

July 24, 2019

City of Edmonton
11004 – 190 Street NW
Edmonton, AB T5S 0G9

ISSUED FOR USE
FILE: ENG.EMAT03618-01
Email: Wanda.Goulden@edmonton.ca

Attention: Wanda Goulden, FEC, FGC, M.Sc., P.Eng., P.Geo

Subject: Concrete Sidewalk & Curb Brine Impact Study
Edmonton, AB

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the City of Edmonton (CoE) to conduct an investigation into the impacts of sodium chloride (salt) and calcium chloride (brine) when placed adjacent to Portland cement concrete (concrete) infrastructure (i.e. concrete sidewalks, curbs and driveways) mainly in residential areas.

The Design and Control of Concrete Mixtures, eighth Canadian edition states *'The most destructive weathering factor is freezing and thawing while the concrete is wet, particularly in the presence of de-icing materials'*. Tetra Tech undertook this research to determine if concrete deterioration was accelerated with the use of salt and brine.

2.0 CITY OF EDMONTON WINTER ROADWAY MAINTENANCE PRACTICES

The current City of Edmonton winter maintenance practices include the use of:

1. Sodium Chloride (NaCl) De-icer (typically with sand as a traction aid).
2. Calcium Chloride (CaCl₂) Anti-icer on arterial roads and bus routes.
3. NaCl De-icer after CaCl₂ Anti-icer*.

*Depending on the intensity and duration of the snowfall event and/or changes in pavement temperature, de-icers may be applied to roadways after pre-treatment with an anti-icer.

Anti-icers are applied before a snow fall event to facilitate snow clearing. De-icers are used to help melt and remove ice and snow from roadways and sidewalks. The effectiveness of salt as a de-icer decreases as the pavement temperature goes down to temperatures below about -10°C. CoE incrementally reduces the amount of salt in the sand mixture as application temperatures drop from -5°C to -25°C. At lower dosages (3%) the salt is primarily used to prevent the road sand from freezing into unmanageable lumps.

Tetra Tech has also completed an overview of research into the effects of de-icing and anti-icing agents on concrete. This includes how sodium chloride (NaCl) salt and/or calcium chloride (CaCl₂) brine solutions effect concrete properties. The literature review focuses on the use of these de-icing and anti-icing materials during winter roadway maintenance on concrete which includes identification of preventative measures. This overview was provided under separate cover.

Tetra Tech is undertaking a laboratory testing program which will determine the scaling resistance of Class C concrete panels (concrete used for roadway works including curb and gutter, sidewalks, walkways, private crossings, swales medians, New Jersey barriers and parapet walls) by applying salt, differing concentrations of brine and a control sample which was exposed only to distilled water. This will help determine how different chemical compounds and concentrations affect Edmonton's typical concrete infrastructure.

Another field study reviewing the effects of salt and brine on main arterial roadway and freeway curbs, medians and bus pads is currently in progress.

3.0 CONCRETE INVESTIGATION

3.1 Areas of Study

Tetra Tech was tasked to determine if there were differences in concrete field performance after the 2018/2019 winter season that could be related to the use of salt with sand and/or brine.

In order to document the field performance of sidewalks and curbs, photographic images of five (5) selected sites were obtained in fall of 2018 and again after street cleaning in spring of 2019. These surveys provided an effective method of documenting field performance and allowed an objective assessment of the effects of the use of salt and/or brine. The photographic surveys completed for this study included a total of 3,208 photographic images of the concrete surfaces obtained in the fall of 2018, and an additional 3,208 images of the same locations obtained in the spring of 2019.

Tetra Tech was informed that residential areas in the CoE only received salt with sand for de-icing while select arterial roadways and freeways use a combination of brine anti-icer and salt (described above). Three residential neighbourhoods were selected for this survey. The following neighbourhoods contained curbs and sidewalks constructed in 2018:

- The Uplands (27 Avenue and 202 Street);
- Belgravia Neighborhood Renewal (78 Avenue and 119 Street); and
- Laurel (17A Avenue and 29 Street).

The Belgravia neighborhood is located directly off a Brine route. It is reasonable to assume that some brine could have been tracked in from the brine route into the neighborhood. Tetra Tech has not surveyed home owners to determine how snow clearing and ice removal is completed on private sidewalks and driveways.

Concrete infrastructure was also surveyed along the following anti-icing routes where a combination of brine and salt was placed on the adjacent roadway:

- 111 Avenue between 124 Street and 132 Street; and
- 178 Street between 87 Avenue and 95 Avenue.

3.2 Concrete Photographic Survey

The sidewalks, curbs and adjacent portions of driveways were surveyed by a GoPro Hero7 Black wide screen mounted on a Trailblazer 889 SL/SE scooter. The curbs, sidewalks and private driveways were photographed every 2 m from the sidewalk. This photographic survey provided a visual log of the concrete surfaces prior and after the winter season. This included 3,208 images of the 5 locations obtained in late fall 2018 and an additional 3,208 images of the same locations obtained in the spring of 2019. Electronic copies of the photos along with corresponding locations have been provided under separate cover.

Once both the pre and post winter surveys were completed, the images were organized by GPS coordinates to permit side by side comparison to determine if any damage was noted. Typical comparison photos are attached. Once all images were visually observed, a site trip by a Tetra Tech concrete specialist was completed to confirm the extent of potential damage observed. Three sites from the photo survey were selected for field review by our concrete specialist.

4.0 CONCRETE OBSERVATIONS

4.1 Anti-Icing (Brine) Routes

4.1.1 111 Avenue

The concrete sidewalks and curbs on the south side of 111 Avenue generally appeared in good condition; however, some mortar flaking was observed at some locations on the north side of the roadway. Mortar flaking is the loss of surface mortar over a sound coarse aggregate particle. Mortar flaking is generally attributed to surface drying caused when the coarse aggregate prevents bleedwater from moving to the surface and balancing evaporation. Mortar flaking from the curb to about 1 m back could be observed in about 20 panels (Photos 1 and 2). It appears that the defect may have been exposure related as this concrete would have been subjected to more freeze thaw cycles than the south side of the road. It is also possible that the snow clearing may have been different along the curb. Two panels also exhibited spalled concrete (Photo 3). This issue seems isolated to only this portion of the sidewalk.

Significant concrete damage was observed on the curbs and sidewalks (Photos 4 to 7). The damage appears to be caused by snow clearing equipment. It appears that snow plows would place the edge of the blade to the edge/face of curb. It also appears that skid steers loaders (or equivalent equipment) may have been used to clear snow from the sidewalks. As this is completed, some of the concrete surface may have been removed. Once the concrete surface mortar is removed, the exposed interior is more prone to be damaged leading to a decrease in service life.

4.1.2 178 Street

It appears only some replacement panels were constructed in 2018 rather than full reconstruction of the sidewalks and curbs. Two panels indicate moderate scaling and cracking damage; however, the scaling and cracking may be subgrade or loading related and not from chemical attack (Photo 8). The new concrete for the sidewalk and bus pad (top of Photo 8) exhibits good concrete with no signs of freeze/thaw distress or chemical attack.

4.2 NaCl₂ (Salt) Routes

4.2.1 Belgravia

The concrete was generally in good condition (Photo 9). Several 2019 images indicate dark spots on the sidewalks. After a visual observation by the Author, it was determined that the spots were caused by tracking of topsoil on the concrete sidewalks.

4.2.2 The Uplands

The sidewalks and curbs appeared to be in good condition from the fall of 2018 to the spring of 2019. It appears that most lots were vacant. Based on our experience with subdivision construction, it is likely that several sections of sidewalk and/or curbs will be removed and replaced after home construction as the construction activities usually damage the concrete.

Due to few residents in the area, most sidewalks were cleared, and salt applied with sand by city of Edmonton contractors. The snow removal would have comprised of skid steers with buckets or brooms removing the snow. Some surface scraping (Photo 10) of the concrete was observed possibly due to snow removal activities.

4.2.3 Laurel

The concrete observed generally appeared in good conditions when compared to the fall of 2018 to the spring of 2019. It appears that only about half of the panels were replaced in 2018. Some of the finished surface comprised of rough texturing/aggressive booming. Some mortar flaking was observed from 2018 to 2019. About three panels appeared to have the top surface damaged (Photo 11). This may have been caused by chipping of ice by the residents causing indentations into the concrete. The damage does not appear to be chemical related.

Some of the private driveways exhibited moderate to severe surface deterioration while the adjacent sidewalks were in good condition (Photo 12).

5.0 CURRENT CONDITION OF INFRASTRUCTURE

Based on the survey of five neighborhoods where concrete was placed in 2018, there is little to no sign of actual or potential damage caused by freeze/thaw distress exacerbated by anti-icing and de-icing solutions. This exposure would include salt and/or brine solutions that may have come into contact with the concrete.

Damage to concrete caused by anti-icing and de-icing solutions would include spalling of the surface which includes removal of surface paste exposing coarse aggregate. Some mortar flaking, and minor scaling (similar to freeze/thaw distress) was observed in two locations (on the north side of 111 Street and limited areas at Laurel) but this may be attributed to construction defects, exposure to more frequent freeze/thaw cycles or ice chipping respectively.

The primary issue observed on the concrete infrastructure was damage from the snow removal equipment on 111 Avenue and the Uplands. The areas of significant damage at 111 Avenue due to snow removal are now somewhat more susceptible to freeze-thaw attack exacerbated by anti-icing and de-icing chemicals and deterioration in general. Some snow removal scraping was observed at the Uplands; however, the damage is not expected to reduce the service life.

6.0 FUTURE OBSERVATIONS

Further investigation into the few distresses observed could be completed in the future. It is suggested that follow-up surveys later this year (late September/early October) and next spring might better identify locations where a detailed investigation, possibly including core sampling, should be concentrated. Should damage be observed from the spring of 2019 to the fall of 2019 (before freezing temperatures), it may not be caused by freeze/thaw distress as influenced by the use of anti-icing and de-icing solutions.

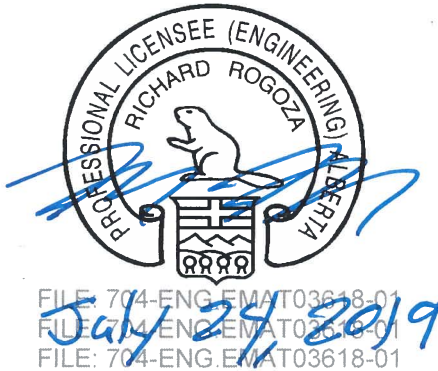
7.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the City of Edmonton and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the City of Edmonton, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix A or Contractual Terms and Conditions executed by both parties.

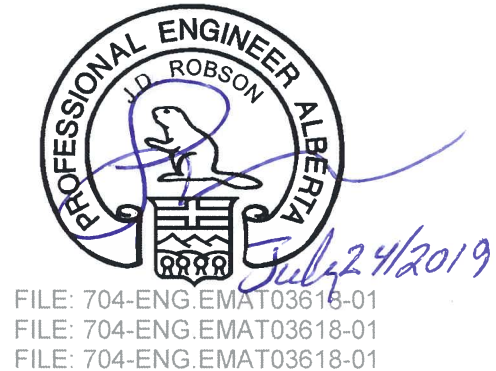
8.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Tetra Tech Canada Inc.



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PERMIT TO PRACTICE TETRA TECH CANADA INC.	
Signature	
Date	<u>July 24/2019</u>
PERMIT NUMBER: P13774	
The Association of Professional Engineers and Geoscientists of Alberta	

PHOTOGRAPHS



Photo 1: 111 Avenue. 2018 photo on left, 2019 photo on right. 2018 photo indicating little surface damage while in 2019 some mortar flaking is visible within ~1 m of the curb.



Photo 2: 111 Avenue and 125 Street. Photo obtained in spring of 2019. Concrete with mortar flaking on surface.



Photo 3: 111 Avenue. 2018 photo on left, 2019 photo on right. Spalling of concrete observed in 2019 image on right. Significant damage observed only on a single panel.

Photo 4: 111 Avenue. Photo obtained in 2019. Surface damage on surface of curb and sidewalk likely caused during snow removal.



Photo 5: 111 Avenue. Photos obtained in 2019. Significant amount of damage to curb constructed in 2018.

Photo 6: 111 Avenue. Photo obtained in 2019.
Chipped concrete curb next to catch basin.



Photo 7: 111 Avenue. Photo obtained in 2019.
Chipped concrete curb next to asphalt path.



Photo 8: 178 Street. 2019 photo. Appears the two replacement concrete panels were poorly constructed. Newer concrete 2 panels up appear in good condition.



Photo 9: Belgravia. 2018 photo on left, 2019 photo on right. Typical concrete section at Belgravia neighborhood.



Photo 10: Uplands. 2018 photo on left, 2019 photo on right. Surface scuffing of the sidewalk near the back of curb is visible in spring 2019. Scuffing not present in fall 2018.



Photo 11: Laurel. 2019 photo. Concrete possibly damaged by chipping of ice from surface.



Photo 12: Laurel. 2018 photo on left, 2019 photo on right. Private driveway exhibiting significant damage while adjacent sidewalk is in good condition.

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

CONSTRUCTION MATERIALS ENGINEERING AND TESTING

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, in fact, caused by the unauthorized use of the Professional Document.

Where TETRA TECH has expressly authorized the use of the Professional Document by a third party (an "Authorized Party"), consideration for such authorization is the Authorized Party's acceptance of these Limitations on Use of this Document as well as any limitations on liability contained in the Contract with the Client (all of which is collectively termed the "Limitations on Liability"). The Authorized Party should carefully review both these Limitations on Use of this Document and the Contract prior to making any use of the Professional Document. Any use made of the Professional Document by an Authorized Party constitutes the Authorized Party's express acceptance of, and agreement to, the Limitations on Liability.

The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH's professional work product and shall remain the copyright property of TETRA TECH.

The Professional Document is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of TETRA TECH. Additional copies of the Document, if required, may be obtained upon request.

1.2 ALTERNATIVE DOCUMENT FORMAT

Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by persons other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary investigation and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental, regulatory, or sediment and erosion issues associated with construction on the subject site.

1.8 VARIATION OF MATERIAL CHARACTERISTICS AND CONDITIONS

Observations and standardized sampling, inspection and testing procedures employed by TETRA TECH will indicate conditions of materials and construction activities only at the precise location and time where and when Services were performed. The Client recognizes that conditions of materials and construction activities at other locations may vary from those measured or observed, and that conditions at one location and time do not necessarily indicate the conditions of apparently identical material(s) at other locations and/or times.

Services of TETRA TECH, even if performed on a continuous basis, should not be interpreted to mean that TETRA TECH is observing, verifying, testing or inspecting all materials on the Project. TETRA TECH is responsible only for those data, interpretations, and recommendations regarding the actual materials and construction activities observed, sampled, inspected or tested, and is not responsible for other parties' interpretations or use of the information developed. TETRA TECH may make certain inferences based upon the information derived from these procedures to formulate professional opinions regarding conditions in other areas.

1.9 SAMPLING, OBSERVATION & TEST LOCATIONS

Unless specifically stated otherwise, the Scope of Services does not include surveying the Site or precisely identifying sampling, observation or test locations, depths or elevations. Sampling, observation and test locations, depths and elevations will be based on field estimates and information furnished by the Client and its representatives. Unless stated otherwise in the report, such locations, depths and elevations provided are approximate.

1.10 CONTRACTOR'S PERFORMANCE

TETRA TECH is not responsible for Contractor's means, methods, techniques or sequences during the performance of its Work. TETRA TECH will not supervise or direct Contractor's Work, nor be liable for any failure of Contractor to complete its Work in accordance with the Project's plans, specifications and applicable codes, laws and regulations. The Client understands and agrees that Contractor, not TETRA TECH, has sole responsibility for the safety of persons and property at the Project Site.

1.11 NOTIFICATION AND LEVEL OF SERVICE

Unless the Client requests or the building code requires full-time services, the Client understands that services provided by TETRA TECH are on an "On-Call" basis. The Client shall assume responsibility for adequate notification and scheduling of TETRA TECH services. TETRA TECH will make every reasonable effort to meet the Client's schedule, but will not guarantee service availability without direct confirmation from with the Client or their agent.

1.12 CERTIFICATIONS

The Client will not require TETRA TECH to execute any certification regarding Services performed or the Work tested or observed unless: 1) TETRA TECH believes that it has performed sufficient Services to provide a sufficient basis to issue the certification; 2) TETRA TECH

believes that the Services performed and Work tested or observed meet the criteria of the certification; and 3) TETRA TECH has reviewed and approved in writing the exact form of such certification prior to execution of the Service Agreement. Any certification by TETRA TECH is limited to the expression of a professional opinion based upon the Services performed by TETRA TECH, and does not constitute a warranty or guarantee, either express or implied.

1.13 WEATHER AND PROTECTION OF MATERIALS

Performance of the Services by TETRA TECH and/or its designated subcontractor may be delayed or excused when such performance is commercially impossible or impracticable as a result of weather events, strikes, shortages or other causes beyond their reasonable control which may also impact cost estimates.

Excavation and construction operations expose materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations, and stockpiles, must be protected from the elements, particularly moisture, desiccation, frost action and construction activities.

1.14 CALCULATIONS AND DESIGN

Where TETRA TECH has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, TETRA TECH's client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by TETRA TECH's Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of TETRA TECH.

1.15 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

1.16 SAMPLES

The Client will provide samples for testing (at the Client's expense). TETRA TECH will retain unused portions of samples only until such time as internal review is accomplished for intended purpose. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded. The duration of sample retention must be discussed in advance.

1.17 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design or testing has been completed. It is incumbent upon TETRA TECH's Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by TETRA TECH or others, it will be referenced in the Construction Materials or Materials Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for this Report.