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Memorandum

Date: June 11, 2018

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APEGA PERMIT TO PRACTICE No. P05038

PROFESSIONAL ENGINEER FAIZAL KANJI ALBERTA

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Subject: **Preliminary Results of Research into the Impacts Salt and Brine on Concrete and Asphalt Conducted by Engineering Services**

At the request of Janet Tecklenborg, Director of Infrastructure Operations, Engineering Services undertook an evaluation to determine the effects of The City of Edmonton's (the City) new anti-icing pilot program on civil infrastructure. Engineering Services developed a program to test $CaCl_2$ (brine) and granular NaCl (salt) applied to both concrete and asphalt materials. Engineering Services' conclusions and comments are presented below.

Literature Review:

While the past research conducted in this area is limited, the available research reviewed suggests that there is a detrimental effect on concrete and asphalt surfaces related to the application of both sodium chloride and calcium chloride. Some of the concrete research found that high concentrations of sodium chloride and calcium chloride produce significant mortar flaking and eventually spalling of the concrete surface (SDDOT, 2008). It was also discovered that adequate concrete curing reduced the number of surface defects (SDDOT, 2008) such as mortar flaking and pop outs. Mortar flaking is where sections of surface concrete dislodge due to delamination of the weakened mortar from the aggregate (Concrete Alberta, 2016). Pop-outs are the result of large, near-surface aggregate that creates a barrier to the bleed water reaching the surface, thus creating a weak surface zone.

Studies performed on asphalt found that erosive effects of salt accelerate the failure of asphalt mixes (Amini & Tehrani, 2016). It was also found that the application of the anti-icing agents produced oxidation and increased the stiffness of the asphalt binder. Increased stiffness is known to produce increased cracking of the pavement surface. The most significant effect of salt application to infrastructure is the increase in the number of freeze-thaw cycles, which leads to accelerated deterioration.

Engineering Services Research:

Engineering Services undertook a study in February 2018 to determine the impact of the City's anti-icing pilot program on infrastructure. Salt and brine samples were collected from the Northwest roadway maintenance yard. The dry sodium chloride salt contains minor amounts of potassium, magnesium and calcium chloride salt. Brine is a saturated solution of calcium chloride that contains minor amounts of sodium, potassium and magnesium chloride. The study was split into two portions: concrete and asphalt. Concrete and asphalt specimens were subjected to various salt and brine rates and multiple freeze-thaw cycles.

Concrete:

The influence of salt and brine on concrete was evaluated using, a surface scaling study in accordance with ASTM C672 "Scaling Resistance of Concrete to Surfaces Exposed to Deicing Chemicals." Concrete slabs were treated with various concentrations of brine, salt, and 4% laboratory grade anhydrous calcium chloride. Concrete slabs were prepared in the Engineering Services laboratory using air-entrained concrete supplied by Lafarge. Two different curing conditions were created: a poor cure (high temperature with low humidity) to imitate poor field conditions; and, proper curing conditions (room temperature in the lab). The samples were put through one freeze-thaw cycle per day (18 hours with a mean temperature of -22°C followed by 6 hours at room temperature). The pH of the solutions was continuously monitored to determine if a chemical reaction was produced. An increase in pH was observed. This increase in alkalinity is due to the lime in the cement paste reacting with the solutions. One extra slab was prepared and deionized water was applied as a control to monitor the physical effects of freeze-thaw.

During this concrete study, the researchers observed that salt and brine exposed specimens conditioned with ideal curing performed roughly 15% better than slabs that were cured under poor conditions. Salt and brine-exposed concrete specimens that were properly cured produced fewer pop-outs than concrete specimens produced with poor curing conditions. All of the samples with brine applied were stained with a red tone. The study concluded that a combination of a chemical reaction and physical freeze-thaw is necessary for surface degeneration to occur. In some cases, slab scaling occurred after five days, considered to be early degradation of slab condition. The brine-exposed sample was slightly more prone to early degradation, and the degradation that occurred was roughly 20% more detrimental than salt-exposed samples.

Different curing compounds and sealants were included in the study but are not discussed in this memo. Sealant performance will be included in the technical paper that will be prepared at a later date. The sealants examined demonstrated variable performance under the test conditions.

Asphalt:

Tests were conducted to evaluate effects of salt on the moisture susceptibility, rutting susceptibility, abrasion resistance and stiffness of asphalt specimens. The asphalt samples were prepared using the Park Paving 10mm-HT mix in the Engineering Services laboratory. The asphalt test program used two different soaking times (3 days and 7 days) with three different solution mixtures (brine, salt, and salt/brine combined).

Moisture susceptibility:

- A tensile strength ratio (TSR) test was performed in accordance to AASHTO T283 "*Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage.*" This test examines the change in tensile strength as a result of water conditioning with a freeze-thaw cycle. The results show that the TSR value increased with increased soaking time, indicating that the mix became less susceptible to moisture. The test results are attributed to the general stiffening of the binder. The brine soaked samples, on average, had similar TSR values compared to the salt soaked samples.

- A Hamburg test was performed according to AASHTO T324 "*Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA).*" This test procedure evaluates the rate of permanent asphalt deformation due to a moving concentrated load when in contact with water. The Hamburg test results on specimens in contact with brine, salt and brine/salt combined were inconclusive.

Rutting resistance:

- A rutting test was performed using the asphalt pavement analyzer (APA). The APA is performed in accordance with AASHTO T340 "*Determining Rutting Susceptibility of HMA.*" The APA consists of an applied wheel load applying a repetitive load through the use of pressurized rubber hose. The test results indicate that, on average, the rutting performance of the salt and brine-soaked asphalt samples had higher rutting resistance than the unconditioned samples. The brine soaked samples, on average, had 12% deeper ruts compared to NaCl soaked samples. The improved rutting performance of the salt exposed sample is attributed to the stiffening of the binder due to the salt application.

Abrasion resistance:

- A Taber test was performed in accordance with a City of Edmonton modified ASTM D4060 *"Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser."* The results of the test indicate 1.5 times the mass loss for all the salt and brine soaked samples compared to the unconditioned samples. It should be noted conditioned samples were observed to be more brittle compared to the unconditioned ones. The brine soaked samples, on average, had 1.5 times the mass loss compared to NaCl soaked samples.

Stiffness:

- Dynamic modulus tests are underway using AASHTO T342 *"Standard Method of Test for Determining Dynamic Modulus of Hot Mix Asphalt (HMA)."* Different temperatures and loading frequencies are being used to evaluate the change in asphalt stiffness. The dynamic modulus test method is very time consuming. Therefore, the results will be included in the final report.

Conclusion:

In conclusion, applying calcium chloride and sodium chloride on the roads may produce impacts to infrastructure in Edmonton. It was concluded that both the chemical and physical (freeze-thaw) reaction need to occur in order for detrimental effects on the samples. Visual deficiencies such as mortar flaking and pop outs became apparent immediately upon freezing. Damage to the samples was restricted to the surface of the cement paste and did not affect the structural capacity of the concrete. Samples treated with brine are roughly 20% more detrimental to concrete compared to NaCl. Also, it was observed that specimens conditioned in ideal conditions performed roughly 15% better compared to specimens conditioned in poor conditions.

The asphalt component of the study showed an increase in binder and mix stiffness. Stiff asphalt mixes are more prone to cracking. Samples treated with brine were more detrimental to asphalt pavement compared to NaCl. This result concurs with the findings documented in other research. While it is known that environmental conditions such as freeze-thaw stiffen and oxidize pavement, the salt application may compound pavement stiffening and oxidation. The extent of damage attributed the chemical effects salt compared to that of freeze-thaw is inconclusive. Application of calcium chloride over the life of a pavement may negatively impact its long-term performance. Engineering Services recommends further testing in this area in the future.

I trust this information is satisfactory. If you have any further questions please contact Aleem Nawla at (587) 599-3211 or Faizal Kanji at (780) 442-7087.

W Goulden

Reviewed by Wanda Goulden, P.Eng., P.Geo.