, there may be maintenance limitations and road salt must be applied. If this is the case, contractors and municipalities should discuss this concern with their local concrete supplier to determine the best mitigation option available. One option may include using lower slumps along with additives to reduce the water content in the mix while providing the desired workability during construction; and
- Upon completion of the curing period and removal of the protection system, avoid large variations in temperature.

Acceptable temperature differentials are indicated in Table 20 of CSA A23.1. (Table 15.3)

**Table 19**  
**Allowable curing regimes**

(See Clauses 4.1.1.1.1, 7.7.1, 7.7.2.1, 7.7.3.2, 7.8.9, 8.12.2, and Table 2.)

Curing type	Name	Description
1	Basic curing	3 d at $\geq 10\text{ }^{\circ}\text{C}$ or for the time necessary to attain 40% of the specified strength.
2	Additional curing*	7 d total at $\geq 10\text{ }^{\circ}\text{C}$ and for the time necessary to attain 70% of the specified strength.
3	Extended wet curing	A wet-curing period of 7 d at $\geq 10\text{ }^{\circ}\text{C}$ and for the time necessary to attain 70% of the specified strength. The curing types allowed are ponding, continuous sprinkling, absorptive mat, or fabric kept continuously wet.

\*When using silica fume concrete, additional curing procedures shall be used. See Clause I.3.13.

- Notes:**
- (1) Curing of plant production of precast concrete shall be as set out in CSA A23.4.
  - (2) It is recommended that concrete be allowed to air-dry for a period of at least one month after the end of the curing period, before exposure to de-icing chemicals.
  - (3) The rate of compressive strength gain in concrete is significantly reduced below  $10\text{ }^{\circ}\text{C}$ .

Table 15.2 – Concrete curing regimes (CSA A23.1)



**Table 20**  
**Maximum permissible temperature differential between concrete surface and ambient to minimize cracking – Wind up to 25 km/h**  
 (See Clauses 7.1.2.5 and 7.5.3 and Figure D.2.)

Thickness of concrete, m	Maximum permissible temperature differential, °C				
	Length-to-height ratio of structural elements*				
	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.

**Note:** See also Figure D.2.

**Table 15.3 – Concrete curing temperature differential (CSA A23.1)**

References:

Canadian Standards Association (CSA) A23.1-14, "Concrete Materials and Methods of Concrete Construction" (2014).

Cement Association of Canada (CAC), Kosmatka, Steven H.; Kerkhoff, B.; Panarese, William C.; MacLeod, Norman F.; and McGrath, R.J. "Design and Control of Concrete Mixtures, 8th Canadian Edition" (2011).

Ontario Provincial Standard Specification, Municipal Edition (OPSS.MUNI) 904, "Construction Specification for Concrete Structures" (2012).

1	Introduction
2	Shoulder, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Sitewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management Plan Development and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC) Analysis
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, Finishing and Curing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 16 - Measurement, Testing and Acceptance of Concrete

This chapter will outline testing requirements, concrete mix design verification and delivery ticket information required for acceptance of concrete by the municipality from samples cast on-site and from cores drilled from the elements. Prior to any pour, the mix design must be submitted to the municipality for review. It must meet specifications stipulated in the contract documents and / or applicable specifications. The concrete supplier must be certified and proof of Ready-mixed Concrete Association of Ontario (RMCAO) Certification must be forwarded to the municipality.

### 16.1 Minimum Testing Qualifications of Laboratories and Personnel

The Municipality shall ensure that the concrete testing agency retained for testing services supplies qualified and certified personnel to perform testing. All concrete testing is to be performed in accordance with Canadian Standards Association (CSA) A23.1/.2 and is a major concern for all members of the construction team. The



Figure 16.1: Concrete compression test (provided by exp Services).

minimum qualifications for the performance of the concrete testing program should be as follows:

**Laboratory Certification Requirements:** The concrete laboratory should be both certified to CSA A283 - Qualification Code for Concrete Testing Laboratories; and also have Canadian Council of Independent Laboratories (CCIL) Type H certification. It is in the best interest of the municipality to obtain copies of both certificates at the pre-construction meeting. In addition, the laboratory should only conduct the concrete testing for the test methods that they are certified to perform. This information is included in CSA A283 and includes the following levels.

- Category O - Basic Tests (CSA A23.2 1A, 1C, 3C, 4C, 5C, 9C & ASTM C1064);
- Category I - Intermediate Tests (CSA A23.2 2A, 3A, 4A, 5A, 6A, 7A, 10A, 11A, 12A, 13A, 2C, 6C, 7C, 14C); and
- Category II - Advanced Tests (CSA A23.2 8A, 9A, 18A, 11C, 12C).

**Field Personnel Certification Requirements:** The concrete field testing technician performing the onsite testing of the concrete must be either CSA or American Concrete Institute (ACI) certified and must have a valid CCIL Type J certification in order to test the concrete. The CCIL Type J certification includes annual verification of testing competence and allows for third party verification of proper testing procedures.

**Concrete Testing and Reporting:** Concrete testing is the most common method used to confirm that the concrete supplied to the project meets the project specifications. The contract documents must therefore clearly identify the concrete test methods (ex. Compression test in Figure 16.1) and the acceptance criteria that will be used to evaluate the concrete supplied to the project. The concrete testing requirements listed below apply to both private developments that will be assumed by the municipality and projects located within the public right-of-way.

1	Introduction
2	Shelwalk, Curf & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

Reviewing the test methods specified and setting up the appropriate concrete verification system is one of the major tasks of the pre-construction meeting. Through the process of measuring key indicators, monitoring the concrete placement and analyzing the results of the testing program, we can; (1) evaluate the consistency of the concrete supplied to the project; (2) improve the concrete production and placing process; and (3) evaluate the effectiveness of the concrete testing system in ensuring quality concrete is supplied to the project.

Where Ontario Provincial Standard Specification, Municipal Edition (OPSS.MUNI) 1350, Material Specification for Concrete - Materials and Production, is referenced in the project specifications, it should be noted that the exposure class, compressive strength, and air content of the concrete being designed must meet the requirements of CSA A23.1-14. Testing of all concrete must meet the requirements of CSA A23.2-14.

### 16.2 Normal Plastic (On-site) Concrete Test Methods

The standard concrete test methods that can be used on all projects include (with highlighted clause):

**CSA A23.2-1C Sampling Plastic Concrete:** Take the sample between the 10% and 90% points of the discharge.

**CSA A23.1-3C Making and Curing Concrete Compression and Flexural Test Specimens:** Mould the specimens in as close proximity as is practicable to the place where they are to be stored during the first 28 h ± 8 hr.

**CSA A23.2-4C Air Content of Plastic Concrete by the Pressure Method:** Complete the test for air content within 10 minutes after obtaining the sample, including transporting and remixing.

**CSA A23.2-5C Slump and Slump Flow of Concrete:** Carry out the entire operation,

from the start of the filling to the removal of the mould, without interruption and within an elapsed time of 2 minutes. (Equipment shown in Figure 16.2)



Figure 16.2: Concrete slump test (cone) apparatus  
Provided by Concrete Ontario

**CSA A23.1-9C Compressive Strength of Cylindrical Concrete Specimens:** Calibration of testing equipment to ASTM E4 is required every 12 months maximum.

### 16.3 Standard Frequency of On-site Testing

**Delivery Ticket Information:** Upon arrival, the delivery ticket must be checked for the mix design number, concrete type and batch time.



Figure 16.3: Concrete air content test Provided by Concrete Ontario



1	Introduction
2	Shewalki, Curp & Gutter Evaluation and Inspection
3	Asset Management Plan Development Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC) Analysis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

The maximum allowable time from batch time to delivery is 90 minutes.

Strength: The frequency for casting concrete cylinders for concrete compression testing should not be less than one test for every 100 m<sup>3</sup> of concrete placed, with no less than one test for each class of concrete placed on any one day as per CSA A23.1-14, Clause 4.4.6.3.1.

Slump: It best practice to test the slump for each casting of strength test cylinders and at periodic intervals to ensure the concrete is being consistency supplied to the jobsite.

Air Content: All concrete mixes should be tested for air entrainment (whether air entrained or not). For classes C-2, C-1 and C-XL, every load until consistency is attained, every 3rd load thereafter. An air test must be performed with every strength test as per CSA A23.1-14, Clause 4.4.4.1.1.3. (Pressure method air meter shown in Figure 16.3)

Speciality Testing Requirements:  
 Non-standard test methods such as Hardened Air Void System (AVS) and Rapid Chloride Permeability (RCP) shall be identified in the contract documents and specifically addressed during the pre-construction meeting.

16.4 Distribution of Concrete Test Reports

Concrete test reports should be immediately distributed to all members of the construction team preferably using Concrete Test Forms & Reporting (CMATS™) provided in Appendix C to ensure that everyone has immediate access to the test information. In all instances, both the person ordering

the concrete and the concrete supplier must have immediate access to the test information since they are in the position to take immediate corrective action to address any potential problems. While 7-day test results are not typically used for acceptance, it is critical that this information be supplied to the construction team since these results may prompt changes to the mix designs on the project even before the 28-day results are available. Maturity testing as shown in Figure 16.4 can also be used to determine how the concrete is performing without waiting 28 days. With respect to a new development or subdivision project; it is best practice that municipal staff and / or their agents are included on the distribution list and receive a copy of the concrete test reports when they are provided to the construction team.



Figure 16.4: Concrete cylinder and maturity monitoring gauge to determine real-time strengths insitu (provided by Concrete Ontario)

## 16.5 Recording and Reporting of Test Reports

Access to the concrete test result information should be supplied instantaneously to all parties identified on the concrete test result distribution list developed at the pre-construction meeting. The testing company should provide an electronic copy of the standard test report in Portable Document Format (PDF) for use by the construction team. In addition to the standard test reports, the material testing company should identify and provide a detailed summary of non-conforming concrete test results with potential risks / recommendations highlighted.

## 16.6 Evaluation of Concrete Hardened Properties

This section describes some of the typical hardened properties specified in concrete construction; provides guidance to the interpretation of test results; and offers recommendations for additional testing in order to provide supplementary information on the concrete evaluated on site.

**Compressive Strength:** CSA A23.1-14 lists the minimum compressive strength for a variety of classes of concrete based on its intended use and exposure condition to the elements. In addition, CSA provides circumstances where the following tests should be performed on concrete cylinders cast on-site during placement of the material, as well as cores that can be drilled from the hardened concrete constructed.

CSA states that the strength level of each class of concrete shall be considered satisfactory if (1) the average strength tests results for all sets of 3 consecutive cylinders for that class (at one particular curing time range) are equal or exceed the specified strength; and that (2) no individual strength test is more than 3.5 MPa below the minimum specified strength for the concrete. Although, these requirements shall not apply to field cured specimens as described in CSA A23.1-14,

Clause 4.4.6.4.4. (Field cured specimens are used to determine the actual strength of the concrete in place to assist in project planning for form removal, cold weather protection removal or other special conditions and therefore the lower acceptance criteria does not apply.)

For in-situ core testing of concrete constructed on-site, CSA recommends that this method should be used in cases where the strengths of the cylinders cast during construction fail to satisfy the requirements mentioned above, or where the casting of cylinder testing was not done as in accordance with the standard sampling / curing requirements. CSA states that the compressive strength of the concrete in the area represented by core tests shall be considered adequate if (1) the average of each set of 3 cores from the portion of the concrete being evaluated is at least 85% of the specified strength; and that (2) no single core is less than 75% of the specified strength. Figure 16.5 shows a typical compression test of a core sample performed in the lab. For additional information, refer to CSA A23.1-14, Clause 4.4.6.6.2.

When combined, maturity testing and concrete cylinder testing can determine the compressive strengths of the pavement prior to opening the roadway to vehicular traffic. As part of this process, the contractor and / or consulting engineering firm can develop a quality control plan with details of all equipment and procedures to be used for estimating the in-place compressive strength of concrete pavement by the maturity method. Once available, the test results can be provided on a regular basis to determine when the roadway can be re-opened for vehicular use. The plan can generally include the following information; (1) field procedure and equipment to be used for maintaining, monitoring and recording the internal temperature of the in-place concrete with respect to time; (2) laboratory calibration procedure and equipment for developing the equivalent age vs. strength relationship;

1	Introduction
2	Shrinkage, Curvature, and Cracking Evaluation and Inspection
3	Asset Management and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

(3) calibration chart indicating temperature-time factor vs. time; and (4) calibration chart indicating temperature vs. time of the concrete and ambient air temperatures.

Hardened Air Void System (AVS): A suitable air void system is important for the long-term performance of concrete exposed to freezing and thawing and to chlorides. The AVS properties shall be determined prior to the start of construction once the materials, mix proportions and mixing procedures have been confirmed for use on the project. Presently, there is no standard requirement for frequency of testing although, it is recommended that cylinders are cast on-site for AVS purposes every 500 m<sup>3</sup> for exposure classes C-XL, C-1, and C-2.

The testing for hardened air voids shall be in accordance with the American Society for Testing and Materials (ASTM) specification C457, using a magnification range of 100-125 times, with testing performed on concrete cylinders cast from delivered concrete in accordance with CSA A23.2-3C. A typical test sample is shown in Figure 16.6. The air void system is considered to be satisfactory when the average spacing factor is  $\leq 230 \mu\text{m}$ , with no single test greater than  $260 \mu\text{m}$  and the air content is  $\geq 3.0\%$  as per CSA A23.1-14, Clause 4.3.3.4.

AVS testing can be used to determine if the quantity of air voids is adequate after cores have been drilled from the concrete. This type of testing is typically carried out if there is concern with early deterioration or if test results of the plastic concrete are inconclusive or not available.

Rapid Chloride Permeability (RCP): The permeability of concrete is important in reinforced concrete structures that are exposed and susceptible to chlorides. The resistance to chloride ion penetration shall be determined in accordance with ASTM C1202, on cylinders cast in accordance with CSA A23.2-3C using the equipment in Figure 16.7. Any mix for which RCP is a requirement



Figure 16.5: Concrete core compression test  
Provided by exp Services

shall be pre-qualified prior to use on a project. Pre-qualification shall include testing of a minimum 2 cylinders, cast of concrete made with the same materials, mix proportions and mixing procedures intended for use on the project. Test results shall be valid for a period



Figure 16.6: Hardened air void test sample  
Provided by exp Services



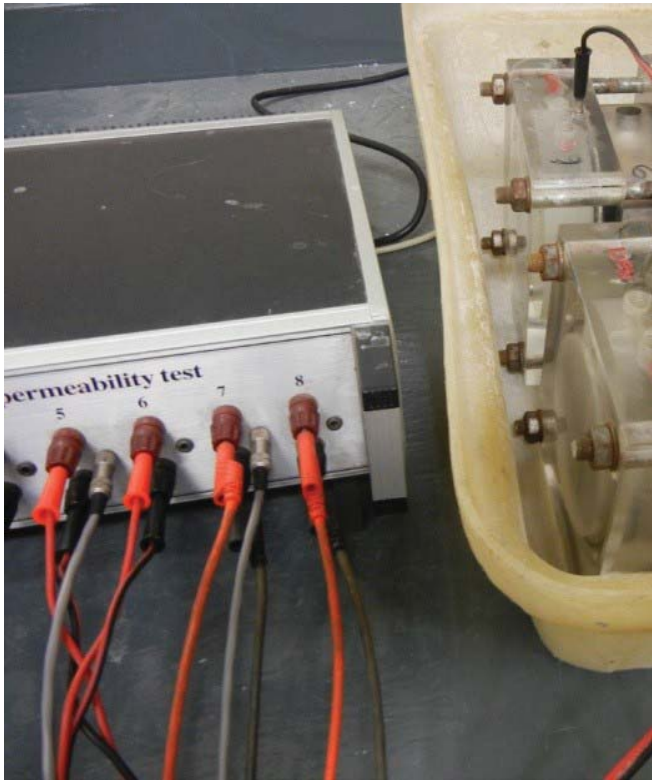


Figure 16.7: Rapid Chloride Permeability test apparatus (provided by exp Services).

of 12 months and may be obtained from the supply of concrete to another project.

The suggested ASTM C1202 acceptance testing parameter for concrete exposure class C-1 is 1500 coulombs average with no single result greater than 1750 coulombs when tested at 56 days. Considering that the ASTM C1202 test is subject to variations, it is recommended that the target coulomb value be less than 1150 to have a reasonable assurance that the 1500 coulomb requirement will be met.

Presently, there is no standard requirement for frequency of testing although, it is recommended that RCP testing be conducted for every 500 m3 of concrete delivered to the site for exposure classes C-XL and C-1.

#### References:

Canadian Standards Association (CSA) A23.1/2-14, "Concrete Materials and Methods of Concrete Construction" (2014).

Cement Association of Canada (CAC), Kosmatka, Steven H.; Kerkhoff, B.; Panarese, William C.; MacLeod, Norman F.; and McGrath, R.J. "Design and Control of Concrete Mixtures, 8th Canadian Edition" (2011).

Ontario Provincial Standard Specification, Municipal Edition (OPSS.MUNI) 1350, "Material Specification for Concrete - Materials and Production" (2014).

1	Introduction
2	Shelwalk, Curt & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA) Analysis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

1	Introduction
2	Shrinkage, Cracks, and Spalling
3	Asset Management Planning and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

## Chapter 17 - Project Closeout and Continuous Improvement

As the construction phase nears completion on a municipal concrete infrastructure project as shown in Figure 17.1, agency representatives and/or the contract administrator for the project should consider the following closeout procedures / processes;

1. Deficiency Identification and Rectification Work;
2. Substantial Completion and Contract Maintenance Period;
3. Continuous Improvement and Lessons Learned; and
4. Contractor and Consultant Performance Evaluation.



Figure 17.1: County Road 22 Provided by County of Essex

### 17.1 Deficiency Identification and Rectification Work

Prior to completion of the construction phase, it is important to revisit the work completed on a project and identify any quality defects or deficiencies to be rectified before final acceptance / closure of the contract. The contract administrator and general contractor performing the work should conduct a final

walkthrough of the project to document deficient work and/or determine the estimated monetary value to rectify these defects. The contract administrator has the right to holdback payment for incomplete or defective work until such time that the contractor addresses these product deficiencies.

During this phase of the project, it is important to keep in mind that the Construction Lien Act does not permit funds to be held back for deficiency work as part of the statutory holdback process. For that reason, the contract administrator needs to determine the monetary value of deficiencies or outstanding work and deduct this amount from the payment certificate, prior to the commencement of statutory holdback process and 45-day construction lien period. Once the contractor has rectified the outstanding work, then the deficiency holdback can be released and payment can be processed accordingly.

### 17.2 Substantial Completion and Contract Maintenance Period

In accordance with the General Conditions of Contract and Construction Lien Act, the maintenance period commences on the date of substantial completion (or date of substantial performance); and the contractor has completed the project to state acceptable by the agency, and is ready for use or is being used for its intended purposes. Once this date has been established, the contract administrator should prepare a certificate of substantial performance and issue a formal notice to the general contractor. Upon receipt of the certificate, the contractor shall publish the date of substantial performance in a construction newspaper (such as the Daily Commercial News) and the date of advertisement shall form the commencement of the 45-day lien period required by the Construction Lien Act.

Within the context of the tender document and the contract, it is imperative that the contract administrator identify the conditions of the contractor's responsibilities and duration of

1	Introduction
2	Shelwalk, Curf & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation Concrete
14	Convey, Laying, Finishing and Finishing Concrete
15	Concrete Protection, Curing and Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

the maintenance period. For the construction of concrete pavements, it is recommended that a two (2) year maintenance period is considered when preparing these conditions, as cracks have been found in the second year after completion. Otherwise the maintenance period is typically one (1) year following the date of substantial completion. It is the responsibility of the agency and the contract administrator to evaluate the needs of each project and determine the most appropriate maintenance period for the work.

### 17.3 Continuous Improvement and Lessons Learned

Following closure of the contract and/or completion of the concrete phase of a project, team members should reconvene to conduct a post-construction meeting to review and document issues encountered on the project. This meeting will provide an opportunity for stakeholders to reflect on problems experienced during the implementation of the project; discuss lessons learned from these issues; identify opportunities to improve best practices; and mitigate similar problems on future contracts. In addition, key stakeholders should have an opportunity to provide input to the contract administrator on the general contractor's performance completing the work. The meeting discussions / outcomes should be documented by the governing agency and considered further as part of the continuous improvement process when planning work on similar projects. Topics to be considered as part of the post-construction meeting include, but are not limited to:

**Specifications / Drawings:** Were the concrete specifications / design drawings clear and complete? Are there any recommendations and how the work was completed or carried-out during construction?

**Communication:** Was the communication process well defined and understood by all parties involved in project? Were construction communiques provided with clear and concise directions? Were problems addressed

collaboratively by all parties involved and was there the proper level of mutual respect?

**Team Identification / Performance:** Did all members of the project team fulfill their responsibilities and meet the objectives / expectations of the contract? Are there any recommendations to improve the delivery of the project and relationship between these parties to ensure project success?

**Concrete Testing:** Was the inspection and quality control testing performed properly? Were the results shared completely and expeditiously with all of the appropriate team members? Are there any quality control changes to be considered as part of future projects?

**Concrete Ordering / Delivery:** Were there any communication problems ordering and delivering the concrete while the work was taking place? If so, how were issues managed and corrected during construction?

**Placement and Finishing:** Were any problems or specific issues during construction? Are there any recommended changes to the construction specifications and placement requirements for concrete?

**Payments:** Was there an acceptable progress payment process and have all monetary issues been resolved?

### 17.4 Contractor and Consultant Performance Evaluation

The client / agency may elect to conduct a formal performance evaluation of the contract administrator and or the general contractor and shall rate the performance of the contractor (or consultant) based on standard set of criteria adopted by the organization. A copy of the Performance Evaluation form should be provided to the contractor for information in advance of the contract commencing. Significant performance issues should be noted in writing with a copy provided to the contractor, the agency's





1	Introduction	
2	Sitewalk, Curbs & Gutter Evaluation and Inspection	purchasing representative and documented in the project file. Performance issues should be discussed in project progress meetings and acknowledged in the minutes in an effort to assist in the contractor during performance evaluation / improvement process.
3	Asset Management Plan/Asset Selection	
4	Concrete Bridges	It is important to note that the intent of such evaluations is to work with the contractor and/or concrete suppliers to improve their performance on agency contracts. Numerous agencies have implemented this evaluation process and experience has shown that quality of work has improved as a result of the program being implemented. The results of a performance evaluation may be disclosed to other municipalities or government bodies upon request, where it can be demonstrated that the general contractor has listed the agency as a reference when bidding on similar work. In order to ensure that the evaluation process is open, transparent and fair, an agency review / sign-off procedure should be established and the contractor should have an opportunity to comment on the evaluation results.
5	Sustainability	
6	Life-Cycle Cost (LCC)	
7	Unshrinkable Fill (U-Fill)	
8	Architectural Concrete	
9	Concrete Jointing	
10	Procurement	
11	Pre-Construction Meetings	Although the performance criteria may vary from agency to agency, the evaluation form should be included in the tender document and/or agency's specifications. Performance evaluation topics may include, but are not limited to;
12	Concrete Procurement Procedures	
13	Transportation and Recreational Concrete	<b>Quality of Work:</b> The contract administrator may consider how the workmanship compares with industry standards; the quality of workmanship provided by other contractors on similar projects; and the contractor's compliance with provisions outlined in the drawings / contract documents.
14	Conveying, Placing and Finishing Concrete	
15	Concrete Protection and Curing Requirements	
16	Measurement, Testing and Acceptance of Concrete	<b>Time Management:</b> For the purpose of evaluating the contractor's performance to manage the delivery of the project, consideration should be given to conditions beyond the general contractor's control such as; availability / access to the site; unexpected changes in soil or site conditions; inclement weather; material / equipment supply
17	Project Close-out and Continuous Improvement	
18	Troubleshooting	

problems; quality of plans and specifications; and significant changes in the scope of work.

**Project Supervision:** The extent to which the general contractor takes control of and effectively manages the work has a direct effect on the successful completion of the project. The evaluating agency should consider the experience / knowledge of the contractor's supervisory staff / superintendent; the contractor's ability to promptly commence the work; provide realistic schedules and project updates; provide a comprehensive work plan; promptly provide reasonable quotations for contract change orders; establish effective quality control procedures; promptly correct defective work as the project progressed; effectively coordinate and manage the work of subcontractors; and co-operate when directions are issued by the agency.

**Contract Compliance:** The effectiveness of the general contractor to administer the work of a contract in accordance with the conditions and special provisions outlined in the drawings/documents. The evaluating agency should consider the contractor's performance when providing specified documents for contract execution; managing occupational health and safety provisions; submitting payment claims accurately to represent the work completed and material delivered to the site; notifying the agency of all subcontracting activities in a timely fashion; dealing with any claims from members of the public; maintaining records of the project; and ability to finalize settlements during contract disputes.



References:

Construction Lien Act R.S.O. 1990, Chapter C.30

OPSS General Conditions OPSS.MUNI 100 November 2006

## Chapter 18 - Troubleshooting

### 18.1 Plastic Concrete

<b>Problem</b>	<b>18.1.1 Air Loss – Concrete pumping</b>
<b>Causes</b>	<b>Severe vertical drop</b>
<b>Discussion</b>	<p>There is normally slight air loss when concrete moves through a concrete pump. Problems occur when the initial air content is low and the air loss out of the pump is below specification or if the pump is incorrectly configured too close to the structure and the concrete is pumped almost vertically and then dropped vertically down onto the structure.</p> 
<b>Prevention</b>	<ol style="list-style-type: none"> <li>1) If cause is low air, then increasing air content of concrete into the pump will correct. Care must be taken if the pump is moved since pump configuration affects the air content. If air dosage is increased, then the pump is moved, the new air content may be higher than expected.</li> <li>2) If cause is pump configuration, then moving the pump to another location is preferred. Otherwise, use of a loop at the end of the pump to prevent free fall of concrete in the pipe will reduce the air loss. Other techniques are to run the last 3-5 metres of the pump hose horizontally along the subgrade or formwork and to place the concrete with the shortest possible vertical drop.</li> </ol>
<b>Repair &amp; Maintenance</b>	<p>If the in-place concrete is suspect for low air content then ASTM C457 testing should be performed on a core sample. If the test does not pass the parameters as outlined in Chapter 16 then concrete is subject to possible removal. Remedial repairs such as application of concrete sealers can reduce water saturation in the concrete which will prevent/reduce damage by freeze/thaw action. The sealer should be maintained for the life of the structure following the manufacturers' recommendations.</p>
<b>Problem</b>	<b>18.1.2 Air loss – Excessive vibration</b>
<b>Causes</b>	<b>Improper use of external vibrators</b>
<b>Discussion</b>	<p>Over vibration of concrete will destabilize the air void structure and compromise the durability of the concrete in place.</p> 
<b>Prevention</b>	<p>Vibrators should only be placed in the concrete as long as required to consolidate. Vibrators should not be used to move the concrete to its final resting position. If vibrators are used on mobile equipment such as slip form pavers then when not in</p>

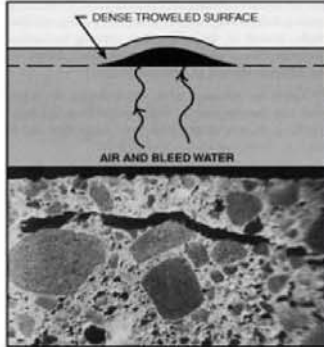

1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

	motion the vibrators should be turned off.
<b>Repair &amp; Maintenance</b>	If the in-place concrete is suspect for low air content then ASTM C457 testing should be performed on a core sample. If the test does not pass the parameters as outlined in Chapter 16 then concrete is subject to possible removal. Remedial repairs such as application of concrete sealers can reduce water saturation in the concrete which will prevent/reduce damage by freeze/thaw action. The sealer should be maintained for the life of the structure following the manufacturers' recommendations.
<b>Problem</b>	<b>18.1.3 Excessive bleeding</b>
<b>Causes</b>	<b>High slump</b> - Due to water addition, poor gradation of concrete fine aggregate, selection of concrete admixtures, concrete placed on a vapour barrier, cool weather and retardation of the concrete.
<b>Discussion</b>	Excessive bleeding for most municipal flatwork applications is not a problem since their works are usually only broom finished. For flatwork with a steel trowel finish, bleeding can lead to delaminations if the concrete is closed too early. Bleeding can be an issue for vertical work since bleeding can lead to differential settlement at the surface of the form creating an irregular surface for the next layer, or a surface elevation that is lower than expected. <div> </div>
<b>Prevention</b>	<ol style="list-style-type: none"> <li>1) The water slump should only be as high as needed to place the concrete. If high slump is required then the use of mid-range and high range water reducing admixtures should be utilized.</li> <li>2) If air content is low, increasing air content will reduce bleeding.</li> <li>3) Correction of deficiencies in the concrete mix design.</li> <li>4) Removal of vapour barrier.</li> <li>5) Place concrete on warm subbase and protect with thermal blankets.</li> </ol>
<b>Repair &amp; Maintenance</b>	Usually bleeding does not create major defects unless the concrete is trowel finished. If the slab has localized blisters then grinding of the surface to remove the delaminated areas will restore the concrete.

<b>Problem</b>	<b>18.1.4 Plastic shrinkage cracking</b>	
<b>Causes</b>	<b>Moisture loss</b> - Rapid moisture loss from the surface while concrete is still plastic. Likely to occur when the relative humidity is low, high ambient or high concrete temperature, windy days, limited bleed of the concrete	
<b>Discussion</b>	Plastic shrinkage cracks are non-structural cracks that are normally perpendicular to the wind direction. They are usually very thin, tight cracks that only penetrate a few millimeters into the surface.	<div> </div>
<b>Prevention</b>	<ol style="list-style-type: none"> <li>1) Wind screens or sun shades.</li> <li>2) Use of fogging equipment.</li> <li>3) Pre-dampen subgrade or formwork.</li> </ol>	




	<p>4) Use of evaporation retardant chemicals (Ensure they are not worked into the concrete surface).</p> <p>5) Placement at night.</p>
Repair & Maintenance	Plastic shrinkage cracks are usually aesthetic concerns not structural. Remediation can be grinding of the surface to remove the concrete to the depth of the crack or complete replacement in extreme cases.


<b>Problem</b>	<b>18.1.5 Blistering</b>
<b>Causes</b>	<b>Poor finishing techniques</b> - Premature finishing of the concrete with steel trowels trapping bleed water under the surface.
<b>Discussion</b>	<p>Blistering normally only occurs in interior concrete that receives multiple passes of steel trowels. If the surface is densified too early then the bleed water is trapped below the surface which will leave an air pocket once the concrete dries. The air pocket is weak and will crack and delaminate under traffic.</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div> <p style="text-align: center;"><b>Concrete Blister</b></p>
<b>Prevention</b>	Use only magnesium or wood floats for exterior applications. Do not use power trowels to close off the surface.
<b>Repair &amp; Maintenance</b>	Grinding of the surface to remove the defects or complete removal of the slab in extreme cases. The concrete under the blistered area is normally a sound material, there removal of the blister is all that is required to fully restore the concrete.

<b>Problem</b>	<b>18.1.6 Segregation</b>
<b>Causes</b>	<b>Several material and construction causes</b> - Poor concrete aggregate gradation, high water slump, poor handling on site, excessive vibration, allowing concrete to fall through restricted area where coarse aggregate will be stripped from the mortar fraction, unstable Self Consolidating Concrete (SCC).

1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Planning and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Placement Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting


Discussion	Segregation has 2 major implications; structural and static appearances. Both need to be repaired accordingly.	
Prevention	<ol style="list-style-type: none"> <li>1) Pour concrete at the maximum slump required to place. Allow the contractor to determine the slump requirement at the time of bidding.</li> <li>2) Ensure water is not added on site above specified slump.</li> <li>3) Only vibrate concrete as much as needed.</li> <li>4) If placing through congested area, use elephant trunks to prevent segregation.</li> <li>5) Perform Visual Stability Index test on SCC concrete to ensure concrete is not prone to segregation.</li> </ol>	
Repair & Maintenance	<p>If excessive water was added to the concrete which led to the segregation then the compressive strengths will be low and the concrete should be removed and replaced.</p> <p>For areas where the coarse aggregate was stripped out of the mortar which may have led to honeycombing then removal of the deficient section and a patch may be appropriate.</p> <p>If excessive segregation has occurred then the concrete mortar fraction will behave differently than the area with the coarse fraction and likely cracking will occur. Removal and replacement of this concrete may be required.</p>	

**18.2 Vertical Work**

Problem	<b>18.2.1 Honeycombing</b>	
Causes	<p><b>Flowability and construction placement</b> - Voids left in the concrete due to failure of the mortar to effectively fill the spaces among the coarse aggregate particles. Can occur if the concrete is dropped through a congested area and segregation occurs, or if the concrete is poured at a high slump into old forms that do not fit tightly together. May also occur in highly reinforced areas where internal vibrators cannot consolidate the concrete.</p>	
Discussion	<p>Honey combing is a structural issue in many cases where the concrete allows moisture to penetrate the surface into the reinforcing bars, or the concrete may not be sufficiently bonded to the reinforcing bars reducing the effectiveness of the rebar.</p>	
Prevention	Allow the contractor to determine the slump required to properly place the concrete	




	prior to bid and order accordingly, prevent the use of very tight bundles of reinforcement bars, ensure forms are in good repair and are held tightly together. The contractor must ensure that the concrete does not segregate during free fall in the forms by using an elephant trunk to keep the concrete confined during freefall. Ensure proper vibration of the concrete. Ensure forms are tight to prevent paste leakage.
Repair & Maintenance	The sections with honeycombing will be chipped out and patched with the appropriate concrete mix. If excessive segregation has occurred then the concrete mortar fraction will behave differently than the area with the high course fraction and cracking will likely occur. Removal and replacement of this concrete may be required.

<b>Problem</b>	<b>18.2.2 Cold Joints</b>	
<b>Causes</b>	<b>Stoppage and delays during construction</b> - Usually caused by delays during the concrete pour. They should not be confused with intentional construction joints placed in the concrete.	
<b>Discussion</b>	Cold joints are sections of concrete that are poorly bonded together due to concrete being placed adjacent to concrete that has already reached initial set.	
<b>Prevention</b>	Proper scheduling of the concrete deliveries is critical to ensure that no cold joints occur. Ensure that the final load is properly scheduled, do not wait until the last truck is on site to determine if the proper order quantity has been placed. Sometimes due to equipment failure or heavy traffic cold joints are unavoidable. In these situations it is best to consider it a construction joint and place bulkheads and insert proper reinforcement in the joint prior to placing the fresh concrete.	
<b>Repair &amp; Maintenance</b>	Cold joints may be unsightly imperfections which need to be completely removed and replaced. In certain situations then can remain in place. If they remain, then it may be necessary to chip out slots into the concrete and insert reinforcing bars or dowels. If the structure needs to be water tight, cold joints may allow water migration. Grout injection may be required to prevent water migration.	

<b>Problem</b>	<b>18.2.3 Bugholes</b>	
<b>Causes</b>	<b>Several material and construction causes</b> - Bugholes are small holes usually less than 15 mm in diameter created on a formed face of concrete. Possible causes are improper use of form release agents, improper concrete mix design, improper consolidation, or vibrators insertions are not properly overlapped or well-spaced.	




1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
Appendix	


Discussion	<p>While bug holes are not a structural concern, architects sometimes design the concrete to have "decorative" finishes such as a P1 Architectural Finish which has a set limit on number of bug holes allowed. Complete elimination of bug holes is very difficult and requires excellent coordination between the concrete producer and forming contractor. Selection of form liners, form release agents, concrete mix design are critical for minimizing of bugholes. The contractor must also be very careful when placing and vibrating the concrete to remove all entrapped air pockets.</p> 
Prevention	<p>Complete prevention of bugholes is not practical since so many variables contribute to it. Since bugholes are caused by the entrapment of air along the formed face anything that will allow the air to escape easier will improve the results. Ensure the internal vibrators are inserted properly with proper insertion patterns, insertion depth and spacing, reduce height of each lift of concrete, move vibrator as close to the formwork as possible, properly apply form release agents. In many cases, the use of Self Consolidating Concrete can dramatically reduce the occurrence of bug holes.</p>
Repair & Maintenance	<p>Bugholes are not structural therefore they do not need to be repaired. If the aesthetics are displeasing then application of a concrete paste worked into the surface can provide a more uniform colour and texture to the formed surface.</p>

**18.3 Flatwork**

<b>Problem</b>	<b>18.3.1 Low Spots</b>
<b>Causes</b>	<p><b>Several construction causes</b> - Low spots are created during the finishing process if there is poor lighting during placement, if the forms or screeds are improperly set, if the grade is damaged during construction, if the concrete has variable slump, or if the concrete finisher has poor placement and finishing techniques.</p>
<b>Discussion</b>	<p>Low spots may become an issue for pavements since they will affect the drainage and therefore the serviceability of the pavement.</p>
<b>Prevention</b>	<p>If placing concrete at night then adequate lighting should be provided to reduce shadows on the concrete during placement. Prior to placement the grade lines and levels should be checked. Manual placement should be reduced as much as possible. The use of a highway straightedge should be considered instead of bullfloats. For manual placement, vibratory screeds should be used to strike off the surface whenever possible.</p>
<b>Repair &amp; Maintenance</b>	<p>During construction, low spots can be filled with fresh concrete provided the concrete will properly mix and bond with the in place concrete. If the in place concrete has set then the concrete may require a bonded overlay or to be replaced.</p>

<b>Problem</b>	<b>18.3.2 Popouts</b>
<b>Causes</b>	<p><b>Material and construction causes</b> - Poor or deleterious aggregate in the concrete that are porous and can absorb water. When the concrete is fully saturated the pressure from the expansion of the water can fracture the soft aggregates and pop off the surface. Concrete not adequately cured with a porous</p>

	mortar fraction.	
Discussion	<p>Popouts are conical fragments that break from the concrete surface. Popouts are usually identified due to the presence of fractured aggregate at the bottom of the hole. All exterior concrete is subjected to popouts. Aggregates used for concrete are required to have a Petrographic number (PN) under 125 for pavements and under 140 for structures, sidewalks, curb and gutter and concrete base. Therefore, by definition, in OPSS 1002, concrete aggregates can have poor or deleterious particles that may cause popouts. For a PN of 140, the aggregate can have up to 6-7% of poor material which can pop off the surface.</p>	
Prevention	<p>Popouts cannot be prevented but they can be reduced by carefully considering the project. If popouts are of huge concern then specifying aggregate sources with a low PN (A PN of 100 means all of the aggregate particles are of good or excellent quality). The added expense to manufacture or import these materials may be prohibitive. Another measure is to reduce the moisture in the concrete by providing adequate drainage through grading or subdrains. Sealers can also be considered to limit inflow of water into the surface of the concrete. Lastly, by curing the concrete properly the mortar will be less porous and the concrete will have the highest possible durability.</p>	
Repair & Maintenance	<p>The easiest method for reducing popouts is to use a good quality sealer on the surface to reduce moisture penetration into the concrete. If the concrete has poor drainage then it is best to remove the concrete, correct the drainage issues and replace with good quality concrete that has been properly cured.</p>	

<b>Problem</b>	<b>18.3.3 Uncontrolled drying shrinkage cracks</b>	
<b>Causes</b>	<b>Design and construction related causes</b> - Improper sawcutting of the concrete or lack of sawcutting operations. Improper curing. Jobsite water addition or improper contraction joint installation.	
Discussion	<p>It is well known that as concrete cures there is a reduction of water and a subsequent loss of volume. Most concrete is designed with control joints to accommodate the volume change and to provide aesthetically pleasing cracks. In general, normal concrete will shrink approximately 0.4 - 0.8 mm per metre of concrete (ASTM C157).</p> <p>Drying shrinkage is a function of water content, cement content, aggregate used as well as admixtures used. The most significant contributor to drying shrinkage is the water content, as water content increases, the higher the volume change and the more shrinkage occurs.</p>	
Prevention	Do not exceed the water/cementitious ratio for the proscribed mix, pour the concrete at the lowest slump possible unless Water Reducing admixtures are used	


1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix



1	Introduction
2	Shrinkage, Curvature, and Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

	to increase the slump, cure the concrete immediately following finishing operation or form removal, cut the concrete as early as possible without the concrete raveling.
<b>Repair &amp; Maintenance</b>	If the cracks are not working cracks (do not increase in width) then they are aesthetic in nature and may be left in place. If the cracks are working cracks (increase in width due to seasonal variation) then they may need to be cross-stitched in order to keep the cracks tight.

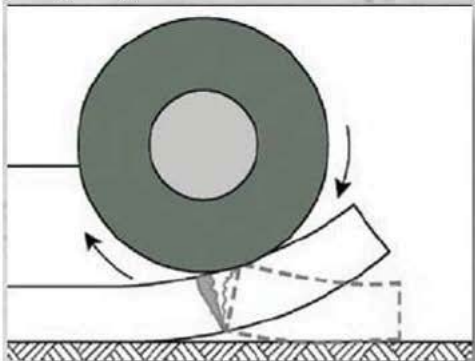
<b>Problem</b>	<b>18.3.4 Settlement Cracks</b>
<b>Causes</b>	<b>Poor concrete support</b> - Loss of support due to erosion of the subgrade or poor compaction of the sub-base / subgrade.
<b>Discussion</b>	Whenever a void is created under a pavement structure during loading the pavement will deflect into the void. If the deflection is significant enough cracking will occur.
<b>Prevention</b>	Ensure subbase is compacted to >95% standard proctor. For pavements with greater than 250 trucks per day, greater than 200 mm thick and high speeds, the use of dowels at the joints is recommended.
<b>Repair &amp; Maintenance</b>	For settlement or erosion issues the slabs can be jacked and a grout mixture is injected into the void. If the panel has significant cracking then the cracked panel should be replaced.

<b>Problem</b>	<b>18.3.5 Cracking</b>
<b>Causes</b>	<b>Poor finishing techniques</b> - Improper or lack of curing, exposure to rapid or prolonged surface drying due to temperature, direct sunlight, dry winds, etc.
<b>Discussion</b>	Cracking cracks are fine random cracks on the surface of the concrete. The cracking is very shallow and does not affect the durability of the concrete. The cracking is purely an aesthetic failure. 
<b>Prevention</b>	Use evaporation retarders if concrete is to be exposed to the elements for prolonged times without any finishing operations. As soon as the concrete has received the final finishing texture, curing must start. If the surface is not shiny it means there is no water protecting the surface.
<b>Repair &amp; Maintenance</b>	This is a purely aesthetic issue, no repairs are required. To improve the aesthetics the concrete surface may be ground in order to remove the crazing cracks.

<b>Problem</b>	<b>18.3.6 Curling</b>
<b>Causes</b>	<b>Design and performance causes</b> - Temperature or moisture differences between

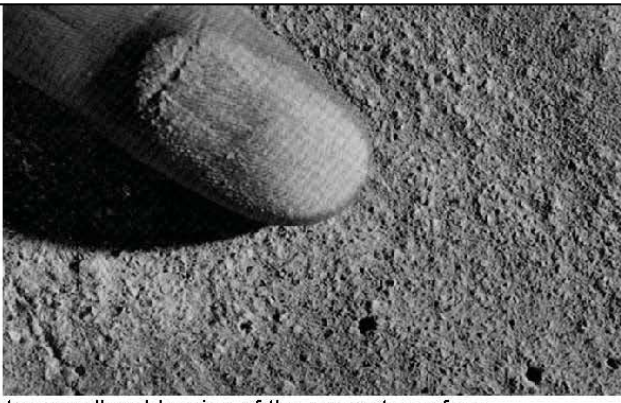



	the top and the bottom of a slab. Large joint spacing. Thin slabs.
Discussion	<p>Curling is the bending of a concrete slab due to differing temperature or differing moisture gradients throughout the slab thickness. If the top and bottom are shrinking or expanding at differing rates then the slab bends accordingly. Curling is more likely to occur in very thin slabs where the self-weight of the concrete does not correct any curling action or in slabs that have very long joint spacing. For slabs with long joint spacing, when the slabs naturally shrink due to drying shrinkage and temperature shrinkage the sawed joint space become larger and aggregate interlock is reduced allowing curling to occur. If aggregate interlock is lost then the slab can easily curl, assuming there is a temperature or moisture gradient. If the slab is reinforced or contains dowels at the joints then the steel reduces the curling action.</p> <p>Slabs naturally curl throughout a day. On a cool morning, the ground is warm and the air is cool and the slab curls down at the edges. As the temperature increases during the day and the surface is hotter than the base of the slab then the slab curls upwards at the edges.</p> <p>It is important for concrete pavements to not be on very strong bases (cement treated, etc.) since weaker bases allow the pavement to deflect into the base during loading. If the base is too strong the curled edges will fracture during traffic loading.</p>
Prevention	Concrete with the lowest drying shrinkage properties and lowest Coefficient of Thermal Expansion will exhibit less curling. Avoid adding water on the jobsite. Do not pour concrete on vapour barriers. Respect the joint spacing limits per American Concrete Institute (ACI) and CSA A23.1 documents. Cure concrete as soon as final finishing operation has been completed.
Repair & Maintenance	Full depth slab repairs need to be performed to remove the damaged concrete. For sections that have not cracked, sawing additional joints may relieve the stresses. Ensure that joints are not in the wheel path.
<b>Problem Causes</b>	<b>18.3.7 Dusting</b> Dusting is the formation of a powder on the concrete surface caused by break down of an extremely weak surface. Typically, dusting occurs only in the top few millimetres of the concrete.



1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Placement Procedures
13	Transportation of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix

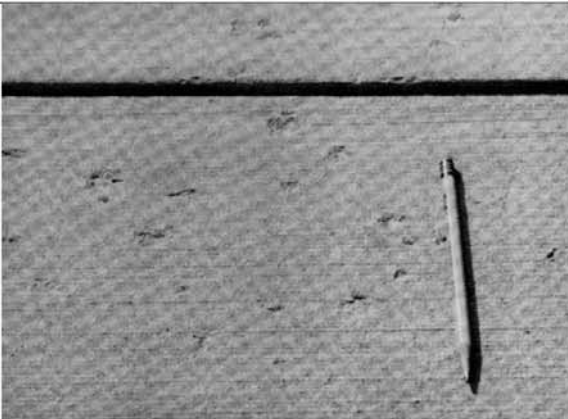
1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Discussion	<p>When concrete is finished the surface layer is always exposed to the worst conditions. If it is not constructed properly it is usually the surface that will fail. Dusting is the formation of a light powder on the surface of the concrete. In municipal applications the usual causes are improper curing, improper protection from the elements as well as blessing of the concrete surface.</p> <p>If concrete is not properly cured, the surface will not be exposed to enough water to hydrate the cement particles. If the concrete surface is weak then it will wear very easily. Similarly, if the surface is exposed to the elements during construction, and it dries out, it will be weaker. Many times during placement, the surface is allowed to dry/crust and then the finisher uses water to "Bless" the concrete, or uses wet tools in order to put moisture back, in order to complete the finishing. When additional water is added the water/cementitious ratio will be increased and a weak surface will occur.</p>	
Prevention	<p>Properly cure the concrete immediately behind final finishing operation. Between finishing operations an evaporation retarder should be used to retain moisture on the surface. The evaporation retarder and/or water should never be working into the surface of the concrete.</p>	
Repair & Maintenance	<p>The surface will naturally wear off. No repair is required.</p>	

<b>Problem</b>	<b>18.3.8 Scaling</b>	
<b>Causes</b>	<p><b>Design and construction causes</b> – Insufficient air entrainment, improper curing, exposure to de-icing chemicals, improper concrete ordered/delivered, finishing while water is on the surface (increased surface w/cm ratio) &amp; placement during adverse weather (extreme heat, extreme cold, rain, etc.).</p>	
Discussion	<p>Scaling, popouts and mortar flaking are often confused for each other but their mechanisms are different. With popouts, soft aggregate expands blowing up the surface. For Mortar flaking the concrete above a piece of aggregate is weak and the surface delaminates. With scaling the concrete paste is weak and the surface delaminates.</p> <p>Scaling is limited to the surface of the concrete in most cases, unless improper air entrainment is used.</p> <p>With scaling the aggregate is not fractured since the damage is limited to the weak mortar layer.</p>	



Prevention	<p>Order the proper concrete for the exposure condition. Ensure air content is in the proper range.</p> <p>Ensure the concrete is properly cured immediately behind final finishing operation.</p> <p>Sparingly use deicing chemicals, if possible, sweep up the salt after each melt.</p> <p>Allow concrete to air dry for at least 30 days prior to exposure to freeze/thaw cycles.</p> <p>Do not allow blessing of the concrete or the use of wet tools during the finishing process.</p> <p>Do not allow bleed water to be finished into the concrete.</p> <p>Use evaporation retarders to protect the concrete between finishing operations.</p> <p>Use a high quality sealer on the concrete.</p>
Repair & Maintenance	<p>If the scaling is caused by improper finishing or curing then grinding the surface to remove the weak layer will restore the concrete.</p> <p>If the scaling is caused by concrete with low air content then complete removal may be required.</p> <p>The use of sealers to prevent adsorption of water into the concrete will improve the durability of the concrete provided moisture is not coming from ground sources.</p> <p>Sealers usually need to be reapplied every 1-2 years.</p>

<b>Problem</b>	<b>18.3.9 Mortar Flaking</b>	
<b>Causes</b>	<p><b>Construction and performance causes –</b></p> <p>Concrete placed during periods of rapid surface drying.</p> <p>Concrete not cured.</p> <p>Curing compound applied too late.</p>	
<b>Discussion</b>	<p>Mortar flaking usually occurs in discreet locations distributed randomly across a pavement surface. If the concrete is not properly cured the area above the large coarse aggregate particles will not receive the water migrating from below up to the surface. If the surface dries out then the mortar will be weak. It is important to cure the concrete to ensure the surface always has adequate moisture to hydrate all the cementitious particles. With Mortar flaking the aggregate particle is sound, only the mortar fraction above the aggregate particle is removed.</p>	
<b>Prevention</b>	Cure the concrete as soon as the final finishing operation has completed. Use evaporation retarder on the concrete between finishing operations.	
<b>Repair &amp; Maintenance</b>	Mortar flaking is an aesthetic concern, once the weak mortar flakes have delaminated the remaining concrete has sufficient durability. If the mortar flaking is severe then grinding of the surface is a viable repair technique.	

<b>Problem</b>	<b>18.3.10 Faulting</b>
<b>Causes</b>	<p><b>Design and performance causes -</b> Faulting due to mud-pumping occurs when there is a high silt content in subgrade /sub-base with high speed traffic, heavy trucks and poor drainage. In order to get faulting there needs to be an aggregate</p>

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation of Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
	Appendix




1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

	material that retains high amounts of moisture, high speed traffic to generate fast slab deflections and heavy trucks to deflect the slab. Without all these components there will not be enough movement to create a suction-type force to pull the aggregate up through the joint. Faulting can also occur in sidewalks where differential settlement / heaving occur during seasonal events.
Discussion	Faulting, also known as "Stepping", of slabs is usually caused by the loss of support or differential movement of a slab which allows one slab to move differently than the adjacent slab. For sidewalks it is important to maintain aggregate interlock in order to reduce the potential for differential movement. It is important not to have too many isolation joints, otherwise the potential for loss of aggregate interlock will occur. Faulting can be a tripping hazard on sidewalks.  On roadways, faulting will cause uncomfortable ride for vehicle passengers. For pavements thicker than 180 mm, dowels can be used to prevent faulting. In parking lots with slow moving vehicles and less than 200 trucks per day faulting due to mud pumping is not normally the predominant failure mechanism.
Prevention	Uniform subgrade, adequate drainage, ensure tight joints, dowel bars for slabs greater than 180 mm thickness (with heavy trucks and high speed traffic).
Repair & Maintenance	For mud-pumping, slab jacking can correct the stepping action of the two slabs. For differential movement, if the underlying issue is non-uniform subgrade then slab jacking would be a temporary fix since more movement will occur every spring. To correct the issue either drainage would need to be improved to reduce movement or the slabs would have to be removed, compaction and potentially cross-hauling to provide uniform support then slab replacement. If the subbase is uniform the slabs will all move uniformly and no faulting would occur.

<b>Problem</b>	<b>18.3.11 Blow-ups</b>
<b>Causes</b>	<b>Thermal expansion of the concrete in hot weather</b>
Discussion	During summer months when concrete expands due to temperature increases the pavement needs space to expand into. Normally the drying shrinkage (4-8 mm per 10 m of sidewalk) is greater than the expansion due to temperature rise (0.08 mm per 10 m of sidewalk per 1 degree change in Temperature) and there is no issue. Date of construction is important since the temperature increase is based on the temperature at construction day. If placement is late in the year and ambient temperature is -5°C, and the temperature in the summer reaches 30°C, then the temperature change is 35°C and the concrete will expand 0.08*35 = 2.8 mm per 10 m of sidewalk. If placed in the summer at 30°C and the temperature is -15°C in the winter then the temperature change is 45°C and the panels will shrink by 3.5 mm per 10 m of sidewalk. The greater the gap in the joints, the more incompressible materials that can fall into the joint. In winter months, as it gets colder we use more salt and sand to keep our pavements safe. These salts and sands lock up the joint and do not allow the expansion required when the temperature increases.  Improper installation or placement of isolation joints can cause blow-ups. Isolation joints should be the full depth of the slab. Isolation joints should be installed to remove all restraint from the slabs (ie. Corners of two intersecting sidewalks, sidewalk placed against a curb, etc.).
Prevention	Install isolation joints full depth. Ensure isolations joints are constructed in the


	proper locations to allow movement of the slabs with minimal restraint. Prevention is best accomplished by power washing or vacuuming the joints in the spring.
Repair & Maintenance	If isolation joints are not installed properly then cutting the isolation joint and filling it with a flexible material will allow movement. If blow ups have occurred then replacement is the only option.

## 18.4 Pavements


<b>Problem</b>	<b>18.4.1 Segregation</b>
<b>Causes</b>	<b>Construction and placement causes</b> - Inadequate mixing, high slump, over vibration, improper concrete mix design, improper transportation, poor aggregate gradation.
<b>Discussion</b>	<p>When a mix segregates, the mortar fraction (Cement, sand, water) separates from the coarse aggregate. If the aggregate gradation is poor then the mix may be too coarse and mortar fraction will not be viscous enough to hold the aggregates together. Water addition also affects the viscosity of the mortar. Segregation can also occur during transportation especially in non-agitating equipment. Lastly, if the concrete is over vibrated segregation can occur. Vibrators should be in a single location for no more than 15 seconds. Vibrators should not be used to move the concrete into final position.</p> 
<b>Prevention</b>	Ensure proper mix design is used with good quality raw materials. Do not add water above what is required to properly place. Ensure concrete is thoroughly mixed prior to discharge into non-agitating trucks or on the job site. If using non-agitating trucks delivery time should be limited to 30 minutes.
<b>Repair &amp; Maintenance</b>	Partial or Full depth repair of the concrete can be used to correct the issue.
<b>Problem</b>	<b>18.4.2 Joint Lockup</b>
<b>Causes</b>	<b>Design and performance causes</b> -Tie bars located too close to doweled joint, tie bars in both directions, restraint from two different directions.




1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Pavement Meetings
12	Concrete Repair Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Curing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting


Discussion	<p>Concrete naturally moves during its service life. Initially, (first 28 days+) the concrete will shrink due to drying shrinkage. Drying shrinkage is normally in the range of 0.04%-0.08%. Concrete can also expand and shrink due to temperature changes. Thermal changes are in the range of 0.000008 mm/mm °C. For a 10 m sidewalk the concrete will shrink or expand approximately 0.8 mm for a 10 °C change in temperature.</p> <p>Some movement also occurs longitudinally due to braking and other tire interactions with the surface.</p> <p>Dowels are normally 20-35 mm smooth bars. Dowels are installed at transverse joints in order to allow lateral movement of the pavement but to not allow vertical movement. Dowels must be aligned properly to allow the lateral movement, if dowels are miss-aligned they will lock up the joint.</p> <p>Tie bars are normally 15-20 mm deformed bars. Tie bars are installed along longitudinal joints to keep the joints tight. Primarily, tie bars are installed to prevent a gap between the lanes for vehicles changing lanes. As well, if lanes separate there will be an increase in water allowed into the subbase. Tie bars should not be installed closer than half the length of the dowel bar plus 300 mm from the doweled joint. Tie bars should not be installed in the transverse direction.</p>	
Prevention	<p>Care should be taken to properly detail the site drawings for tie bars and dowels. Dowel bars need to be properly aligned to allow movement.</p>	
Repair & Maintenance	<p>If dowel bars are miss-aligned then the bars need to be cut and a dowel bar retrofit needs to be performed.</p> <p>If tie-bars are too close to the doweled joint the tie bars that are too close should be cut.</p> <p>If tie-bars are installed in both directions then the transverse tie-bars need to be cut and a dowel bar retrofit needs to be performed (assuming the pavement requires dowels).</p>	
Problem Causes	<p><b>18.4.3 Longitudinal / transverse cracking following placement</b></p>	
	<p><b>Design and construction causes</b> - Improper joint spacing, improper sawcut depth, non-activated sawcut, sawcutting too late, curling/warping, Loss of support, Settlement/heave and restraint of the slab and sympathy cracking.</p>	



Discussion	<p>Longitudinal joint cracking tends to occur either near the edge of the pavement between lanes or at the edge of the pavement at the shoulder.</p> <p>When the cracking occurs near the longitudinal joint between adjacent lanes, the cracking is usually due to improper construction of the joint. Either the joint was not cut deep enough (1/4-1/3 the pavement thickness), or the sawcutting operation occurred too late and the crack formed prior to sawcutting.</p> <p>When the cracking occurs at the edge of the pavement, at the shoulder, then the cracking is usually due to fatigue of the pavement. Either the subbase is weak in this area and support is lost, or the shoulder is weak and there is little to no load transfer. For designs with edge load conditions, the pavement needs to be thickened to accommodate the load condition. The pavement could also have settled or heaved to create the cracking.</p> <p>If the cracks are occurring mid-slab then there may be too much restraint caused by tying too many lanes together (Max 4 lanes), or other embedment's causing the restraint. Heaving, settlement and loss of support can also cause mid-slab cracking.</p> <p>For transverse cracks, all the causes need to be investigated. Transverse cracks can also occur due to sympathy cracking from the curb. If the joints are not lined up between the pavement and the curb and the two elements are not separated by an isolation joint then any cracks that occur in one element will likely crack the adjacent element. Re-entrant corners around catch-basins can also cause cracking if not properly detailed.</p>	
Prevention	Prevention of cracking will depend on the type of cracks that are formed. Proper detailing for the design and proper construction will prevent most occurrences.	
Repair & Maintenance	<p>For longitudinal cracking at the centreline, cross-stitching of the crack or rebar retrofitting can prevent the crack from opening further provided that the crack occurred due to poor construction.</p> <p>For longitudinal cracking at the pavement edge, cross-stitching or rebar retrofitting can prevent the crack from opening up. If the crack occurred due to the slabs being too restrained then adding further reinforcement will cause more cracking to occur in another location. For issues with fatigue or heaving then the slab will have to be replaced and the proper design details will have to be investigated.</p> <p>For transverse cracking, dowel bar retrofitting can be a cost effective solution for sawcutting errors, curling/warping and misaligned dowel bars (restraint). For cracking caused by loss of support, slab stabilization may be a good solution followed by dowel bar retrofit. If there are heaving issues caused by subsurface conditions, they would require a full depth slab replacement as well as correction of the cause from the heaving.</p>	

1	Introduction
2	Shrinkage, Curvature & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

<b>Problem</b>	<b>18.4.4 Low skid resistance</b>	
<b>Causes</b>	<b>Aggregate polishing</b>	
Discussion	<p>As vehicles travel on a pavement the surface wears which will reduce the skid resistance of the pavement. In order to provide good skid resistance the pavement must have good micro and macro texture.</p> <p>Unlike other pavements, concrete pavements do not normally get milled and overlaid which not only repairs deficiencies but also improves skid resistance. Because concrete pavements last a very long time the surface may not have acceptable skid resistance even though the pavement is not at the end of its service life. To correct the skid resistance for concrete pavements the typical repair is to diamond grind and/or diamond groove the surface to expose the non-polished aggregate.</p>	
Prevention	Use high quality aggregate for the surface if using two stage wet-on-wet pavement placement.	
Repair & Maintenance	Diamond grinding or diamond grooving.	

<b>Problem</b>	<b>18.4.5 Noise Complaints</b>	
<b>Causes</b>	<b>Joints open more than 20 mm, faulting and texture</b>	
Discussion	<p>A common complaint about concrete pavements is the noise generated by the tires riding on the concrete. There is a distinct high pitch whine from most concrete pavements in Ontario. There are three predominate causes for the noise.</p> <p>The first reason may be that the joints have opened up or the joint sealant has been replaced too many times and the joint is now greater than 20 mm wide. If the pavement is designed with too many isolation joints, as the isolation joint material compresses joints open wider. When the joints are very wide there is a distinct joint slap as the tire passes over the joint. For MTO projects the joint spacing is staggered in order to not create a repetitive sound every 4.5 metres. By staggering the noise the driver is less likely to be lulled to sleep.</p> <p>The second reason for noise is faulting of the joint. If the approach slab is elevated</p>	



	<p>when the tire hits the raised portion, a noise occurs. If the faulting is severe then the noise will be significant.</p> <p>The last reason may be due to the texture of the pavement which is applied to improve skid resistance. For low speed traffic (under 60 km/h) a burlap drag finish is all that is required for skid resistance. Burlap drag finishes are quiet. For higher speed traffic the concrete needs to have tining in order to provide sufficient micro and macro texture. Tining can be placed in several ways, typically transverse or longitudinal. Transverse tining is the most common in Ontario, it is also the surface that generates the loudest noise. Longitudinal tining is quieter than transverse. To get quieter than longitudinal tining additional operations need to be performed. Diamond grinding will improve the ride as well as reduce noise. The best surface for noise reduction is "Next Generation Concrete Surface (NGCS)". NGCS is by far the quietest surface available, NGCS is a combination of Diamond Grooving and Diamond Grinding.</p>
Prevention	Keep isolation joints to a minimum to keep joints as tight as possible, use dowels on pavements greater than 180 mm thick, longitudinal tining, diamond grinding or NGCS surface texture.
Repair & Maintenance	Full depth slab repair, slab jacking, diamond grinding or Next Generation Concrete Surface.

**18.5 Common Troubleshooting**

<b>Problem</b>	<b>18.5.1 Low Strength</b>
<b>Causes</b>	<b>Poor material selection, poor construction practices, poor testing practices.</b>
Discussion	<p>The raw material selection, batching and mixing of the concrete must be correctly performed in order to ensure quality concrete. RMCAO certified plants are required to demonstrate yearly their ability to batch concrete to specific tolerances as well as demonstrate their ability to meet the quality requirements per CSA A23.1. The certification process is completed through third party engineers and is the best program in North America.</p> <p>Water addition is allowed on-site provided (CSA A23.1):</p> <ul style="list-style-type: none"> <li>• The w/cm ratio is not exceeded.</li> <li>• No more than 60 minutes have elapsed from time of batching unless a retarding admixture or hydration stabilizer has been used.</li> <li>• No more than 16L/m<sup>3</sup> or 10% of the mixing water shall be used.</li> <li>• Mixer drum shall turn at mixing speed for 30 revolutions or equivalent time limit.</li> <li>• Water above added and signing authority must be recorded on the delivery ticket.</li> </ul> <p>It is also important to check the air content of all concrete, as air content increases the compressive strength decreases. Air content should be checked for air entrained and non-air entrained mixes.</p> <p>Concrete on-site must be properly placed, consolidated, and cured to ensure strength requirement is met.</p> <p>Strength is a predominant indicator of concrete quality and a significant amount of</p>




1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

	<p>testing is done in order to ensure adequate strength is achieved. In general, the higher the cement content, or the lower the water/cementitious ratio the higher the compressive strength will be. Testing plays a significant role in determining if the strength has been achieved. Testing of concrete can be performed on cylinders left in the field cured with the structure or cylinders can be tested per CSA A23.2 to determine if the concrete in "ideal" condition would achieve strength. Choosing the cylinder storage location can have a dramatic impact on the results.</p> <p>Field cured concrete cylinders are good for determining when forms can be stripped or when a pavement can be opened to traffic. Field curing determines the actual strength of the in-place concrete. Field curing is very difficult to achieve in practice since cylinders cast are rarely in the exact same condition as the structure. Alternative methods are maturity testing or coring of the structure.</p> <p>Concrete curing per CSA A23.2 is used to determine if the concrete supply is consistent and is capable of achieving the target strength. Cylinders in the field must be kept at 15 -25 °C for entire field curing period. That period can be 24-72 hours depending on the compressive strength.</p> <p>Concrete cylinders are greatly affected by how they are cast, stored, handled and tested. Rarely are the methods favourable to achieving higher strengths. If cylinders are stored below 15 C for the 24 hour period then the 28 day strength will be higher than normal (7 days may be lower). If the concrete compression machine is travelling at a faster rate than the standard states strengths will be higher. All other methods (round bottom, improper consolidation, impact damage, etc.) result in lower strengths.</p>
Prevention	Ensure appropriate mix is ordered, ensure proper curing methods are used for the application, and ensure CSA A23.2 Test Methods are properly followed.
Repair & Maintenance	If the strength is low, check engineering design to ensure design strength is required. If low and the structure cannot be re-engineered then removal and replacement may be required.

<b>Problem</b>	<b>18.5.2 Thermal Cracking</b>
<b>Causes</b>	<b>Construction and curing causes</b> - Highly accelerated concrete mixes which gain substantial heat, improper removal of thermal blankets during cool weather.
<b>Discussion</b>	<p>As concrete gains in temperature it expands, conversely as it cools concrete shrinks. If part of the concrete is expanding while another section is shrinking there is a build-up of stress in the concrete. If the stress is greater than the strength of the concrete a crack will form. General rule of thumb suggests a temperature difference from the core of the concrete (usually the hottest point) to the coolest location be no more than a 20 °C difference.</p> <p>When accelerating concrete or during cold weather conditions thermal blankets should be used to control the temperature. Concrete temperatures for accelerated concrete may be higher than 50 °C, if this is the case then blankets need to be removed a layer at a time until the concrete temperature drops. For concrete less than 1 m thick, the maximum temperature drop per 24 hour period is 20 °C. Protection should not be removed until the average concrete temperature is less than 10 °C from ambient air temperature.</p> <p>For thick structures, the concrete in the centre of the structure will get significantly higher than the exposed concrete surfaces. In this situation it is recommended to</p>

	<p>use Type MH and LH equivalent mixes. Moderate Heat and Low Heat mixes are designed using fly ash or ground granulated blast furnace slag to replace a portion of the Portland cement. In extreme cases, cooling pipes are installed into the concrete to reduce the internal temperature. At no time do you want the concrete temperature to be above 70 °C, otherwise Delayed Ettringite Formation can occur.</p> <p>For bridge structures placed in cool weather, the underside as well as the deck portion of the concrete needs to be protected to control heat rise.</p>
Prevention	Prevention is solely based on controlling the temperature of the concretes surface using thermal blankets or other suitable methods.
Repair & Maintenance	If concrete is cracked due to thermal expansion there are two possible solutions. For limited cracking it is possible to crack-stitch the concrete to keep the cracks tight. Otherwise, the concrete will need to be removed and replaced in the cracked areas.

<b>Problem</b>	<b>18.5.3 Delamination</b>
<b>Causes</b>	Scaling, blistering, power trowelling concrete with high air content.
<b>Discussion</b>	<p>Delamination is a catch all term for various failure modes in concrete. Delamination occurs when a distinct layer of the concrete is faulty and the remaining concrete is good.</p> <p>For scaling, blistering problems the poor concrete is limited to the top surface that was wetted to have a higher than designed water/cementitious ratio, improperly cured, hard troweled with bleed water present, etc.</p>
Prevention	Please see the various problem statements above for their respective prevention, repair and maintenance requirements.
Repair & Maintenance	Please see the various problem statements above for their respective prevention, repair and maintenance requirements.

<b>Problem</b>	<b>18.5.4 Discolouration</b>
<b>Causes</b>	<b>Construction and curing causes</b> - Calcium chloride, changing w/cm ratio, added water, troweling too late, different ages of concrete, changing raw materials, different pigment dosage (coloured concrete), surface texture changes, etc.
<b>Discussion</b>	<p>Discolouration can occur for various reasons, in most cases the colour change is very slight and is not noticeable. How we perceive colour is a combination of the surface texture and the actual colour of the concrete. How we finish the concrete and how light reflects off the surface texture can provide distinct colour variations. Some decorative concrete techniques are to simply broom in different directions to provide an architectural finish.</p> <p>Another way to change the colour of concrete is to have a varying water content (w/cm ratio changes, wet tools, dry load next to wet load, etc.). As water is added to concrete the paste becomes lighter in colour. Notice in the picture the lighter striations due to excess water on the broom during texturing.</p>
	




1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

	<p>When power troweling concrete certain timing is necessary to get the required finish. If delays occur, mix has high cement content, sunshine on the surface then the concrete can set up faster than anticipated. In these situations the finisher may get onto the concrete late and then have to work the surface more to get the final finish. When this occurs the surface tends to get a darker grey colour which is sometimes called "burning the surface".</p> <p>Lastly, the use of accelerating admixtures, specifically calcium chloride, will change the colour of the concrete. Calcium chloride should not be used in concrete that has reinforcing steel. Calcium chloride will make concrete darker in colour, in high dosages the concrete will have a dark grey colour similar to the "burnt surface" look of over finishing. Sometimes calcium chloride is requested in concrete for the last few trucks of the day in order to accelerate the strength gain. In late fall, when concrete is slower to gain strength, in order to protect the concrete from local residents walking or impressing the concrete with "decorations" accelerators are requested to prevent this occurrence. In these cases, a non-chloride accelerator should be requested. Non-chloride accelerators do not affect the colour of the concrete as much as calcium chloride.</p> <p>Unless the discolouration is due to addition of water the problem is solely aesthetic and may not need to be corrected.</p>
Prevention	Consistent slump, do not add water to the surface through blessing or wet tools, do not use calcium chloride, finish concrete at appropriate time.
Repair & Maintenance	<p>For vertical work, sack-rubbing the surface with a mortar will even out the discolouration. For horizontal surfaces, slight discolouration will fade in time as carbonation occurs on the concrete.</p> <p>If the discolouration is due to water addition and the w/cm ratio has been compromised then the concrete may need to be replaced. If the water addition is only at the surface then grinding the weaker compromised surface layer will remove the discoloured concrete.</p>

<b>Problem</b>	<b>18.5.5 Alkali Aggregate Reactivity (Silica or Carbonate)</b>
<b>Causes</b>	<b>Chemical reaction</b> - Combination of water, cement alkalis and either silica or carbonate aggregate.
<b>Discussion</b>	<p>Alkali Silica Reaction (ASR) needs three components in order to occur. There needs to be a siliceous aggregate that is reactive, sufficiently high alkali in the cement and a source of water. When these three components are available a chemical reaction occurs which will create a gel that swells. As the gel expands it will crack the surrounding concrete and eventually lead to a failure. If the cracking occurs over reinforcing bars, the cracks allow more water into the system and the steel will corrode faster and accelerate the deterioration.</p> <p>Alkali Carbonate Reaction (ACR) needs three components as well. A dolomitic aggregate source that is reactive, sufficiently high alkali in the cement and water. Some dolomitic aggregates along the Trent-Severn waterway have been known to cause this reaction. In this reaction, the alkalis and water react with the dolomite to form brucite. Brucite has a high volume than dolomite which will create stresses in the concrete. Typically, ACR potential sources are not good sources for concrete aggregates due to loss of strength, etc.</p>
<b>Prevention</b>	ASR: Low reactive aggregates tested by accelerated mortar bar test or concrete prism test. Low alkali cement (not readily available in Ontario), lowering the cement alkalis by replacing some of the cement with fly ash or slag, prevent ingress of



	water or use Lithium Nitrate Additives in the concrete.  ACR: Non-reactive dolomite sources, blending aggregates to reduce reactive material, reduction of maximum aggregate size.
Repair & Maintenance	The distressed surfaces need to be removed. For areas with potential for AAR, inhibiting ingress of water may eliminate the distress. By eliminating any one of the three causes for the reaction the problem will be eliminated. In some cases, impregnating the surface with Lithium ions can reduce the potential for ASR.

<b>Problem</b>	<b>18.5.6 Contamination</b>
<b>Causes</b>	<b>Material and construction causes</b> - Impurities in the concrete supply, littering on site, etc.
Discussion	<p>Contamination can occur for a couple of reasons and it is usually not intended. During production of concrete there are many differing processes which can lead to a contaminant being in the concrete. Sometimes it can be tools (Wrenches, screw drivers, etc.) that are inadvertently left in a stockpile. When the aggregates go through the ready-mix plant the tools will go through the process as well. Sometimes, especially for portable plants, stockpiles may not be on concrete pads. If the aggregate stockpiles are on a clay base, if the loader digs too deep while loading the plant there is a possibility of clay contamination in the concrete. Training of the loader operators will usually correct this and minimize risk.</p>  <p>Another possible method of contamination is litter on site. If the construction workers throw their wrappers, cigarette butts, etc. onto the subbase during the pour then as the concrete is placed the litter will be mixed into the concrete. In many cases the litter is a light material that will float to the surface of the concrete. This may lead to localized spalling of the surface.</p>
Prevention	Properly account for tools after work near raw materials, training of the loader operators especially when there base material is soil based. Ensure enough trash bins (with lids) are available on site and do not allow personnel on site to throw cigarette butts onto the subbase or into the concrete during placement.
Repair & Maintenance	Usually the contamination is isolated into a small location. Localized patching may be required to remove the contaminant. Ensure the existing concrete in the patch is clean and free of dust to ensure a good bond between the patch material and the good concrete underneath.

References:

PCA - Concrete Information - Concrete Slab Surface Defects: Causes, Prevention & Repair

Concrete Ontario - Conc

1	Introduction
2	Shrinkage, Curvature, Cracking and Inspection
3	Asset Management, Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
Appendix	

## Appendix

### Appendix A: RMCAO Plant Certification Program

One of the most valuable initiatives of Concrete Ontario (RMCAO) is the assurance of quality concrete supply and production through the execution of a strict plant certification process. The RMCAO certification process was first implemented in the early 1960's. Starting in 2015, the RMCAO Plant Certification Program also includes a requirement to meet or exceed Ministry of Environment standards for water discharge, air pollution discharge and noise. It is completed by independent third party engineers and has become the most stringent concrete certification program in North America.

RMCAO certification designation means that all materials, material handling, batching methods and tolerances, statistical product quality analysis, truck mixers, weighing equipment, certificates and records meet or exceed CSA A23.1 requirements.

Current concrete specifications such as those of the Ministry of Transportation (MTO), Ontario Municipalities, Ontario Ministry of Agriculture (OMAF), consulting engineers, design/build firms and general contractors typically require RMCAO plant certification.

Highlights of the RMCAO Plant Certification process include:

- Third party consulting engineer inspections
- Raw material conformance to CSA, OPSS or MTO requirements
- Scale inspection and calibration on a 6 month basis
- Batching inspection and accuracy requirements
- Inspection and certification of mixing and transportation equipment
- Standardizing of minimum information requirements for delivery tickets and mix designs
- Implementation of a mix design statistical analysis program for two categories of concrete
- Record keeping
- Random plant inspections and audits
- Ensures producer meets or exceeds Ministry of Environment requirements

For additional information please contact Concrete Ontario (RMCAO) at [www.rmcao.org](http://www.rmcao.org) or [info@rmcao.org](mailto:info@rmcao.org)



1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation Concrete
14	Convey, Grading, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

## Appendix B: OGCA Gold Seal Program

The Ontario General Contractors Association (OGCA) remains a strong supporter of continuing education for the construction industry. Gold Seal is an excellent opportunity for contractors to expand the qualifications of their staff which in return improves the professionalism at every level from the site to the office, and results in better productivity, fewer problems, safer sites and a better bottom line for the contractor.

The Gold Seal Certification Program was developed by the Canadian Construction Association to recognize the skills and competence of the key managerial positions of Superintendent, Estimator and Project Manager on a national basis.

### Certification Requirements

Certification of Superintendents, Estimators and Project Managers requires satisfaction of 3 criteria – Experience – Education – Examination. Applicants must have a minimum level of experience and have undertaken at least five construction management courses totalling 150 hours of instruction to qualify to write the Gold Seal examination. The only exemption from the three criteria permitted by the National Gold Seal Committee is for “senior” managers who have a lengthy demonstrated track record in the industry. A separate guideline is available upon request by senior practitioners. A development category, known as the Gold Seal Intern (GSI), is available to candidates who do not meet the examination eligibility criteria.

Experience as a Superintendent, Estimator or Project Manager in a non-residential construction firm is the first critical criterion to be met. In order to be eligible to challenge the Gold Seal examination, an applicant must document a minimum of three years’ experience in the occupation.

Education in construction management courses is a key requirement. The Gold Seal Certification program will recognize construction management training in subject areas defined in the Gold Seal Curriculum Standard. The Curriculum details the content of the following management courses:

- Law and Contracts in Construction
- Construction Planning and Scheduling
- Project Costing Control and Accounting
- Construction Job Site Controls
- Communication
- Construction Safety
- Management of Human Resources
- Construction Estimating

For more information, please contact [www.ogca.ca](http://www.ogca.ca) or [www.cca-acc.com](http://www.cca-acc.com)



## Appendix C: Concrete Test Forms & Reporting - CMATS™

Log onto... [WWW.CMATS.COM](http://WWW.CMATS.COM)

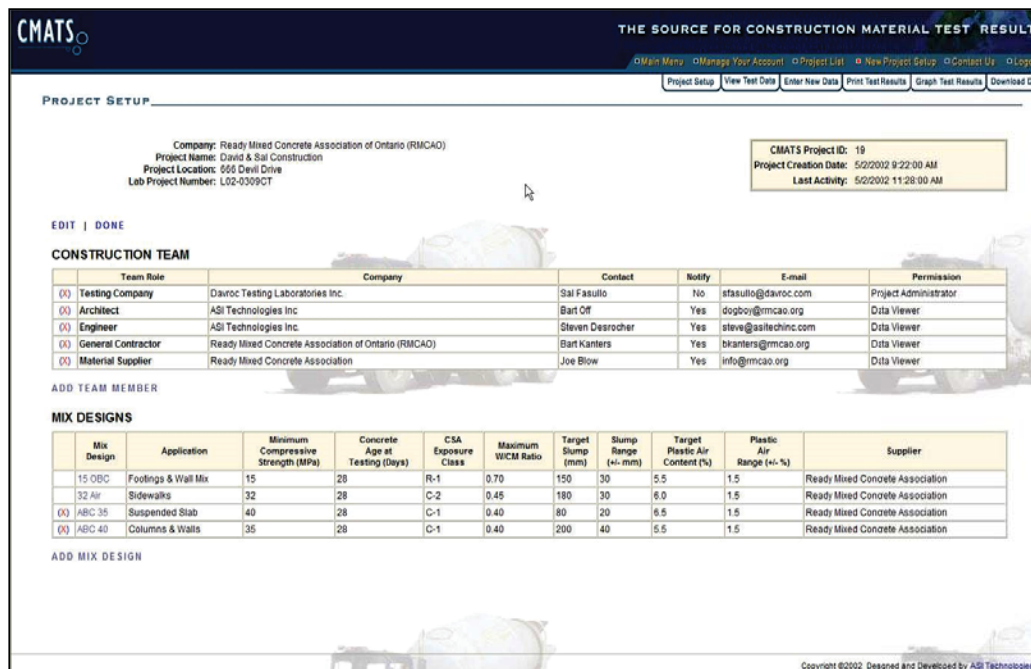
### What Is CMATS™?

CMATS™ is a secure website where construction industry concrete test data can be recorded, viewed and distributed to owners, architects, engineers, testing companies, contractors and material suppliers, on a project by project basis.

### How CMATS™ Works

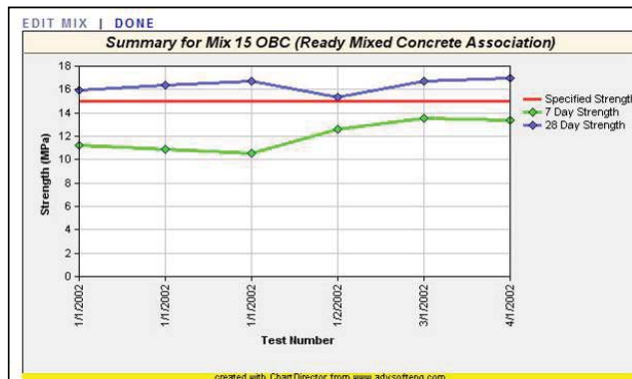
Quite simply, users access the CMATS™ website via their web browser and enter their email address and password to **instantly obtain access to the test results for all the projects they are involved with.** CMATS™ mirrors the existing paper method of providing test information to construction team members and is implemented by the testing company. At the start of a new project, the testing company identifies those who will be given access to the test information (owner, architect, engineer, etc.) when they create a new project.

The software immediately notifies all the users via email of the new project and updates their security records to provide them access. The testing company then performs the necessary testing and inputs the results into CMATS™. Once the information has been entered, reviewed and certified by the supervising engineer of the testing company, the information is then immediately viewable to all users.



**Key Advantages of CMATS™ include:**

- Instant secure access to the project data from any location via the internet
- Rapid distribution of material test results to all members of the construction team
- Quality assurance features to identify trends and provide statistical analysis
- Graphing features allow users to view control charts on material quality
- Electronic notification when new test data is available
- Eliminates repetitive data entry
- Eliminates paper handling and distribution costs
- Creates greater accountability while improving project communication
- Improved reaction times result in a higher quality final project
- Download features allow users to create historic records electronically and to perform additional statistical analysis



While CMATS™ currently handles concrete test results, work is underway to add additional modules for both aggregate and hot mixed asphalt test data. In fact, CMATS™ can be easily adapted to any reporting system that uses standardized reporting forms.

For more information regarding CMATS™, please visit [www.cmats.com](http://www.cmats.com) and register as a new user you will then be able to try the system yourself and see just how easy it is to use.

**Contact Information:** Bart Kanters, P.Eng. @ (905) 507-1122 or [bkanters@rmcao.org](mailto:bkanters@rmcao.org)

**CMATS** THE SOURCE FOR CONSTRUCTION MATERIAL TEST RESULTS

Company: Ready Mixed Concrete Association of Ontario (RMCAO)  
 Project Name: David & Sai Construction  
 Project Location: 668 Devil Drive  
 Lab Project Number: L02-0309CT

CMATS Project ID: 19  
 Project Creation Date: 5/2/2002 9:22:00 AM  
 Last Activity: 5/2/2002 11:28:00 AM

Current Concrete Mix Design and Supplier: 15 OBC - 15 MPa (Ready Mixed Concrete Association)

Mix Design Code	Application	Early Minimum Compressive Strength (MPa)	Early Concrete Age at Testing (Days)	Final Minimum Compressive Strength (MPa)	Final Concrete Age at Testing (Days)	CSA Exposure Class	Maximum W/C Ratio	Specified Slump (mm)	Tolerances in Slump (+/- mm)	Target Plastic Air Content (%)	Plastic Air Range (+/- %)	Nominal Aggregate Size (mm)
15 OBC	Footings & Wall Mix			15	28	R-1	0.7	150	30	5.5	1.5	20

EDIT MIX | DONE

Test #	Date Cast (mm/dd/yy)	Time Mixer Charged	Concrete Temp (°C)	Ambient Temp (°C)	Measured Slump (mm)	Measured Air Content (%)	7 Day Strength (MPa)	28 Day Strength (MPa)	28 Day Strength (MPa)	28 Day Average (MPa)
5	1/1/2002	9:04 am	33	32	150	5.6	11.2	15.9		15.9
5	1/1/2002	9:04 am	33	32	150	5.6	10.9	15.9	16.9	16.4
1	1/1/2002	9:30 am	23	-5	160	5.8	10.5	16.5	16.9	16.7
2	1/2/2002	10:45 am	18	-10	180	6.2	12.6	15.2	15.5	15.35
3	3/1/2002	4:23 pm	29	-10	180	7.1	13.5	16.5	16.9	16.7
6	4/1/2002	10:12 am	32	15	150	5.7	13.4	16.8	17.2	17

Averages for Mix

Measured Slump (mm)	162
Measured Air Content (%)	6
7 Day Strength (MPa)	12
28 Day Strength (MPa)	16.4

1	Introduction
2	Sitewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Plan and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

## Appendix D: Concrete Order Form

VOLUME	m3	DATE	CUSTOMER
	yd3		
STRENGTH	MPa	TIME	ADDRESS
	PSI		
AIR	%	CONVEYOR	DESCRIPTION
	0%		
CALCIUM	%	Yes	No
FIBRE	COLOUR	FIBRE	DESCRIPTION



Concrete Mix Design Submission

Contract \_\_\_\_\_ Date Submitted \_\_\_\_\_  
 Location \_\_\_\_\_ Submitted To \_\_\_\_\_  
 Contractor \_\_\_\_\_ Contact \_\_\_\_\_  
 Batch Plants: Primary \_\_\_\_\_ Secondary \_\_\_\_\_

Concrete Supplier: Name \_\_\_\_\_  
 Address \_\_\_\_\_  
 City/Province \_\_\_\_\_  
 Telephone \_\_\_\_\_ Fax \_\_\_\_\_ Email \_\_\_\_\_

MIX CODE					
<b>Application / Element / Location</b>					
<b>SPECIFICATION</b>	<b>Structural Requirements</b>				
	- CSA Exposure Class				
	- Maximum W/CM				
	- Minimum Specified Strength, MPa @ Days				
	- Nominal Maximum Aggregate Size, mm				
	- HVSCM Type 1 or 2				
	- Plastic Air Content, %				
	<b>Durability Requirements</b>				
	- Exposure to Sulphate Attack				
	- Alkali Aggregate Reactivity				
<b>Architectural Requirements</b>					
- Colour / Texture					
- Other					
<b>CONTRACTOR REQUIREMENTS</b>	<b>Rate, m<sup>3</sup>/h</b>				
	<b>Quantity, m<sup>3</sup></b>				
	<b>Slump Range, mm</b>				
	<b>Strength @ Age, MPa @ Days</b>				
	<b>Other</b>				
	<b>Specialty Information</b>				
	- Concrete Set, Delay, Normal, Accelerated				
	<b>Method of Placement</b>				
<b>MATERIALS SECTION</b>	<b>Material</b>	<b>Source</b>			
	Cement				
	SCM - Slag				
	SCM - _____				
	Water				
	Fine Agg.				
	Coarse Agg.				
	A.E.A.				
	W.R.				
	S.P.				

Form Submitted By:

Print Name: \_\_\_\_\_ Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Contractor's Representative Receiving Form:

Print Name: \_\_\_\_\_ Signature: \_\_\_\_\_ Date: \_\_\_\_\_

- 1 Introduction
- 2 Sidewalk, Curb & Gutter Evaluation and Inspection
- 3 Asset Management Pavement Selection
- 4 Concrete Bridges
- 5 Sustainability
- 6 Life-Cycle Cost (LCCA) Basis
- 7 Unsprinkable Fill (U-Fill)
- 8 Architectural Concrete
- 9 Concrete Jointing
- 10 Procurement
- 11 Pre-Construction Placement Meetings
- 12 Concrete Construction Procedures
- 13 Transportation of Concrete
- 14 Conveying, Handling, and Finishing Concrete
- 15 Concrete Protection and Curing Requirements
- 16 Measurement, Testing and Acceptance of Concrete
- 17 Project Closeout and Continuous Improvement
- 18 Troubleshooting

1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Plan and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

**NOTES:**

- 1) The “**Concrete Supplier**” provides to the contractor, a valid “**Certificate of Concrete Production Facilities**” as issued by Concrete Ontario (Formerly Ready-mixed Concrete Association of Ontario), as described in CSA A23.1 Table 5.
- 2) All Concrete and materials shall be supplied in conformance to CSA A23.1-04.
- 3) Concrete testing shall electronically incorporate **CMATS™** ([www.cmats.com](http://www.cmats.com)) and shall be used by the testing company.
- 4) Concrete tests not done according to CSA Standards shall not be accepted for any basis of measurement.
- 5) The Owner shall be responsible for all concrete performance when specifying any material proportion(s).

## Appendix F: Checklist for Concrete Pre-Construction Conference



# *Checklist for the Concrete Pre-Construction Conference*

1  
Introduction

2  
Sidewalk,  
Curb & Gutter  
Evaluation  
and Inspection

3  
Asset  
Management  
(MAY)  
Pavement  
Selection

4  
Concrete  
Bridges

5  
Sustainability

6  
Life-Cycle  
Cost (LCCA)  
Analysis

7  
Unsprinkable  
Fill (U-Fill)

8  
Architectural  
Concrete

9  
Concrete  
Jointing

10  
Procurement

11  
Pre-  
Construction  
Placement  
Meetings

12  
Concrete  
Construction  
Procedures

13  
Transportation  
Construction  
of Concrete

14  
Convey,  
Casting,  
Curing and  
Finishing  
Concrete

15  
Concrete  
Protection  
and Curing  
Requirements

16  
Measurement,  
Testing and  
Acceptance of  
Concrete

17  
Project  
Closeout and  
Continuous  
Improvement

18  
Troubleshooting



1	Introduction
2	Sitewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Payment Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC) (U-FCM)
7	Unsprinkled Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre- Construction Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
Appendix	

## 18 Introduction

Pre-construction meetings are of prime importance in planning concrete construction work because many potential problems can be avoided at the right time – before the start of the project when the cost impact is relatively low.

In 1999, the National Ready-mixed Concrete Association (NRMCA) and the American Society of Concrete Contractors (ASCC) joined in a partnership to enhance the quality of concrete construction. This checklist is one of the ongoing initiatives of the partnership.

With permission of the original author, Concrete Ontario (RMCAO) and the Ontario General Contractors Association (OGCA) have reviewed and revised this document for use on Canadian construction projects following the requirements of the most recent CSA A23.1/2 Standard.

The checklist allocates responsibilities and establishes procedures related to concrete construction – subgrade preparation, forming, concrete mix design, necessary equipment, ordering and scheduling materials and operations, placing, consolidating, finishing, jointing, curing and protection, testing and acceptance, as well as safety and environmental issues.

The checklist covers some of the issues that need to be discussed at a pre-construction meeting and is not intended to be all-inclusive.

This checklist is meant to be a guide and is not intended to address all safety issues. Please operate safely and within all the legislations in your area.

## 19



1	Introduction
2	Sidewalk, Curbs & Gutter Evaluation and Inspection
3	Asset Management and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA) Basis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
<b>Appendix</b>	

## Index

- A. Project Information
- B. Construction Process
- C. Concrete Requirements
- D. Ordering and Scheduling Concrete
- E. Environmental Aspects
- F. Quality Control/Assurance
- G. Safety

### References

Canadian Standards Association  
 CSA A23.1  
 CSA A23.2  
 CMATS™ [www.cmats.com](http://www.cmats.com)

1 Introduction

2 Sidewalk Curb & Gutter Evaluation and Inspection

3 Asset Management Plan and Selection

4 Concrete Bridges

5 Sustainability

6 Life-Cycle Cost Analysis (LCCA)

7 Unsprinklable Fill (U-Fill)

8 Architectural Concrete

9 Concrete Jointing

10 Procurement

11 Pre-Construction Meeting

12 Concrete Curing Procedures

13 Transportation and Receiving Concrete

14 Convey, Placing, and Finishing Concrete

15 Concrete Protection and Curing Requirements

16 Measurement, Testing and Acceptance of Concrete

17 Project Closeout and Continuous Improvement

18 Troubleshooting

Appendix

### Sample Checklist for the Concrete Pre-Construction Conference

#### A. Project Information

1. Project name

\_\_\_\_\_

2. Location

\_\_\_\_\_

3. Project start date

\_\_\_\_\_

4. Project completion date

\_\_\_\_\_

5. Project participants

Contact \_\_\_\_\_

Owner \_\_\_\_\_

Architect \_\_\_\_\_

Structural Engineer \_\_\_\_\_

Construction Manager/General Contractor \_\_\_\_\_

Concrete Contractor \_\_\_\_\_

Concrete Supplier \_\_\_\_\_

Concrete Pumping Contractor \_\_\_\_\_

Concrete Finisher \_\_\_\_\_

Testing Laboratory \_\_\_\_\_

Inspection Agency \_\_\_\_\_

Other \_\_\_\_\_

6. Background information about the project

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

7. Unique features of the project

\_\_\_\_\_



1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA) Basis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

---



---



---

8. Distribution of completed checklist

Project Participants \_\_\_\_\_

Others \_\_\_\_\_

**B. Construction Process**

1. Review notes and changes on drawings that may affect construction process

---



---



---

2. Sequence of construction and milestone dates

Foundations \_\_\_\_\_

Walls \_\_\_\_\_

Structural slabs \_\_\_\_\_

Slab-on-grade interior \_\_\_\_\_

Slab-on-grade exterior \_\_\_\_\_

3. Construction/acceptance of base/subgrade, compaction, elevation. Responsibility for:

Providing base and subgrade elevations to contractors

---



---



---

Stability of the base and or subgrade under construction traffic

---



---



---

Protecting the base and/or subgrade from water damage

---

1 Introduction	
2 Sidewalk Curb & Gutter Evaluation and Inspection	
3 Asset Management Pavement Selection	<hr/> <hr/> <hr/>
4 Concrete Bridges	<p>Compacting and final grading of the base and subgrade after all plumbing installations are complete</p>
5 Sustainability	<hr/> <hr/> <hr/>
6 Life-Cycle Cost (LCCA)	<hr/> <hr/> <hr/>
7 Unshrinkable Fill (U-Fill)	<p>Location of electrical lines (conduit)</p> <p>In subgrade trenched and backfilled with rock</p>
8 Architectural Concrete	<hr/> <p>In rock subgrade</p> <hr/>
9 Concrete Jointing	<p>Protection from truck traffic if required</p> <hr/>
10 Procurement	<p>4. Responsibility for site access roads and their maintenance</p> <hr/> <hr/>
11 Pre- Construction Placement Meetings	<p>5. Responsibility for available space for pumping operations if required</p> <p>Access for two trucks to pump, one on each side</p>
12 Concrete Curing Procedures	<hr/> <p>Staging area for testing and slump adjustment</p> <hr/>
13 Transportation and Receiving Concrete	<hr/> <p>6. Person responsible for directing trucks to pump or placement area</p> <hr/>
14 Convey, Placing, and Finishing Concrete	<hr/> <p>7. Responsibility for directing/backing up trucks</p> <hr/>
15 Concrete Protection and Curing Requirements	<hr/> <p>8. Responsibility for power, lighting, water, and water pressure during placing and finishing</p> <hr/>
16 Measurement, Testing and Acceptance of Concrete	<hr/> <p>9. Responsibility for controlling the ambient temperatures (subgrade, forms, and air)</p> <hr/>
17 Project Closeout and Continuous Improvement	
18 Troubleshooting	

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation Concrete
14	Conveying, Lifting and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

---

## 10. Forms

Form sizes, types

---

Lifting equipment required

---

Form materials, accessories

---

Review location of reinforcement, embedded items, waterstops, drains, openings, openings for frames, etc.

---

Scheduling form erection and removal correlated to reinforcing and concreting operations

---

Responsibility for installation and inspection

Reinforcement

---

Embedded items

---

Waterstops

---

Drains

---

Opening frames

---

Responsibility for form inspections

Preliminary – prior to rebar placement

---

Semifinal – with rebars, embedded items, waterstops and drains

---

**Note:** Reinforcement inspection must include:  
 Location and spacing to allow access for vibration equipment and proper coverage  
 Spacing of reinforcement in relation to aggregate size



1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Final – before placing concrete

---

11. Vapor retarder or vapor barrier membrane

Type of membrane

---

Location of membrane relative to subgrade

---

Effect on curling

---

Effect on bonding of applied floor coverings

---

Basis of acceptance for installation of moisture sensitive flooring materials (wood, carpet, tiles) on the slab

Moisture emission requirements for flooring materials to be installed

---

Responsibility for

Testing and reporting of the test results

---

Acceptance of the slab

---

12. Placing concrete: equipment and procedures

Deposit from truck

---

—

---

Buggy

---

Belt conveyor

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Placing, Consolidating and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

---



---

Bucket placement

---



---

Pumping

---



---

Other

---



---

13. Consolidation of concrete: equipment and procedures

Vibrators

---



---

Vibratory screeds (surface vibrators)

---



---

Back up equipment

---



---

Power source

---



---

Other

1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

14. Responsibility for inspection of placing and consolidation of concrete

15. Ventilation in enclosed spaces

Type of test required

Responsibility for ventilation:

During placement

During finishing

16. Strike off technique

Hand strike off

Vibratory screed

Laser screed

Other

17. Finishing

Types of finishes

- Area 1

- Area 2

- Area 3

- Area 4



1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA) Analysis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction, Placement Meetings
12	Concrete Construction Procedures
13	Transportation and Concrete
14	Conveying, Laying, Finishing and Formwork
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Special materials for finishes

\_\_\_\_\_

Dry-shake hardener

Rate of application

\_\_\_\_\_

Procedure to install

\_\_\_\_\_

Tools and equipment required

\_\_\_\_\_

Back up tools and equipment required

\_\_\_\_\_

18. Specified tolerances for

Vertical concrete surfaces:

Plumbness \_\_\_\_\_

Dimensions \_\_\_\_\_

Thickness \_\_\_\_\_

Texture \_\_\_\_\_

Colour \_\_\_\_\_

Acceptable variances \_\_\_\_\_

Surface defects \_\_\_\_\_

Others \_\_\_\_\_

Slabs-on-grade and floors

Flatness/levelness \_\_\_\_\_

Dimensions \_\_\_\_\_

Thickness \_\_\_\_\_

Texture \_\_\_\_\_

Colour \_\_\_\_\_

Acceptable variances \_\_\_\_\_

Surface defects \_\_\_\_\_

1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Plan and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Joint spacing \_\_\_\_\_  
 Others \_\_\_\_\_

Elevated slabs

Flatness/levelness \_\_\_\_\_

Dimensions \_\_\_\_\_

Thickness \_\_\_\_\_

How it will be determined \_\_\_\_\_

Texture \_\_\_\_\_

Colour \_\_\_\_\_

Acceptable variances \_\_\_\_\_

Surface defects \_\_\_\_\_

Others \_\_\_\_\_

Procedures for measuring tolerances (when and how)

\_\_\_\_\_

Review specifications for possible conflict between the concrete installer and other trades

\_\_\_\_\_

\_\_\_\_\_

Review specifications for conflict between the surface profile provided by the concrete installer and the surface profile required by installer of finished material

\_\_\_\_\_

\_\_\_\_\_

Responsibility for

Reporting F-numbers to concrete contractor \_\_\_\_\_

Accepting floors \_\_\_\_\_

Measuring tolerances \_\_\_\_\_

Repairing "air or bug holes" in vertical surfaces \_\_\_\_\_

Removing curing compounds prior to application of sealers \_\_\_\_\_

19. Jointing

Review/verification of contraction, isolation, and construction joint layout plans

Structures (walls)                      Yes                      No







Locations \_\_\_\_\_

22. Protection of concrete

Roof and walls Yes No

Specify \_\_\_\_\_

Floors coverings Yes No

Specify \_\_\_\_\_

Floor protection Yes No

Specify age/strength of floor prior to the use of floor by

Foot traffic \_\_\_\_\_

Pneumatic tire traffic \_\_\_\_\_

Hard wheel traffic \_\_\_\_\_

Construction traffic \_\_\_\_\_

Specify age/strength of floor when

Equipment is installed \_\_\_\_\_

Racks are erected \_\_\_\_\_

23. Responsibility for storage areas and site security

\_\_\_\_\_  
 \_\_\_\_\_

24. Form removal

What is the minimum strength requirement for form removal? \_\_\_\_\_ MPa

What formal report is required before form removal?

\_\_\_\_\_

Type of field or in-place strength tests (if used) and evaluation criteria?

\_\_\_\_\_

Name(s) of personnel authorized to approve form removal

\_\_\_\_\_

25. Procedures for hot weather concreting

\_\_\_\_\_  
 \_\_\_\_\_

26. Procedures for cold weather concreting

1	Introduction
2	Stipendiary Curt & Gutter Evaluation and Inspection
3	Asset Management Payment Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC) (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre- Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

**C. Concrete Requirements**

1. Concrete mix designations

All concrete materials and supply shall conform to CSA A23.1

2. Concrete mix designs submittal

Have mix submissions been received	Yes	No
Prescriptive requirements	Yes	No
Performance requirements	Yes	No

Comments: \_\_\_\_\_  
\_\_\_\_\_

Copies of the mix submittal provided to

Owner	Yes	No
Architect	Yes	No
Structural engineer	Yes	No
Construction manager or general contractor	Yes	No
Concrete contractor	Yes	No
Concrete pumping contractor	Yes	No
Concrete finisher	Yes	No
Testing laboratory	Yes	No
Inspection agency	Yes	No

3. Additional mix designs required      Yes      No

Specify \_\_\_\_\_

4. Consideration for aggregates other than CSA – prescriptive specification only

Gradation \_\_\_\_\_  
\_\_\_\_\_

Sand requirements \_\_\_\_\_  
\_\_\_\_\_

5. Pumped concrete      Yes      No



6. High early strength      Yes      No      Strength required \_\_\_\_\_ MPa at age \_\_\_\_\_
7. Lightweight concrete      Yes      No
8. Other      Yes      No

Comments \_\_\_\_\_

9. Concrete supply

RMCAO Production Facility Certification received      Yes      No – do not proceed with supply

Primary Plant \_\_\_\_\_ Backup Plant \_\_\_\_\_

Plant Contacts \_\_\_\_\_ Phone Number \_\_\_\_\_

Revolutions or time limits for mixing concrete \_\_\_\_\_

**Note:** Refer to CSA A23.1

10. Review project specifications for conflicts in performance requirements (compressive/flexural strength, durability, shrinkage, curling and water-cementitious materials ratio, water content, slump, air content)

\_\_\_\_\_

\_\_\_\_\_

11. Other performance ingredient materials required

- |                                     |     |    |
|-------------------------------------|-----|----|
| Mid range water reducing admixture  | Yes | No |
| High range water reducing admixture | Yes | No |
| Non-chloride accelerator            | Yes | No |
| Corrosion inhibitors                | Yes | No |
| Fly ash                             | Yes | No |
| GGBF slag                           | Yes | No |
| Silica fume                         | Yes | No |
| Fibres                              | Yes | No |
| Colour                              | Yes | No |
| Other                               | Yes | No |

**Note 1** Batching all ingredient materials at the plant ensures best quality control of concrete.

Jobsite modifications to mixture shall be documented on the delivery tickets.

**Note 2:** Add appendices with the approved concrete mix design submittals

12. Project specification requirements for air content

1	Introduction
2	Shrinkage, Curing, and Evaluation and Inspection
3	Asset Management Plan and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Planning Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Normal weight air-entrained concrete (not recommended if floors require a machine troweled finish, but recommended for all exterior work)

Comments \_\_\_\_\_  
 \_\_\_\_\_

Are adjustments to air content allowed on the jobsite    Yes                  No

Comments \_\_\_\_\_  
 \_\_\_\_\_

Air-entrained lightweight concrete for interior slabs

Comments \_\_\_\_\_  
 \_\_\_\_\_

Other requirements

Comments \_\_\_\_\_  
 \_\_\_\_\_

13. Project specification requirements for slump limits

Conventional concrete                  Max. \_\_\_\_\_                  Min. \_\_\_\_\_

Pumped concrete                        Max. \_\_\_\_\_                  Min. \_\_\_\_\_

Comments \_\_\_\_\_  
 \_\_\_\_\_

Plasticized concrete                  Max. \_\_\_\_\_                  Min. \_\_\_\_\_

Comments \_\_\_\_\_  
 \_\_\_\_\_

Other:    Max. \_\_\_\_\_                  Min. \_\_\_\_\_

Comments \_\_\_\_\_  
 \_\_\_\_\_

14. Jobsite slump adjustments

Responsibility for:

Making/permitting jobsite slump adjustments \_\_\_\_\_

Recording of adjusted batch \_\_\_\_\_

Materials permitted to adjust the slump:

Water                                  Mid-range water reducer                  High-range water reducer

Procedure to be followed and limitations that apply to jobsite slump adjustment (maximum amount, subsequent mixing, sampling of the load) \_\_\_\_\_  
 \_\_\_\_\_

15. Project specification requirements for temperature

Required temperature of concrete as delivered: \_\_\_\_\_ Max: \_\_\_\_\_ °C  
 Min: \_\_\_\_\_ °C

Responsible person for requiring and approving special measures to meet concrete temperatures such as hot water, heated aggregate, cold water, ice, liquid nitrogen  
 \_\_\_\_\_  
 \_\_\_\_\_

Outline procedure to be followed and limitations that apply for measurement of concrete temperature and acceptance of concrete at the jobsite  
 \_\_\_\_\_  
 \_\_\_\_\_

16. Project specification requirements for concrete delivery time – 120 minutes as per CSA A23.1/2

Other \_\_\_\_\_

17. Project specification requirements for lightweight concrete

Maximum unit weight \_\_\_\_\_  
 Slump \_\_\_\_\_  
 Air content \_\_\_\_\_  
 Pumping operations \_\_\_\_\_

18. Architectural concrete

<u>Finish details</u>	<u>Location</u>
Exposed aggregate _____	_____
Smooth finish _____	_____
Rubbed finish _____	_____
Colored _____	_____
Imprinted _____	_____
Details (grouted joints, textured)	
Special materials	
Cement _____	



1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Planning and Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Aggregates \_\_\_\_\_

Water \_\_\_\_\_

Admixtures \_\_\_\_\_

Sealers \_\_\_\_\_

Release agents \_\_\_\_\_

Architectural samples or mock-ups

Location \_\_\_\_\_

Preservation \_\_\_\_\_

Responsibility for acceptance \_\_\_\_\_

Repair methods \_\_\_\_\_

**D. Ordering and Scheduling Concrete**

1. Person(s) responsible for ordering concrete (concrete must be ordered by mix design code)  
\_\_\_\_\_
2. Minimum time notice required for most placements  
\_\_\_\_\_
3. Define large and specialty orders  
\_\_\_\_\_
4. Minimum notice required for large and specialty placements  
\_\_\_\_\_
5. Procedure for handling will call orders  
\_\_\_\_\_
6. Procedure for handling revised orders  
\_\_\_\_\_
7. Contact name(s) and phone number(s) for last-minute cancellations  
Supplier \_\_\_\_\_  
Concrete contractor \_\_\_\_\_  
Construction manager or general contractor \_\_\_\_\_
8. Person on jobsite responsible for reviewing delivery ticket prior to placement  
\_\_\_\_\_



1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA) Basis
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Lifting, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

9. Regular hours are between \_\_\_\_\_ am and \_\_\_\_\_ pm  
 Regular workdays are \_\_\_\_\_ through \_\_\_\_\_ not including designated holidays

10. Are there any anticipated holiday and/or overtime placements?  Yes  No  
 Comments \_\_\_\_\_

11. Delivery schedules  
 Location of placement \_\_\_\_\_  
 Anticipated placement sizes \_\_\_\_\_ cubic metres  
 Minimum load size \_\_\_\_\_ cubic metres  
 What are anticipated placement rates? \_\_\_\_\_ cubic metres/hour  
 Approximate placements dates \_\_\_\_\_  
 Inclement weather plant capability \_\_\_\_\_

12. Concrete delivery  
 Acceptance/rejection responsibility \_\_\_\_\_  
 Any traffic restrictions at or near the jobsite                      Yes                      No  
 Comments \_\_\_\_\_  
 Any restrictions on entrance to or exits from jobsite            Yes                      No  
 Comments \_\_\_\_\_  
 Other Items  
 Comments \_\_\_\_\_

13. Trucks:  
 Number of trucks \_\_\_\_\_  
 Interval schedule (turn around time) \_\_\_\_\_

**E. Environmental Aspects**

1. Environmentally sensitive areas around the project:            Yes                      No  
 Comments \_\_\_\_\_  
 2. Contractor identified concrete wash out area at the jobsite \_\_\_\_\_  
 3. Responsibility for clean up of the wash out areas \_\_\_\_\_  
 4. Person responsible for directing trucks to the wash out area \_\_\_\_\_  
 5. Are spill response kits available on site?                              Yes                      No

1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

- Comments \_\_\_\_\_
6. On-site emergency contact person \_\_\_\_\_
  7. Responsibility for disposal of curing compounds \_\_\_\_\_
  8. Other items \_\_\_\_\_

**F. Quality Control/Assurance**

1. CSA/CCIL Accreditation requirements for laboratory \_\_\_\_\_
2. Certification requirements for
  - Laboratory testing technicians name(s)  
CSA Concrete Laboratory Testing Technician \_\_\_\_\_
  - Field testing technicians name(s)  
ACI Grade I Certified \_\_\_\_\_
  - CSA Certified Concrete Tester \_\_\_\_\_
  - CCIL Type J Certified Concrete Tester \_\_\_\_\_
3. Advance notice for scheduling testing personnel \_\_\_\_\_
4. Procedures for verification of specified requirements
  - Strength tests \_\_\_\_\_
  - Other \_\_\_\_\_

**F.1. Concrete Sampling and Testing Requirements**

1. Sampling frequency \_\_\_\_\_
2. Sampling location
  - Point of discharge \_\_\_\_\_
  - Point of placement \_\_\_\_\_
  - Comments (agreement on sampling location) \_\_\_\_\_
3. Tests performed on each sample
  - Slump \_\_\_\_\_
  - Temperature \_\_\_\_\_
  - Density (unit weight) \_\_\_\_\_
  - Air content \_\_\_\_\_
  - Compressive strength \_\_\_\_\_
  - Flexural strength \_\_\_\_\_



1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction, Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Placing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Other \_\_\_\_\_

4. Cylinder size for compressive strength test

100X200 mm                      150x300 mm

5. Beam size for flexural strength test

150X150 mm                      Length: refer to CSA A23.2 – 3C

Other size \_\_\_\_\_

**Note:** If beam breaks are low, compare acceptable concrete with suspect concrete by coring

6. Number of cylinders per sample \_\_\_\_\_

(hardened cylinder weight must be recorded on concrete strength reports)

7. Number of beams per sample \_\_\_\_\_

8. Number of cylinders/beams to be cured \_\_\_\_\_ Field? \_\_\_\_\_ Lab?

\_\_\_\_\_

9. At what ages are cylinders/beams to be tested? \_\_\_\_\_

10. Number of cylinders/beams per test (minimum 2) \_\_\_\_\_

11. Are reserve cylinders/beams required?                      Yes \_\_\_\_\_ No      How many?

12. Frequency of yield tests and compliance checks (three-load average of unit weight)

\_\_\_\_\_

**F.2. Test Cylinder Storage and Transportation**

1. As per CSA A23.2

**F.3. Acceptance/Rejection of Fresh Concrete**

1. Who has the authority to accept/reject a concrete delivery?

\_\_\_\_\_

**Note:** A second person may be designated as having the authority for FINAL rejection of a concrete delivery

2. What criteria will be used to reject concrete?

Slump \_\_\_\_\_

Air content \_\_\_\_\_

Unit weight \_\_\_\_\_

Temperature \_\_\_\_\_



Load testing in accordance with CSA A23.1

Other \_\_\_\_\_

Remove and replace

Comments \_\_\_\_\_

3. How do the project specifications handle additional testing? \_\_\_\_\_

\_\_\_\_\_

If additional testing is required, \_\_\_\_\_ will notify the following parties

\_\_\_\_\_  
 \_\_\_\_\_

4. What investigative procedures will be used?

\_\_\_\_\_  
 \_\_\_\_\_

5. Who will be employed to conduct additional testing and who employs them?

\_\_\_\_\_  
 \_\_\_\_\_

6. How will the test results be evaluated?

\_\_\_\_\_  
 \_\_\_\_\_

7. Who will pay the costs of additional testing?

Specified strength confirmed \_\_\_\_\_

Specified strength not confirmed \_\_\_\_\_

**G. Safety**

1. Personal protective equipment required:

Hard hats	Yes	No
Safety boots	Yes	No
Eye protection	Yes	No
Safety vests	Yes	No
Specific protective clothing	Yes	No
Respirators	Yes	No
Other		



1	Introduction
2	Spewalk Curt & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre- Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Receiving Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

2. Responsibility for

First aid supplies \_\_\_\_\_

Providing and maintaining information such as Material Safety Data Sheets (MSDS) and Spills  
Response Plans at the jobsite \_\_\_\_\_

Job site Ingress and Egress \_\_\_\_\_

Fall protection \_\_\_\_\_

Safety inspections \_\_\_\_\_

Signalers \_\_\_\_\_

Safety meetings \_\_\_\_\_

3. Emergency contacts \_\_\_\_\_

\_\_\_\_\_

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

## Appendix G: CCIL Concrete Certification Program

The Ready-mixed Concrete Association of Ontario (RMCAO) and the Canadian Council of Independent Laboratories (CCIL) in conjunction with the major owner stakeholder, have created a new concrete certification program to improve the quality of concrete field testing of both CSA and ACI certified field personnel.

While the draft program is currently under review by the various industry stakeholders, RMCAO is very encouraged by achievements that have already been made. The draft CCIL Concrete Certification Program has been modelled on the existing CCIL Asphalt and Aggregate certification programs and will include two new CCIL certification classes for concrete:

- *Type H* – Concrete Compressive Strength Testing
- *Type J* – Concrete Field Testing

The *Type H* certification will be strictly for concrete testing labs only and will be based upon the laboratory holding current CSA lab certification and the lab successfully participating in concrete strength correlation program (based on the current MTO correlation program).

The *Type J* certification will be for all concrete field testing personnel and will be based upon the technician holding either CSA or ACI certification. This class of certification will apply to both lab technicians and concrete industry personnel alike.

The CCIL Concrete Certification Program will be managed by a program manager hired directly by CCIL that reports to a Concrete Administration Committee of nine members. The proposed Administration Committee structure is as follows:

- 3 Representatives from CCIL (including the Chair)
- 3 Representatives from RMCAO
- 1 Representative from the Ministry of Transportation of Ontario (MTO)
- 1 Representative from the Municipal Engineers Association (MEA)
- 1 Representative from the structural consulting engineering community

The proposed certification program represents a huge opportunity for all the industry stakeholders to work together and in a positive and constructive manner to ensure that all concrete testing is performed to the applicable CSA standards. This program also recognizes the importance and value of the existing CSA and ACI certification programs while adding greater accountability to all components of the practice of testing concrete.

For more information, please contact Bart Kanters, P.Eng. (905) 507-1122 or [bkanters@rmcao.org](mailto:bkanters@rmcao.org)

## Appendix H: Checklist for Concrete Pumping



# Checklist for Pumping Ready Mixed Concrete<sup>©</sup>

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

## Introduction

20 This short Checklist for Concrete Pumping was developed by National Ready-mixed Concrete Association (NRMCA), American Society of Concrete Contractors (ASCC) and the American Concrete Pumping Association (ACPA). With permission of the original author, Concrete Ontario (RMCAO) and the Ontario General Contractors Association (OGCA) have reviewed and revised this document for use on Canadian construction projects following the requirements of the most recent CSA A23.1/2.

The intent of this document is to identify details of the process of pumping concrete prior to the start of the placement so that all impacted parties are aware of the issues related to the construction specification, equipment and schedules, responsible persons and jobsite safety.

The presumption is that on larger projects the concrete construction team has been through a pre-construction conference and has addressed the pertinent items in the **Checklist for Concrete Pre-Construction Conference** and those items are excluded from this document. This document can be included in a broader pre-construction meeting agenda.

This checklist is not intended to be all inclusive of the items that need to be considered and depending on a specific project many items regarding specification requirements, testing details, construction logistics and jobsite safety may need to be addressed in greater detail than outlined in this document. Many of these items will be critical to the success of the project and should be discussed and agreed upon prior to the placement of concrete with appropriate notification to the owner and his representative.





1 Introduction  
 2 Sidewalk Curb & Gutter Evaluation and Inspection  
 3 Asset Management Plan and Pavement Selection  
 4 Concrete Bridges  
 5 Sustainability  
 6 Life-Cycle Cost (LCCA)  
 7 Unsprinklable Fill (U-Fill)  
 8 Architectural Concrete  
 9 Concrete Jointing  
 10 Procurement  
 11 Pre-Construction Placement Meetings  
 12 Concrete Placement Procedures  
 13 Transportation and Receiving Concrete  
 14 Convey, Placing, and Finishing Concrete  
 15 Concrete Protection and Curing Requirements  
 16 Measurement, Testing and Acceptance of Concrete  
 17 Project Closeout and Continuous Improvement  
 18 Troubleshooting

### Checklist for Concrete Pumping

Project: \_\_\_\_\_

Location: \_\_\_\_\_

Directions: \_\_\_\_\_

(Map on back)

#### 1. Contacts

Who	Name	Phone	Mobile	Fax	E-Mail
C. Contractor					
RMC Supplier					
Pump Contractor					

#### 2. General Conditions

Start Time	Pump:	am/pm	Concrete:	am/pm
Placement Location	<input type="checkbox"/> Slabs	<input type="checkbox"/> Walls	<input type="checkbox"/> Footings	Other
Placement Rate (m <sup>3</sup> /hr.)		Volume (m <sup>3</sup> )		
Type of Pump	<input type="checkbox"/> Regular	<input type="checkbox"/> Z-Boom	<input type="checkbox"/> Telescoping	<input type="checkbox"/> Trailer
Size of Pump (m)		Pipeline dia, mm		
Pumping Distance (m)	Vertical		Horizontal	
Slump/Air Spec	<input type="checkbox"/> Point of Discharge		<input type="checkbox"/> Point of Placement	
Testing	<input type="checkbox"/> Point of Discharge		<input type="checkbox"/> Point of Placement	
Priming Agent	<input type="checkbox"/> Grout		<input type="checkbox"/> Slick Pack	

#### 3. Concrete Mixture

Strength (MPa)	28 days:		Other _____:	
Max Size of Aggregate (mm)		(no larger than 1/3 pipeline diameter)		
Density (kg/m <sup>3</sup> )		Lightweight	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Slump (mm)		Air (%)		
Water Reducer	<input type="checkbox"/> Regular	<input type="checkbox"/> MRWR	<input type="checkbox"/> HRWR	
Fibres	<input type="checkbox"/> Yes	<input type="checkbox"/> No		
Special Requirements				
Set Time Requirements (hr.)	Initial:		Final:	
Water Addition Permitted	<input type="checkbox"/> Yes	<input type="checkbox"/> No		

#### 4. Jobsite/Safety

Wash Out Area	<input type="checkbox"/> Yes	<input type="checkbox"/> No	Location: _____
Power Lines	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Safe Set Up Area	<input type="checkbox"/> Yes	<input type="checkbox"/> No	Restrictions: _____

<b>Clean Water Available for Washout</b>	<input type="checkbox"/> Yes	<input type="checkbox"/> No	

**5. Notes**

---



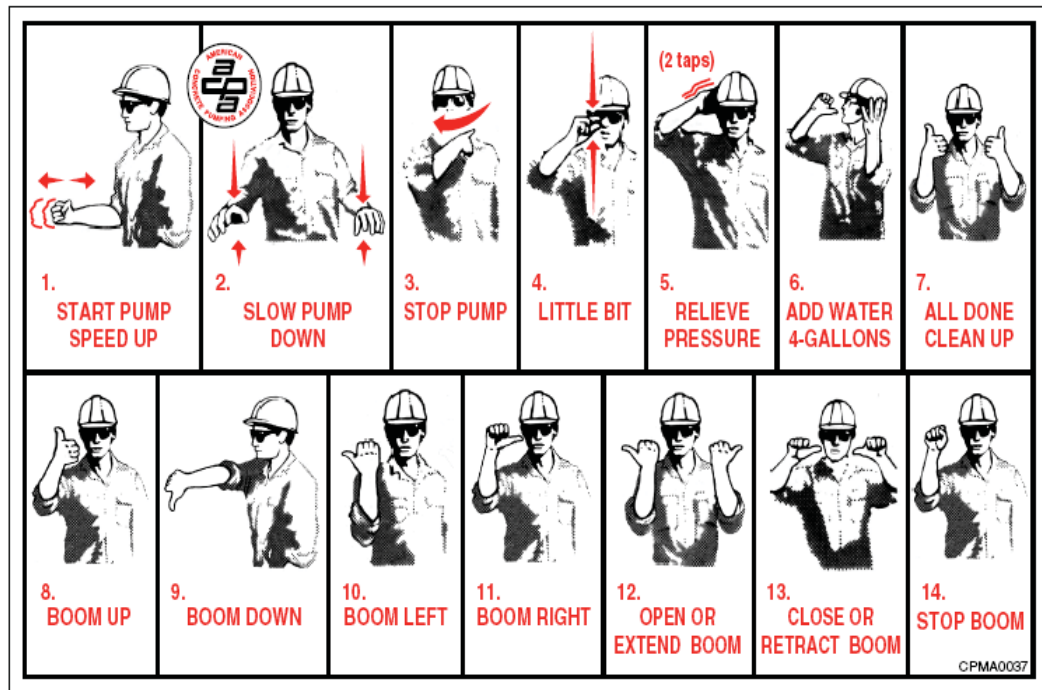
---



---

Courtesy ACPA

**CONCRETE PUMP OPERATORS HAND SIGNALS**



1	Introduction
2	Shrinkage, Curing & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Placement Procedures
13	Transportation and Recreational Concrete
14	Convey, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

## Appendix I: Speciality Concrete Applications

While special concrete performance can be defined in an infinite number of ways, some of the more common examples of specialty performance include the following descriptions. Always consult with your concrete supplier and concrete sub-contractors.

- Self Consolidating Concrete (SCC)** – Concrete with extremely high slump and flow characteristics that can be placed with little or no concrete consolidation. This concrete offers advantages to the owner and contractor where there is congested concrete reinforcing steel or restricting formwork that prevents traditional consolidation; improved architectural appearance of the concrete surface, significantly reduced labour and placement costs due to the extreme flow characteristics; and resistance to concrete segregation under adverse site conditions. Caution must also be exercised when first using this product due to its high flowability and fluidity. The formwork must have a high quality of surface finish since the concrete will mirror any imperfections that exist. The contractor must also ensure that formwork is tight to prevent leakage at form panel edges and they must account for the additional formwork pressures initially generated by the product
- Winter Concrete** – Concrete that has been proportioned to provide normal or improved concrete set characteristics during cold weather construction periods. The objective is to modify the mix design to offset the extended concrete setting period that results from lower air, concrete and formwork temperatures encountered in winter months.
- High Early Concrete** – Concrete that provides a strength gain at earlier times than normal set concrete. High early strengths achieved at prescribed times of one, three or seven days can offer the opportunity to “fly” forms faster resulting in a faster scheduling for building construction and labour and equipment. This concrete may also apply to a faster set time concrete that may be applicable in areas where there are noise by-laws or concerns, and also other labour issues such as cost and equipment availability.
- Fibre Reinforced Concrete** – Synthetic or steel fibres can offer a range of benefits to the owner. Sometimes referred to micro, macro and structural fibres they can offer greater resistance to plastic shrinkage cracking of the concrete as well as other advantages.
- C-XL Concrete** – New to CSA A23.1-04, the C-XL designation is for structurally reinforced concrete exposed to chlorides or other severe environments with or without freezing and thawing conditions, to provide concrete that would meet higher durability performance expectations than C-1, A-1 or S-1 classes of exposure as per CSA A23.1. There is a chloride ion penetrability limit of <1000 coulombs within 56 d that is generally used as a pre-qualification to concrete supply.
- LEED™ Concrete** – Leadership in Energy and Environmental Design (LEED™) is a voluntary, market-based rating system for defining what elements make a building “green” and to quantify how “green” a building is in comparison to another building. LEED™ is based on accepted energy and environmental principles and strikes a balance between known effective practices and emerging concepts. It encourages a whole building approach over a building's life cycle that guides a collaborative and integrated design and construction process.
- Decorative Concrete** – Concrete that has been designed to meet visual or other aesthetic performance characteristics such as colour, texture, finish or pattern. These performance concretes are concerned with concrete relating to overall mix consistency, flow and consolidation, and finish and uniformity.



- **Surface Hardened Concrete** – Typically concrete floors that require a “hardener” to be applied need a concrete mix that has been designed so the concrete can easily accept the “hardener” for its application to be monolithic. Several things must be carefully considered by the concrete supplier, such as water content, SCMs (i.e. fly ash or slag) for available surface moisture, set and finish time, and entrained air content. Concrete to receive a surface hardener should not be air entrained.
- **High Volume Supplementary Cementing Materials Concrete (HVSCM 1 & 2)** – CSA A23.1-04 has included these designations for concrete that contains a level of supplementary cementing materials above that typically used for normal construction.

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Place, and Finish Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting



## Appendix J: Summary of CSA Exposure Classes



T E C H N I C A L   S P E C I F I C A T I O N S

# Concrete Exposure Classes



# Power of Concrete

Determination of the minimum concrete performance properties is based upon identifying the following key requirements:

- **Applicable Exposure Conditions** – The designer must assess the environmental conditions that the concrete will be exposed to during its service life. Direct input is also required from the owner regarding possible future uses since they can significantly affect the exposure class selection.
- **Structural Requirements** – The designer must determine the minimum concrete properties required to meet the applicable loading conditions.
- **Architectural Requirements** – The designer must consider the effects of selecting various architectural finishes on concrete material properties.
- **Minimum Durability Requirements** – Based upon the designer's assessment of the exposure conditions, the CSA A23.1 standard sets minimum concrete properties.

In cases where these various factors result in differing material properties, the designer must select the most stringent requirement as the minimum concrete performance requirement.

CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Tables 1 – 4, outline the minimum durability requirements.



1 Introduction

2 Sidewalk, Curb & Gutter Evaluation and Inspection

3 Asset Management Pavement Selection

4 Concrete Bridges

5 Sustainability

6 Life-Cycle Cost Analysis (LCCA)

7 Unsprinkable Fill (U-Fill)

8 Architectural Concrete

9 Concrete Jointing

10 Procurement

11 Pre-Construction Meetings

12 Concrete Placement Procedures

13 Transportation and Receiving Concrete

14 Convey, Placing, and Finishing Concrete

15 Concrete Protection and Curing Requirements

16 Measurement, Testing and Acceptance of Concrete

17 Project Closeout and Continuous Improvement

18 Troubleshooting

Appendix

CSA A23.1 – TABLE 1

**Definitions of C, F, N, A, and S exposure classes**

(See Clauses 4.1.1.1.1, 4.1.1.5, 4.4.4.1.1.1, 4.4.4.1.1.2, 6.6.7.5.1, 8.4.1.2 and Tables 2 and 12.)

C-XL	Structurally reinforced concrete exposed to chlorides or other severe environments with or without freezing and thawing conditions, with higher durability performance expectations than the C-1, A-1 or S-1 classes.
C-1	Structurally reinforced concrete exposed to chlorides with or without freezing and thawing conditions. Examples: bridge decks, parking decks and ramps, portions of marine structures located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools.
C-2	Non-structurally reinforced (i.e. plain) concrete exposed to chlorides and freezing and thawing. Examples: garage floors, porches, steps, pavements, sidewalks, curbs, and gutters.
C-3	Continuously submerged concrete exposed to chlorides but not to freezing and thawing. Examples: underwater portions of marine structures.
C-4	Non-structurally reinforced concrete exposed to chlorides but not to freezing and thawing. Examples: underground parking slabs on grade.
F-1	Concrete exposed to freezing and thawing in a saturated condition but not to chlorides. Examples: pool decks, patios, tennis courts, freshwater pools, and freshwater control structures.
F-2	Concrete in an unsaturated condition exposed to freezing and thawing but not to chlorides. Examples: exterior walls and columns.
N	Concrete not exposed to chlorides nor to freezing and thawing. Examples: footings and interior slabs, walls and columns.
A-1	Structurally reinforced concrete exposed to severe manure and/or silage gases, with or without freeze-thaw exposure. Concrete exposed to the vapour above municipal sewage or industrial effluent, where hydrogen sulphide gas may be generated. Examples: reinforced beams, slabs and columns over manure pits and silos, canals, pig slats, access holes, enclosed chambers, and pipes that are partially filled with effluents.
A-2	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure. Examples: reinforced walls in exterior manure tanks, silos and feed bunkers, exterior slabs.
A-3	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure in a continuously submerged condition. Concrete continuously submerged in municipal or industrial effluents. Examples: interior gutter walls, beams, slabs and columns, sewage pipes that are continuously full (e.g., force mains), and submerged portions of sewage treatment structures.
A-4	Non-structurally-reinforced concrete exposed to moderate manure and/or silage gases and liquids, without freeze-thaw exposure. Examples: interior slabs on grade.
S-1	Concrete subjected to very severe sulphate exposure (Tables 2 and 3).
S-2	Concrete subjected to severe sulphate exposure (Tables 2 and 3).
S-3	Concrete subjected to moderate sulphate exposure (Tables 2 and 3).

Notes:

1. **"C" classes pertain to chloride exposure.**
2. "F" classes pertain to freezing and thawing exposure without chlorides.
3. "N" class is exposed to neither chlorides nor freezing and thawing.
4. "A" class pertains to agricultural, municipal or industrial projects exposed to human or animal wastes.
5. All classes of concrete, exposed to sulphates, shall comply with the minimum requirements of "S" class noted in Tables 2 and 3.

1	Introduction
2	Shrinkage, Cracks & Gutter Evaluation and Inspection
3	Asset Management Plan and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Reception of Concrete
14	Conveying, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

CSA A23.1 – TABLE 2

**Definitions of C, F, N, R, S and A classes of exposure**

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6, 4.1.2.1, 4.3.1, 7.4.1.1, 8.8.3, and 8.8.6.1, and Table 1.)

Requirements for specifying concrete							
Class of exposure *	Maximum water-to-cementing materials ratio †	Minimum specified compressive strength (MPa) and age (d) at test ‡	Air content category as per Table 4	Curing Type (see Table 20)			Chloride ion penetrability test requirements and age at test ‡
				Normal Concrete	HVSCM 1	HVSCM 2	
C-XL	0.4	50 within 56 d	1 or 2§	3	3	3	< 1,000 coulombs within 56 d
C-1 or A-1	0.40	35 at 28 d	1 or 2§	2	3	2	< 1,500 coulombs within 56 d
C-2 or A-2	0.45	32 at 28 d	1	2	2	2	
C-3 or A-3	0.50	30 at 28 d	2	1	2	2	
C-4** or A-4	0.55	25 at 28 d	2	1	2	2	
F-1	0.50	30 at 28 d	1	2	3	2	
F-2	0.55	25 at 28 d	2††	1	2	2	
N ††	For structural design	For structural design	None	1	2	2	
S-1	0.40	35 at 56 d	2	2	3	2	
S-2	0.45	32 at 56 d	2	2	3	2	
S-3	0.50	30 at 56 d	2	1	2	2	

\* See Table 1 for description of classes of exposure

† The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementing materials ratio. The water-to-cementing materials ratio shall not be exceeded for a given class of exposure.

‡ In accordance with ASTM C 1202. An age different from that indicated may be specified by the owner. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, but without calcium nitrite, shall be prequalified to meet the requirements for the permeability index in his Table.

§ Use Category 1 for concrete exposed to freezing and thawing. Use air content Category 2 for concrete not exposed to freezing and thawing.

\*\* For class of exposure C-4, the requirement for air entrainment should be waived when a steel trowelled finish is required. The addition of supplementary cementing materials may be used to provide reduced permeability in the long term, if that is required.

†† Interior ice rink slabs and freezer slabs with a steel trowelled finish have been found to perform satisfactory without entrained air.

‡‡ See Clause 8.12 for concrete mixes for concrete floors.

**CSA A23.1 TABLE 3**

<b>Additional requirements for concrete subjected to sulphate attack*</b>							
(See Clauses 4.1.1.1.1, 4.1.1.6.2, 4.1.1.6.3, Tables 1 and 6, and Annex L)							
Class of exposure	Degree of exposure	Water soluble sulphate (SO <sub>4</sub> ) † in soil sample, %	Sulphate (SO <sub>4</sub> ) in groundwater sample, mg/L ‡	Water soluble sulphate (SO <sub>4</sub> ) in recycled aggregate sample, %	Cementing materials to be used §††	Performance requirements §	
						Maximum expansion when testing using CSA A3004-c8, %	
						At 6 months	At 12 months ††
S-1	Very severe	> 2.0	> 10,000	> 2.0	HS or HSb	0.05	0.10
S-2	Severe	0.20–2.0	1,500–10,000	0.60–2.0	HS or HSb	0.05	0.10
S-3	Moderate	0.10–0.20	150–1,500	0.20–0.60	MS, MSb, LH, HS or HSb	0.10	
<p>* For sea water exposure, see Clause 4.1.1.5</p> <p>† As per CSA A23.2-3B</p> <p>‡ As per CSA A23.2.B</p> <p>§ Where combinations of supplementary materials and Portland or blended hydraulic cements are to be used instead of the cementing materials listed, the performance requirements shall be used to demonstrate performance against sulphate exposure (see Clauses 4.1.1.6.2, 4.2.1.1, and 4.2.1.3, and 4.2.1.4). Such combinations shall not be designated as blended cements.</p> <p>** Type HS cement shall not be used in reinforced concrete exposed to both chloride and sulphates. Refer to Clause 4.1.1.6.3.</p> <p>†† If the expansion is greater than 0.05% at 6 months but less than 0.10% at 1 year, the cementing materials combination under test shall be considered to have passed.</p>							

**CSA A23.1 TABLE 4**

<b>Requirements for the air content categories</b>			
(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.3.1, 4.3.3.1, 4.3.3.2, and 4.4.4.1.1 and Table 2.)			
This	Range in air content * for concretes with indicated nominal maximum sizes of coarse aggregate, %		
	10 mm	14 – 20 mm	28 – 40 mm
Air content category			
1 †	6–9	5–8	4–7
2	5–8	4–7	3–6
<p>* At the point of discharge from the delivery equipment, unless otherwise specified.</p> <p>† For hardened concrete, see Clause 4.3.3.2.</p> <p><b>Notes:</b></p> <p>(1) The above difference in air contents has been established based upon the difference in mortar fraction volume required for specific coarse aggregate sizes.</p> <p>(2) Air contents measured after pumping or slip forming may be significantly lower than those measured at the end of the chute.</p>			

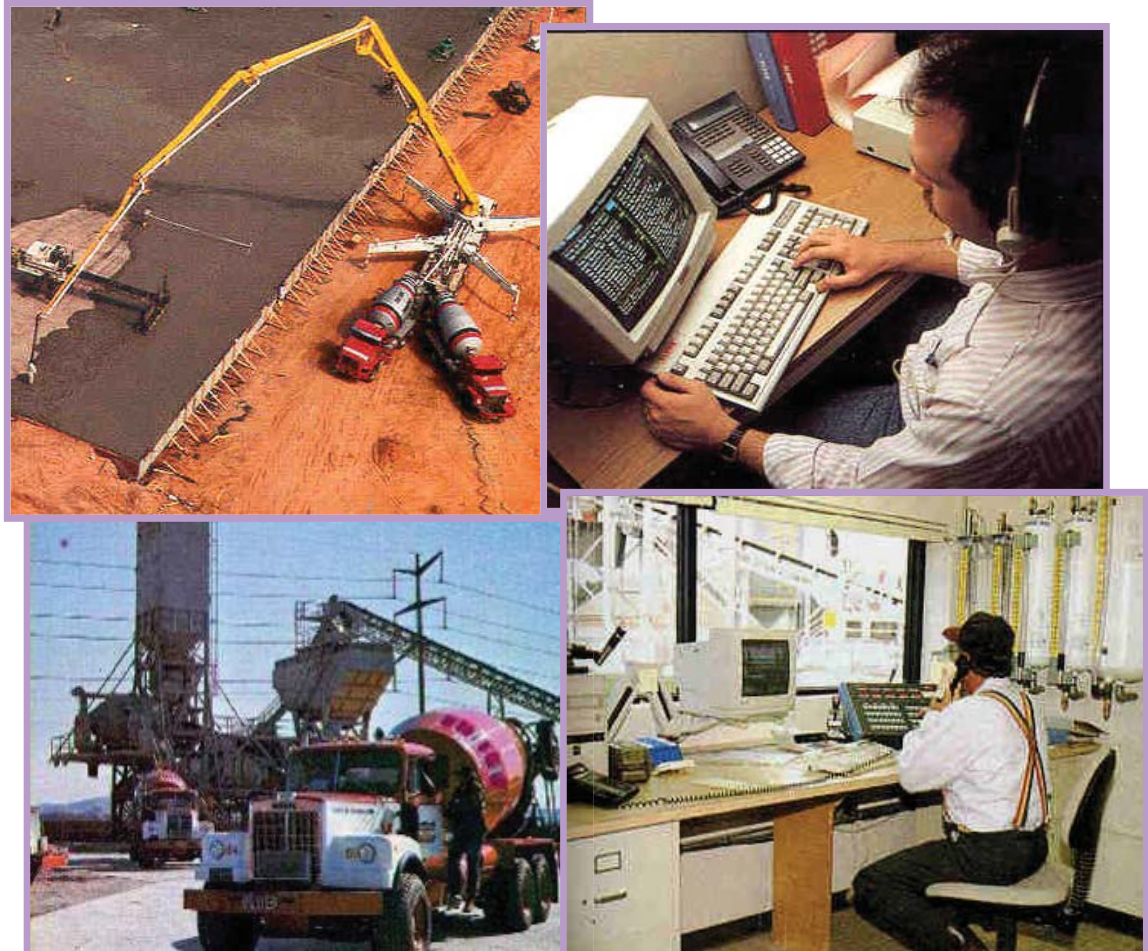
References

- 1 CSA A23.1-14 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International



1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management and Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Procedures
13	Transportation and Concrete
14	Convey, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

Appendix K: Checklist for Concrete Ordering and Scheduling



*Checklist for Ordering and Scheduling Ready Mixed Concrete<sup>©</sup>*

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost (LCC)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Procedures
13	Transportation of Concrete
14	Conveying, Storing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

## Introduction

A Task Group of the National Ready-mixed Concrete Association (NRMCA) and the American Society of Concrete Contractors (ASCC) has developed this checklist for Ordering and Scheduling Ready-mixed Concrete. With permission of the original author, Concrete Ontario (RMCAO) and the Ontario General Contractors Association (OGCA) have reviewed and revised this document for use on Canadian construction projects following the requirements of the most recent CSA A23.1/2 Standard.

The intent is to simplify the ordering process through a logical approach while establishing the necessary information from the supplier's and the purchaser's perspective, especially on smaller projects. The presumption is that on larger projects the concrete construction team has been through a pre-construction conference and has addressed the pertinent items in the **Checklist for Concrete Pre-Construction Conference** and those items are excluded from this document. The ordering requirements of CSA A23.1/2 *Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete* generally govern unless over-ridden by the purchaser.

A Task Group of Concrete Ontario (RMCAO) and the Ontario General Contractors Association (OGCA) has revised this document for use on Canadian projects with the co-operation and permission of the RMC Foundation and NRMCA.

Besides items covered in this checklist other items that need to be defined and clarified between the supplier and purchaser include:

- **Advance notice for concrete orders**
- **Add-on orders**
- **Change orders**
- **Will call orders and advance confirmation**
- **After hours placements and charges,**
- **Weekend/holiday orders and charges**
- **Cancellation of orders**
- **Clean-up load estimates and advance notice**
- **Additional charges for items such as returned concrete, short loads, etc.**
- **Requirements for personnel and plant certification**

This checklist will facilitate the *person taking the order* to assist the *person placing the order* by walking him/her through these items and documenting the order.

The section on type of construction is to facilitate tracking changes in concrete market segments for promotion activities.



### Checklist for Concrete Ordering and Scheduling

**Project:** \_\_\_\_\_

**Location:** \_\_\_\_\_

	Name	Phone	Mobile	Fax
<b>Order taken by</b>				
<b>Ordered by</b>				
<b>Purchased by</b>				

<b>Time/Date Called</b>		<b>Quantity (m<sup>3</sup>)</b>	
<b>Date Required</b>		<b>Truck Spacing/Duration</b>	
<b>Start Time</b>		<b>Placement Rate (m<sup>3</sup>/hr.)</b>	

Location	Mix Code	Strength (MPa)	Min. cement content (kg/m <sup>3</sup> )			Slump (mm)		Air Content (%)		
			No	Yes			±	No	Yes	

**Concrete Temperature Limits**       No       Yes      Minimum: \_\_\_\_°C      Maximum: \_\_\_\_°C

Admixtures or Other Ingredients	No	Plant-added	Site-added	Admixtures or Other Ingredients	No	Plant-added	Site-added
<b>Synthetic Fibres</b>				<b>High Range Water Reducer</b>			
<b>Steel Fibres</b>				<b>Accelerator</b>	<b>Chloride</b>		
<b>High Early Strength</b>					<b>Non-Chloride</b>		
<b>Mid-Range Water Reducer</b>				<b>Maximum Aggregate Size (mm):</b>			

**Directions to the Jobsite** \_\_\_\_\_

**Site Access** \_\_\_\_\_

**Transportation Units Access** \_\_\_\_\_

**Safety Info to Drivers** \_\_\_\_\_

**Wash-Out Areas** \_\_\_\_\_ **Other** \_\_\_\_\_

**Placement Method**  Pumping     Conveyor     Bucket     Other \_\_\_\_\_

**Emergency Contacts** for schedule changes, equipment breakdown, plant/truck breakdown, mixture adjustments

	Contact	Phone	Mobile	Home Phone
<b>Supplier</b>				
<b>Contractor</b>				

1	Introduction
2	Sidewalk, Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA) Analysis
7	Unshrinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Convey, Handling, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

<b>General Contractor</b>				
---------------------------	--	--	--	--

**Type of Project**

- |  |   |   |
|--|---|---|
| <input type="checkbox"/> Highway                   | <input type="checkbox"/> Streets and local roads        | <input type="checkbox"/> Recreational paving  |
| <input type="checkbox"/> Airports                  | <input type="checkbox"/> Parking garages                | <input type="checkbox"/> Tilt-Up construction |
| <input type="checkbox"/> Bridges                   | <input type="checkbox"/> Transit                        | <input type="checkbox"/> Buildings            |
| <input type="checkbox"/> Water resource structures | <input type="checkbox"/> Waste management structures    | <input type="checkbox"/> Flowable fill        |
| <input type="checkbox"/> Parking areas             | <input type="checkbox"/> Driveways/residential flatwork | <input type="checkbox"/> Basement walls       |
| <input type="checkbox"/> Residential walls (ICFs)  | <input type="checkbox"/> Other:                         |   |
-



1	Introduction
2	Shrinkage, Cracks & Gutter Evaluation and Inspection
3	Asset Management Plan Development Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinklable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Curing Procedures
13	Transportation and Recycled Concrete
14	Conveying, Placing, Finishing and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
Appendix	

This document was created as a joint publication of both the Ontario General Contractors Association and the Concrete Ontario. Additional technical information was also supplied by allied concrete and related associations in both Canada and the United States as identified in the document.

## Website Links

American Concrete Pumping Association (ACPA) - [www.concretepumpers.com](http://www.concretepumpers.com)

American Society of Concrete Contractors (ASCC) - [www.asconline.org](http://www.asconline.org)

American Concrete Institute (ACI) ([www.aci-int.org](http://www.aci-int.org))

Canadian Standards Association (CSA) ([www.csa.ca](http://www.csa.ca))

Concrete Floor Contractors Association of Ontario (CFCAO) ([www.concretefloors.ca](http://www.concretefloors.ca))

Concrete Construction Magazine ([www.concreteconstruction.net](http://www.concreteconstruction.net))

National Ready-mixed Concrete Association (NRMCA) ([www.nrmca.org](http://www.nrmca.org))

Ontario General Contractors Association (OGCA) ([www.ogca.ca](http://www.ogca.ca))

Concrete Ontario (RMCAO) ([www.rmcao.org](http://www.rmcao.org))

Ready-mixed Concrete Foundation (RMC) ([www.rmc-foundation.org](http://www.rmc-foundation.org))

World of Concrete ([www.worldofconcrete.com](http://www.worldofconcrete.com))

# Appendix L: Inspection Checklist for Concrete Works

## CONCRETE CURB & GUTTER

DATE: \_\_\_\_\_ TIME: \_\_\_\_\_ am/pm to \_\_\_\_\_ am/pm

MUNICIPALITY: \_\_\_\_\_ CONTRACTOR: \_\_\_\_\_

PROJECT / CONTRACT NO.: \_\_\_\_\_ PROJECT LOCATION: \_\_\_\_\_

WEATHER: \_\_\_\_\_ TEMP: \_\_\_\_\_ CONTRACT / PAY ITEM NO.: \_\_\_\_\_

CURB & GUTTER TYPE (OPSS, OPSD): \_\_\_\_\_ APPROXIMATE QUANTITY: \_\_\_\_\_

LOCATION OF POUR: \_\_\_\_\_

**GRADE** IS GRADE COMPACTED PROPERLY?: yes / no If no, list remediation measures: \_\_\_\_\_

IS THERE ADEQUATE MOISTURE IN GRADE?: yes / no If no, too wet too dry

If no, circle remediation measures: remove/replace existing material dry existing material add moisture

other: \_\_\_\_\_

**FORMS** (If applicable) Are all forms placed correctly and securely?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

Have all forms been checked to ensure they do vary more than 1/4" from plane in any 3 metre section?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

CONCRETE SUPPLIER: \_\_\_\_\_ APPROVED MIX DESIGN: yes /no

PLANT LOCATION: \_\_\_\_\_ MIX DESIGN #: \_\_\_\_\_

**TESTING (frequency of testing is based on qty of pour)** NO. TESTS REQUIRED / FREQUENCY: \_\_\_\_\_

TESTING COMPANY: \_\_\_\_\_ RECORD TEST RESULTS IN FIELD DIARY: yes / no

CONCRETE TESTING TECHNICIAN'S NAME AND CREDENTIALS: \_\_\_\_\_ ACI / CSA / CCIL

**CONCRETE PLACEMENT** Have concrete tickets tickets been checked for correct mix design? yes / no

Has concrete ticket information been entered into field notes? ie. time, load #, truck # yes / no

Has water been added to mixer truck? yes / no If yes, when? \_\_\_\_\_ **Concrete re-tested? Yes / no**

Was concrete discharged from the truck within the allotted time frame?: yes / no (90mins in hot weather, 120mins in other)

If no, note result: \_\_\_\_\_

**JOINTS** Are expansion / isolation joints installed correctly (FULL DEPTH) and at the proper spacing?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

Are expansion joints a minimum of 1/4" thick?: yes / no If no, list remediation measure(s): \_\_\_\_\_

**FINISHING CONCRETE** Is proper floating equipment being used to smooth out concrete?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

**WATER MUST NOT BE ADDED TO AID IN FINISHING SURFACE** \_\_\_\_\_ (Inspector must sign to verify)

Are proper edging tools being used to provide clean edges so concrete doesn't spill or tear?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

What method is being used to add texture to concrete surface: burlap turf drag broom other: \_\_\_\_\_

Is the amount of texture as specified in contract documents?: yes / no

**CURING CONCRETE** Circle curing method: curing compound burlap other: \_\_\_\_\_

Approximate time curing application placed after texturing: \_\_\_\_\_ mins Is entire exposed area of concrete covered: yes / no

If no, list remediation measure(s): \_\_\_\_\_

Are Cold Weather Curing Practices Required (Temp < 5° C): yes / no

1	Introduction
2	Stakeholder Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life Cycle Cost (LCCA) Basis
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Placement Meetings
12	Concrete Construction Procedures
13	Transportation of Concrete
14	Conveying, Landing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting

**CONCRETE SIDEWALK**

DATE: \_\_\_\_\_ TIME: \_\_\_\_\_ am/pm to \_\_\_\_\_ am/pm

MUNICIPALITY: \_\_\_\_\_ CONTRACTOR: \_\_\_\_\_

PROJECT / CONTRACT NO.: \_\_\_\_\_ PROJECT LOCATION: \_\_\_\_\_

WEATHER: \_\_\_\_\_ TEMP: \_\_\_\_\_ CONTRACT / PAY ITEM NO.: \_\_\_\_\_

SIDEWALK TYPE (OPSS; OPSD): \_\_\_\_\_ APPROXIMATE QUANTITY: \_\_\_\_\_

LOCATION OF POUR: \_\_\_\_\_

**GRADE** IS GRADE COMPACTED PROPERLY?: yes / no If no, list remediation measures: \_\_\_\_\_

IS THERE ADEQUATE MOISTURE IN GRADE?: yes / no If no, too wet too dry

If no, circle remediation measures: remove/replace existing material dry existing material add moisture

other: \_\_\_\_\_

**FORMS** (If applicable) Are all forms placed correctly and securely?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

Have all forms been checked to ensure they do vary more than 1/4" from plane in any 3 metre section?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

CONCRETE SUPPLIER: \_\_\_\_\_ APPROVED MIX DESIGN: yes / no

PLANT LOCATION: \_\_\_\_\_ MIX DESIGN #: \_\_\_\_\_

**TESTING (frequency of testing is based on qty of pour)** NO. TESTS REQUIRED / FREQUENCY: \_\_\_\_\_

TESTING COMPANY: \_\_\_\_\_ RECORD TEST RESULTS IN FIELD DIARY: yes / no

CONCRETE TESTING TECHNICIAN'S NAME AND CREDENTIALS: \_\_\_\_\_ ACI / CSA / CCIL

**CONCRETE PLACEMENT** Have concrete tickets tickets been checked for correct mix design? yes / no

Has concrete ticket information been entered into field notes? i.e. time, load #, truck # yes / no

Has water been added to mixer truck? yes / no If yes, when? \_\_\_\_\_ **Concrete re-tested? Yes / no**

Was concrete discharged from the truck within the allotted time frame?: yes / no (90mins in hot weather, 120mins in other)

If no, note result: \_\_\_\_\_

**JOINTS** Are expansion / isolation joints installed correctly (FULL DEPTH) and at the proper spacing?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

Are expansion joints a minimum of 1/4" thick?: yes / no If no, list remediation measure(s): \_\_\_\_\_

**FINISHING CONCRETE** Is proper floating equipment being used to smooth out concrete?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

**WATER MUST NOT BE ADDED TO AID IN FINISHING SURFACE** \_\_\_\_\_ (Inspector must sign to verify)

Are proper edging tools being used to provide clean edges so concrete doesn't spall or tear?: yes / no

If no, list remediation measure(s): \_\_\_\_\_

What method is being used to add texture to concrete surface: burlap turf drag broom other: \_\_\_\_\_

Is the amount of texture as specified in contract documents?: yes / no

**CURING CONCRETE** Circle curing method: curing compound burlap other: \_\_\_\_\_

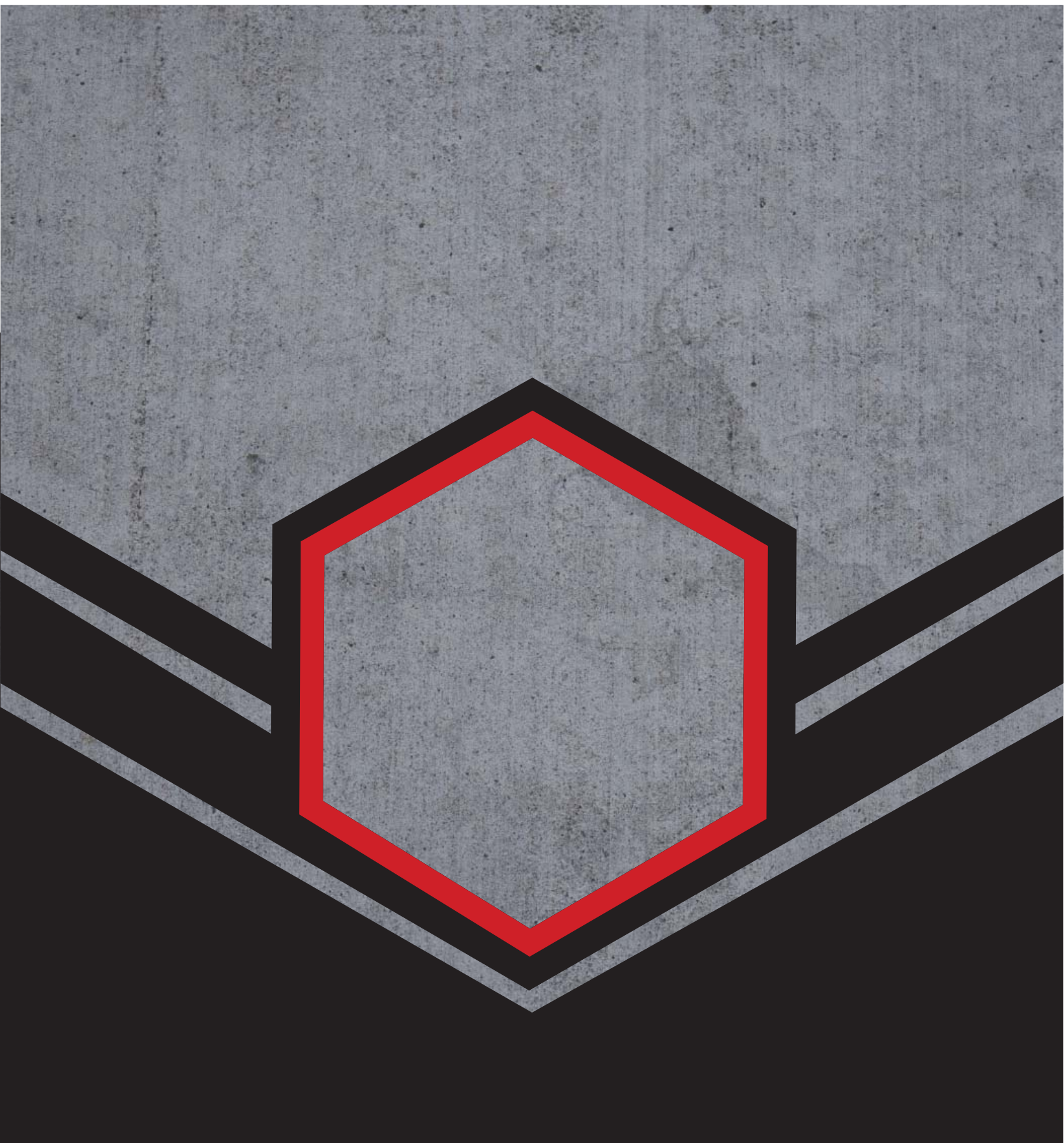
Approximate time curing application placed after texturing: \_\_\_\_\_ mins Is entire exposed area of concrete covered: yes / no

If no, list remediation measure(s): \_\_\_\_\_

Are Cold Weather Curing Practices Required (Temp < 5° C): yes / no

1	Introduction
2	Sidewalk Curb & Gutter Evaluation and Inspection
3	Asset Management Pavement Selection
4	Concrete Bridges
5	Sustainability
6	Life-Cycle Cost Analysis (LCCA)
7	Unsprinkable Fill (U-Fill)
8	Architectural Concrete
9	Concrete Jointing
10	Procurement
11	Pre-Construction Meetings
12	Concrete Casting Procedures
13	Transportation and Receiving Concrete
14	Conveying, Placing, and Finishing Concrete
15	Concrete Protection and Curing Requirements
16	Measurement, Testing and Acceptance of Concrete
17	Project Closeout and Continuous Improvement
18	Troubleshooting
Appendix	





Layout and design courtesy of the Ontario Good Roads Association



**OGRA Municipal Concrete Liaison Committee**