



THURBER ENGINEERING LTD.

March 1, 2024

File No.: 20663

BC Ministry of Transportation
310 – 1500 Woolridge Street
Coquitlam, BC
V3K 0B8

Attention: Vincent Ong / Mohsin Gohir

KENSINGTON WESTBOUND OFF-RAMP CAPPING SLAB REPAIR SUMMARY OF CONCRETE DURABILITY ASSESSMENT

Dear Vincent / Mohsin,

This report summarizes concrete durability assessment performed by Thurber Engineering Ltd. (Thurber) for the new cast-in-place concrete capping slab for the westbound off-ramp of the Kensington Avenue interchange.

It is a condition of this letter report that the performance of Thurber's professional services is subject to the attached Statement of Limitations and Conditions.

1. BACKGROUND

1.1 General

The Kensington westbound ramps and Kensington underpass approach embankment are built on a pile-supported embankment. Pavement distress, including edge cracking and peak and trough distress has occurred on the off-ramp and northbound Kensington lanes near the intersection. Thurber completed an assessment of remediation options for the Kensington interchange westbound ramps in a memo dated November 7, 2018.

A cast-in-place concrete capping slab repair concept is proposed. The proposed capping slab will comprise a 250 mm thick cast-in-place concrete slab reinforced with two mats of black steel reinforcement. The specified concrete cover is 50 mm (top and bottom). The slab will be surfaced with 80 mm of asphalt placed directly over the concrete surface (no waterproofing membrane). Helical piles will be required for a portion of the off-ramp to re-establish a full-width shoulder where the existing barrier has been shifted in an area of edge cracking. The proposed capping slab will roughly match the limits of pavement surface repairs completed in fall 2022.



1.2 Service Life and Durability Strategies

The design service life for the capping slab is 50 years, which is consistent with the design service life of a continuously reinforced concrete pavement system.

A service life can be broadly defined as the elapsed time during which the concrete element can adequately meet its performance and serviceability requirements. Reaching the end of the service life essentially means that a major rehabilitation must be performed in order to keep the structure operational and does not mean a permanent loss of the structure.

Two general approaches were utilized for the durability assessment:

- “Deemed to Satisfy” approach – application of prescriptive rules and provisions from the codes and standards (such as CSA Standards) to substantially avoid concrete deterioration.
- “Design to Resist” approach – deterioration is allowed to a certain defined limit state based on the performed resistance assessment or modelling.

“Deemed to Satisfy” approach was used to address the following concrete degradation mechanism relevant to the subject concrete element, which were classified as Category 1 degradation mechanisms:

- Alkali-Aggregate Reaction (AAR).
- Sulphate attack.
- Freeze-thaw deterioration.
- Excessive shrinkage cracking.

“Design to Resist” approach was used to address the following degradation mechanism, which is classified as Category 2 degradation mechanism:

- Chloride induced reinforcing steel corrosion.

For this project, as related to reinforcing steel corrosion, the service life is defined as corrosion initiation period plus corrosion propagation period (elapsed time from corrosion initiation to first reinforcing steel corrosion related concrete damage). A fixed corrosion propagation period of six years was used for the service life assessment.

Due to the relatively impermeable asphalt overlay over the slab surface, which is expected to provide sufficient barrier between the concrete and carbon dioxide in air and prevent substantial

concrete saturation, carbonation induced reinforcing steel corrosion is not considered to be a relevant concrete deterioration mechanism within the specified service life of 50 years.

The above-listed deterioration mechanisms are discussed in further detail in Section 2 below.

2. DURABILITY ASSESSMENT RESULTS

2.1 Category 1 Degradation Mechanisms

Category 1 concrete degradation mechanisms and associated mitigation methods are summarized in Table 1 below.

Table 1: Concrete Degradation Mechanisms and Mitigation Methods

CONCRETE DEGRADATION MECHANISM	MITIGATION METHODS
Alkali-Aggregate Reaction (AAR)	<ul style="list-style-type: none"> - Non-reactive concrete aggregates, or - Mitigating the reaction as per preventative measures outlined in CSA A23.2-27A Standard Practice.
Sulphate Attack	<ul style="list-style-type: none"> - Backfill materials with water-soluble sulphate concentration of below 0.1%. - Adequate drainage.
Freeze-Thaw Deterioration	<ul style="list-style-type: none"> - Freeze-thaw resistant aggregates compliant with requirements specified in Table 12 of CSA A23.1-19. - C-1 Class of Exposure as per Table 2 of CSA A23.2-19. - Hardened concrete air-void system in accordance with Clause 4.3.3 of CSA A23.1-19. - Adequate drainage to reduce degree of concrete water saturation. - Adequate concrete maturity prior to exposure to cyclic freezing and thawing in saturated condition. - A minimum air-drying period of 30 days after final curing and prior to exposure to freezing conditions and deicing salts.
Excessive Shrinkage Cracking	<ul style="list-style-type: none"> - 7-day wet curing. - Adequate reinforcement. - Concrete shrinkage consistent with requirements specified in Clause 8.8 of CSA A23.1-19 (when tested in accordance with CSA A23.2-21 Standard Test Method).

2.2 Category 2 Degradation Mechanism

Life-365 software was used for concrete chloride ion diffusion analysis to determine the length of the corrosion initiation period. The corrosion initiation period can be defined as a time period necessary for chloride ions to penetrate the concrete cover and accumulate in sufficient quantity at the depth of the reinforcement to initiate corrosion of the steel. The model predicts the initiation

period assuming a crack free concrete section and that the diffusion is the dominant mechanism. The model is based on Fick's second law of diffusion.

The following input parameters were used for the assessment:

- **Exposure Conditions:** The location specific climatic conditions and structure specific chloride exposure conditions from Life-365 database were used for the analysis.
- **Element Geometry and Design Parameters:** The following inputs were used for the analysis:
 - Slab thickness: 250 mm.
 - Concrete cover over the top rebar mat: 50 mm.
 - Reinforcing steel material: Carbon (Black) Steel.
- **Protection Systems:** It is assumed that the asphalt overlay will remain 70% impermeable for a period of 10 years. Please note, that this is a conservative assumption as the asphalt will be repaired and/or replaced during the service life of the slab.
- **Concrete Mix Design Parameters:** The following inputs were used for the analysis:
 - Class of Exposure: C-1
 - W/C Ratio: 0.38
 - Cement Type: GU/GUL
 - SCMs: 25% Type F Fly Ash

Results of the analysis indicated corrosion initiation period of 46 years. As discussed in Section 1.2, the service life has been defined as the end of a 6-year corrosion propagation period. Therefore, the service life of the cast-in-place concrete capping slab was estimated to be **52 years**, which meets the desired service life of 50 years.

Life-365 report is provided in Appendix A for your reference.

3. CONCRETE MIX DESIGN SPECIFICATIONS

Capping slab concrete mix specifications derived from the durability assessment are summarized in Table 2 below.



Table 2: Concrete Mix Specifications

PROPERTY	TEST PROCEDURE	SPECIFIED VALUE
Compressive Strength 7 days / 28 days	CSA A23.2-9C	25 MPa / 35 MPa
CSA Cement Type	-	GU/GUL
Type F Fly Ash Content ¹	-	≥25%
CSA Class of Exposure	-	C-1
Fresh Concrete Air Content	CSA A23.2-7C	5-8%
Maximum Water/Cement Ratio	-	0.38
Hardened Concrete Air-Void System Average Spacing Factor	ASTM C457	≤0.23 mm
Slump	CSA A23.2-5C	To be proposed by the Contractor based on concrete placement and consolidation methods ²
Chloride Ion Penetrability (91 days)	CSA A23.2-23C	<1500 Coulombs
Shrinkage (75 mm prism; 28-day drying)	CSA A23.2-23C	≤0.04%
Chloride Migration Coefficient	NT Build 492	≤7.10E-12 m ² /sec

NOTES:

- (1) Type F fly ash content can be lowered if silica fume is used in the concrete mix.
- (2) Subject to approval by the Engineer of Record.

All tests listed in Column 2 of Table 2 above must be performed during the concrete trial batching to verify compliance of the proposed concrete mix with requirements specified in Column 3.

4. CONCRETE PLACEMENT AND QUALITY CONTROL

Concrete production, placement, curing and quality control testing during construction shall comply with requirements specified in Section 211 of BC MoTI 2020 Standard Specification for Highway Construction.

As discussed above, crack free concrete section was assumed for the service life analysis. Therefore, the top surface of the slab shall be visually assessed prior to the asphalt overlay placement. All cracks identified on the top surface shall be measured using a crack comparator. All cracks with a width (at the surface) of over 0.2 mm shall be documented and repaired by gravity feeding a suitable low viscosity epoxy repair material.



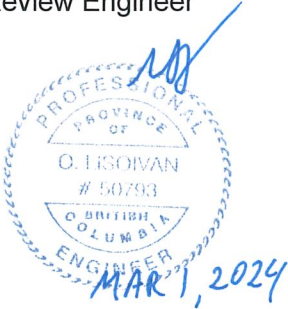
THURBER ENGINEERING LTD.

To confirm concrete cover over the top reinforcing steel mat, ground penetrating radar (GPR) scanning should be performed along the entire footprint of the capping slab. All areas with lower than the specified concrete cover should be documented on a plan view drawing.

5. CLOSURE

We trust this is sufficient for your present needs. Please contact us if you have any questions.

Yours truly,
Thurber Engineering Ltd.
Paul Wilson, M.Eng., P.Eng.
Review Engineer



Oleksandr Lisoivan, P.Eng.
Construction Materials Engineer

Attachments:

- Statement of Limitations and Conditions
- Appendix A – Life-365 Report

Thurber Engineering Ltd.
Permit to Practice # 1001319



STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client, the BC Ministry of Transportation and Infrastructure (MoTI) and Authorized Users as defined in the MoTI Special Conditions Form H0461d. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Any use which an unauthorized third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any unauthorized third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

APPENDIX A

Life-365 Report

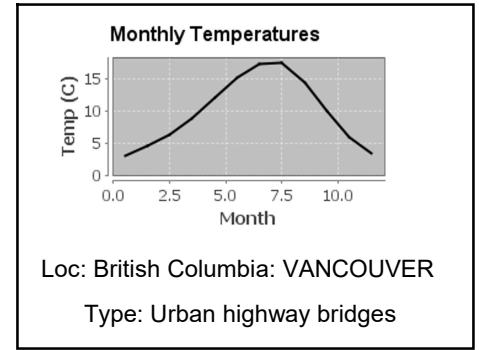
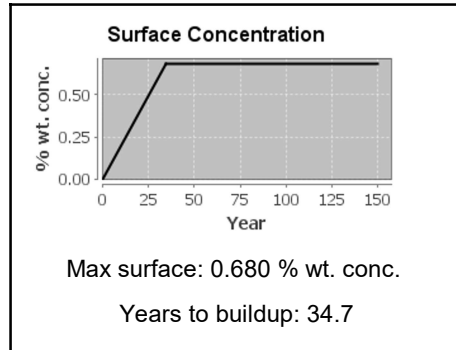
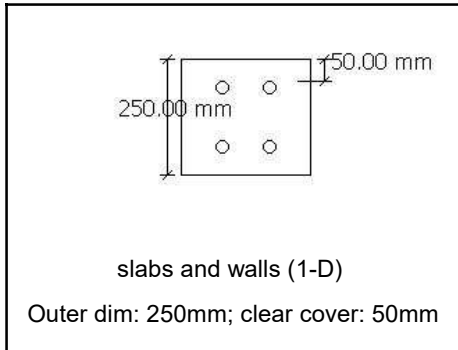
Life-365 v2.2 - Concrete Mixes and Service Lives

Project: Kensington Off-Ramp Remediation

Description: Default settings for a new project

Analyst: OL

Date: 01/31/2024



Concrete Mixes

Alt name	User?	w/cm	SCMs	Inhib.	Barrier	Reinf.
Base case		0.38	Class F Fly Ash (25%);		Membrane	Black Steel
Alternative 1		0.38	Class F Fly Ash (25%);		Membrane	Black Steel

"n/a" indicates that, since the user is specifying the diffusion properties of this mix, this value is not specified.

Diffusion Properties and Service Lives

Alt name	D28	m	Ct	Init.	Prop.	Service life
Base case	7.11E-12 m*m/sec	0.4	0.05 % wt. conc.	46.3 yrs	6 yrs	52.3 yrs
Alternative 1	7.11E-12 m*m/sec	0.4	0.05 % wt. conc.	46.3 yrs	6 yrs	52.3 yrs

"->" indicates that the user has directly specified this value; "+" indicates the service life exceeds the study period.