Attachment 3 – Standards and Specifications for Concrete

1.0 Concrete Material Specifications

The City of Calgary has developed specifications for Portland cement concrete for concrete use on sidewalks, pavements, curbs and gutters. Below is a photo of concrete sidewalk in good condition.

Figure 1.0-1 Example of Concrete Sidewalk In Very Good Condition

1.1 Concrete Properties

Minimum requirements for concrete material placed on sidewalks:

Minimum Cement Content (kg/m3)	Maximum Water to Cementing Materials Ratio	Nominal Maximum Coarse Aggregate Size (mm)	Minimum Compressive Strength at 28 Days (MPa)	Air Content (%)
310	0.45	20	32	5-8

Table 1.1-1: Minimum Requirement for Sidewalk Concrete Material

Concrete placed prior to September 30 shall attain the minimum allowable compressive strength in 28 days. For concrete placed after September 30 and before May 1, minimum allowable compressive strength shall be attained in seven days.

Supplementary cementing material of Type F is added up to 20%. Starting in 2016, it became mandatory to use synthetic fibers in concrete for City Roads contracts.

1.2 Cold Weather Requirements

1.2.1 Air Temperature

When the air temperature is at or below 5°C, or when there is a probability of the temperature falling below 5°C within 24 hours of placing as forecast by the nearest official meteorological office, cold weather requirements for concrete placement shall apply.

1.2.2 Off Season Concrete

Between September 30 and the subsequent May 1, the minimum allowable concrete compressive strength shall be attained in seven days.

Contractors shall adequately cover and protect the freshly placed concrete and cure for a minimum of 7 days curing above 10°C is required as per Canadian Standards Association (CSA) standards.

2.0 Compliance Program

The compliance program monitors the quality of concrete materials used for rehabilitation of sidewalk construction or improvements where The City is to be the ultimate owner. The program is intended to provide The City a high level of confidence in the quality of materials and workmanship used on City projects. Quality assurance testing is part of compliance program to assure specification requirements are met for concrete.

Random testing for concrete includes plastic concrete testing (slump and air) and compressive strength testing at 7 and 28 days. Compressive strength of cylinders that are below the specified minimum limit would either trigger penalties or a coring program to determine strength of cores taken from the concrete lot in question.

2.1 Daily Dispatching Procedure

The program operates on a daily basis to monitor the quality of concrete placed within the City. Testing technicians are dispatched from material testing laboratories to test concrete to ensure material compliance according to the City's Standards Specifications. Daily messages from the contractors are received through the dedicated City compliance phone line for their concrete pouring. QA testing firms are notified every day before 7:30 am to do testing on jobs assigned to them.

2.2 Concrete Compliance Testing

All concrete supplied for City contracts and new subdivisions are tested daily on a random basis by The City for quality assurance testing. All concrete supplied for City contracts and new subdivision has to conform to Canadian Standards Association (CSA) Standards. All concrete testing personnel are certified by the American Concrete Institute (ACI) or CSA or Canadian Council of Independent Laboratories (CCIL). The following are tests conducted to monitor the quality of concrete placed:

- Slump Test - To assess workability of concrete and water content
- Air Content Test - To determine if enough air is (5% to 8%) in the mix for freeze thaw protection
- Compressive Strength of Concrete Test - 3 cylinders are casted and broken after 7 and 28 days to determine the compressive strength. City's minimum compressive strength requirement is 32 MPa in 28 days. Concrete placed prior to September 30 shall attain the minimum allowable compressive strength in 28 days. For concrete placed after September 30 and before May 1, minimum allowable compressive strength shall be attained in 7 days.

Contractors performs inspections and quality control testing necessary to ensure that the work conform to the requirements of the specifications and the contract.

2.3 Verification Testing

Compliance verification testing is done if a contractor challenges compliance testing results. Cores are extracted from sections of concrete deemed unacceptable by the City. Cores are tested by third party consultant. Penalties/Payment adjustments are assessed for non-compliance work as per Specifications.

In 2012, a new verification process was implemented. In addition to analyzing compressive strength of cores, the sample will be analyzed to determine the air void characteristics of concrete in question. A new type of penalty criteria was introduced and was based on the spacing factor of air voids in concrete.

The following table is used for payment adjustments:

Spacing Factor		Low Strength	
Between 0.230 mm and 0.260 mm	50% deduction	Between 0.230 mm and 0.260 mm	50% deduction
> 0.260 mm	90% deduction or remove and replace	> 0.260 mm	90% deduction or remove and replace

Table 2.3-1 Penalties and Payment Adjustments for Non-Compliance Work

2.4 Compliance Data

In 2015, the City has tested samples from 52,000 cubic metres of concrete placed in sidewalks. Below is City of Calgary Compliance dashboard report for 2014 and 2015 concrete:

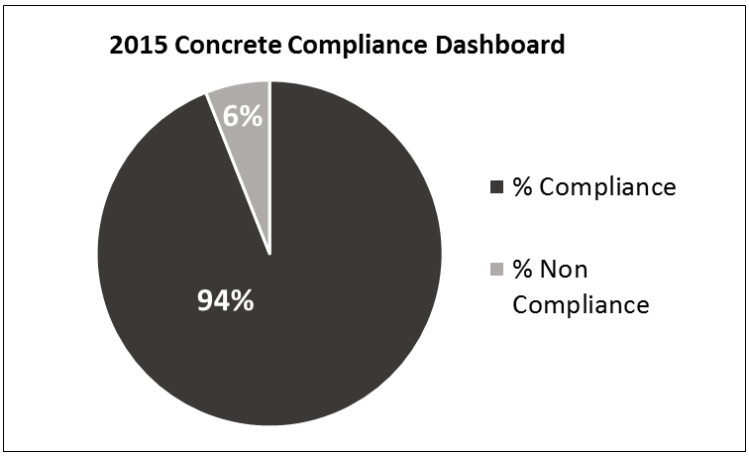

Figure 2.3-1 Compliance dashboard report for 2015 Concrete

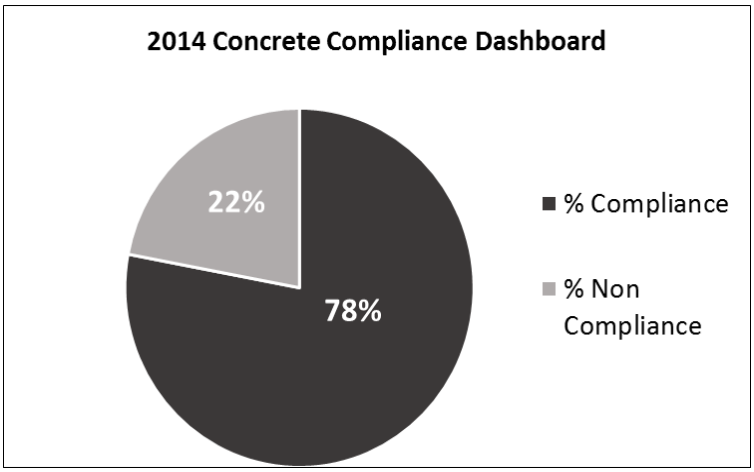

Figure 2.3-2 Compliance dashboard report for 2014 Concrete

3.0 Design Standards for Sidewalks

The existing monolithic sidewalk design standard for concrete thickness is 100 mm of concrete placed on a prepared subgrade. For subdivisions, no gravel or other material is placed beneath the concrete slab. For all Roads projects, 100 mm to 150 mm gravel of recycled concrete is used as base material beneath the concrete slab. As of 2016, it is mandatory to use fibers in all Roads contracts. Fibers are added to the concrete mix in a plastic state and are effective in reducing plastic shrinkage cracking.

The existing standard can be enhanced by the addition of gravel base or increasing the thickness of concrete. The City has conducted several studies in the past that have confirmed that the City of Calgary is in the lower half in comparison to other major municipalities. A summary of the most current sidewalk designs for different municipalities is presented below.

Municipality	Concrete Thickness (mm)	Granular Base (mm)
Calgary	100	Not required
Edmonton	120	150
Lethbridge	130	100

Municipality	Concrete Thickness (mm)	Granular Base (mm)
Red Deer	115	Not required
Toronto	150	150
Hamilton	125	150
Kitchener	125	125
Guelph	125	75
Windsor	115	50
Kingston	125	100
Regina	130	150
Winnipeg	100	Base course as required
Saskatoon	115	20 mm levelling course
Saint John	100 (150 at driveway)	150
Vernon	120	Min 100
Vancouver	100	100
NRC1	Min 100	150
Hartford, Connecticut	150	150
Wisconsin DOT	Min 100 (150 at driveway)	Min 100
Florida Tech	150	150

Table 3.0-1 Concrete Thickness Comparison Between Canadian Municipalities

4.0 Causes of Concrete Sidewalk Failures

4.1 Construction Damages

It is common practice in new subdivisions (residential, commercial and industrial), that the underground utilities and surface improvements (paved roads, sidewalks, curbs & gutters, catch basins etc) are in place prior to the commencement of residential and commercial developments. During the construction stage of residential and commercial developments, the surface improvements are subjected to large volumes of construction related vehicle traffic and equipment.

Concrete sidewalks, curbs and gutters are constructed in the new subdivisions soon after the lots are developed to allow easy access and emergency access. Lack of drainage, damage by the road construction equipment, and the traffic associated with home construction (cranes, backhoes digging the basements, gravel trucks, concrete trucks and pump trucks) leads to excessive concrete cracking and crack displacement. The damage results in severe block cracking of concrete and settlement where the subgrade is allowed to saturate.

The City has completed a report in 2008, which identified 40% of concrete sidewalk, curb and gutter replacements at Final Maintenance Certificate (FMC) stage were damaged due to third party activities in new subdivisions.

4.2 Shallow Utility Settlement Damages

The damage by shallow utility work occurs when the backfill soils are placed in the utility trenches without compaction effort, especially in winter months when backfill soil is frozen. These settlements

can be substantial and when the soils under the sidewalk settles, the concrete will collapse under its own weight.

4.3 Frost Heave Cracking

Frost effects occur when frost-susceptible soils in the subgrade freeze with an available source of groundwater (or capillary groundwater), surface water, or their own moisture content. Upon freezing, ice lenses form in the subgrade, causing frost heave. Upon thawing, the ice lenses thaw resulting in significant saturations of subgrade soils, which leads to soil weakness and non-uniform settlement. Most of the Calgary area soils are classified as silty clay tills. The potential for frost susceptibility and loss of strength during thaw is considered high. Concrete sidewalks placed directly on this type of soil experience high risk for heaving followed by thawing, soil weakening, and settlement. The most common type of sidewalk cracks associated with frost heave are longitudinal cracks extending through multiple panels.

4.4 Concrete Placed in Shoulders Seasons

The winter season across Alberta is quite long and satisfying shorter construction schedules frequently requires placing concrete in winter or shoulder season months. Concrete in plastic state (freshly placed concrete and not fully hardened) is prone to freezing and, unless protected from low temperatures, the damage to concrete by freezing in a plastic state and/or slow strength development leading to cracking will occur.

4.5 Tree Root Damage

As trees expand and grow over time, roots that are overgrown and/or near the surface of the adjacent sidewalk may push up the concrete sidewalk slab or cause cracking. Damaged or heaving sidewalks can pose a tripping hazard to pedestrians. Figure 4.5-1 shows multiple tree root issues within one block face.

Figure 4.5-1 Photo Showing Multiple Tree Root Issues Within One Block Face

The hazards caused by tree roots are usually addressed by the cutting the trip edge, filling the gap to create a ramp or replacing the concrete sidewalk.

5.0 Other Observations

5.1 Decorative Concrete

The City has decorative concrete mostly in downtown core and in some new subdivisions at roundabouts and cross walks. Decorative concrete is used to enhance the esthetic of the structure while still serving as an important structural functional. Challenges surrounding decorative concrete are improper control joints, issues with multiple pours and colour variations. Control joints are used to control random cracking on concrete slabs. Joint placements are usually sacrificed for atheistic purposes rather than durability. Multiple concrete pours to build the final surface also affects the durability of sidewalks. Multiple pours mean the concrete is placed in a non-continuous manner. Concrete placed in this manner is more prone to cracking due to thermal expansion and contraction. The decorative concrete mix with colour is slightly different than the conventional mixes in terms of

adding properly selected coloring products and water cement ratio. The placement of such concrete onsite is a challenge because of multiple pours (depending on the surface pattern) that can result in inconsistent color shades and patterns. In addition, proper curing of concrete is important to reduce surface shrinkage cracking and obtain the proper strength.

Figure 4.6.1 – Decorative concrete at Auburn Bay

5.2 Spalling

Spalling is a surface deficiency in which concrete is broken up, flaked and becomes pitted. In some cases, chunks of concrete break loose from the surface and can also start to crack. Spalling is a deeper surface defect than scaling, often appearing as circular or oval depressions on surfaces or as elongated cavities along joints. It is caused by a combination of poor installation/construction practices, improperly constructed joints, environmental factors and corroded reinforcing steel. Spalling, at a low level, is mainly a cosmetic problem but severe spalling can lead to structural damage if not dealt with immediately. If left untreated, large enough fragments of concrete could come out which could lead to serious consequences.

5.3 Cement Production and Mix Designs

Concrete production and changes to mix designs in recent years has contributed to concrete mixes that are more prone to cracking than 50 years ago. Some of the changes to cement and concrete production were a result of the construction industry's demand for high early strength to deliver shorter construction schedules, and the contractual penalty structures are based almost solely on compressive strength. To satisfy the demand for higher and earlier concrete strength, the cement manufacturers increased the fineness of the cement to provide a more reactive cement and altered the cement chemistry to increase the amount of tricalcium silicate in Portland cement (contributing to faster strength gain). Another method to assure high early strength development of concrete is to lower the w/cm ratio with the workability achieved by the use of water reducing admixtures. A combination of high cement levels and low w/cm in concrete mix results in higher shrinkage at early age, and microcracks due to shrinkage frequently develop in concrete before contraction joints, either by tooling or by saw cutting, are introduced. In addition, fine cement paste on the concrete flatwork surfaces has a higher tendency to dry out, resulting in dusting of the surface and subsequent scaling.

6.0 Inspections

All contract work and internal projects within the Roads Business Unit are inspected on a daily basis. The large amount of concrete placed for all projects makes it challenging to be on every site for each concrete placement. The inspectors have multiple project sites which they effectively manage their time to capture as many inspections as possible and are trained to inspect all civil work.

For subdivisions, consultants working for the developers inspect all activities. The City sub-division officers work closely with these consultants. Typically site visits occur approximately two to three times per week during active construction. In between CCC and FMC stage, the site visits are two to three times per month. At the FMC stage, daily inspections are conducted to ensure all deficiencies are identified prior to acceptance. Roads manages the compliance program and provides compliance or non-compliance statements for concrete based on the quality assurance results. If the concrete fails to meet the specifications, there is either a financial penalty or the concrete is replaced at no cost to the City. Quality control testing is mandatory on all Roads projects and must be submitted with mix designs to Roads Materials & Research.

Roads has approximately 33 inspectors assigned to concrete projects, as many projects occur during the construction season (May to September). The shoulder season is October to April. Programs include miscellaneous concrete repairs, Roads excavation permit repairs, surface overlay concrete repairs, Local improvement full block replacement program, wheelchair ramp program, development permit driveway program, various street improvements program, sub-divisions, mudjacking repairs, and any special request for concrete work needed within the City of Calgary. The inspections are conducted from pre-construction inspections to construction completion.

6.1 Construction Division

In the construction division, there are 3 groups that would provide concrete inspection services.

City Forces

- Roads has 4 foreman for inspecting concrete projects completed by City Forces. This includes 3 for the quality after the pouring is completed. 1 foreman for inspection during the pouring stage and managing the pouring crew. Up to 3 Foreman will inspect during various stages in the construction process.

Contracted Services Division

- 3-4 project inspectors during construction projects and after completion for quality.
- Materials and Research
- 3 inspectors that will review inspections reports submitted to Roads. They conduct frequent site visits to provide technical support and approve material designs submitted to Roads on projects.

6.2 Development and Projects Division

The personnel listed below conduct daily inspections on projects and developments that is under the responsibility of the Development and Projects Division:

- 3 subdivision officers
- 4 project inspectors
- 5 Roads indemnified agreement / surface improvements inspectors

- 5 Various Concrete Construction & Block Replacement Construction Coordinators / Inspectors
- 2 Local Improvement Paving Construction Coordinator / Inspector

6.3 Roads Maintenance

Once a year, Roads Maintenance will conduct a condition survey to locate and inspect defects on the sidewalk, curb and gutter networks.

- 9 Foreman and 9 Technicians inspect conditions of sidewalk network once a year for defects.

7.0 Warranty Process

After construction completion of concrete sidewalks, curbs and gutter, it is subject to an inspection prior to the issuance of construction completion certificate (CCC). After the CCC is issued, the two-year warranty period begins. At the end of the two-year warranty period, the concrete sidewalks, curbs and gutters are subject to final maintenance certificate (FMC) inspection, prior to the assets being handed over to the City. All damaged concrete identified during FMC inspections are replaced by the contractors at no cost to the City. Concrete replaced at FMC has no additional warranty. The warranty period for concrete assets is two years and is common for many municipalities.

8.0 Recommendations / Improvements

1) Train staff to provide adequate pedestrian accommodation during sidewalk construction. Dedicated staff have been assigned to conduct a five level inspection. The goal is to maintain access at all times. Providing detours, delaying projects, pouring concrete multiple times in the same section, building ramps and closing one corner at a time are strategies that will be employed.
2) Continue to work with Calgary Home Builders Association/Urban Development Institute (CHBA/UDI) and Roadbuilders to review the current concrete specifications to improve the durability of concrete assets.
3) Encourage all City employees to report damage to City assets by third party when observed. A memorandum will be sent from Roads to all other Business Unit requesting their assistance by reporting these incidents through 311. As part of this memorandum, Roads will indicate that expertise is available in-house to assist with concrete related concerns and issues,
4) Encourage contractors to look for ways to protect City assets during construction using products that bridges over curbs and sidewalks so these assets do not get damaged. During best practice seminars, Roads will invite suppliers with innovative products that industry users can trial to minimize damage to concrete assets,
5) Continue to identify concrete sidewalks, curbs and gutters projects that are adjacent to pending large developments, infills or projects by other Business Units. Roads will reschedule these projects to prevent new concrete from damaged during construction,
6) Improve the tracking of deficiency repairs prior to issuance of CCC and FMC.
7) Continue to use the Roads' electronic map system (eMAPS) to identify projects that are in the same area which will improve the coordination between projects, and
8) Improve the condition survey process to include asset management concepts.