THURBER ENGINEERING LTD.

MEMORANDUM

To: Ryan Gustafson, P.Eng
BC Ministry of Transportation and Infrastructure
Date: November 4, 2022

From: Warren Wunderlick, P.Eng, Jessica Dhami, M.A.Sc., GIT
File: 33450

Review: J. Suzanne Powell, Ph.D., P.Eng.

PENDER ISLAND – CANAL ROAD DIP SLIDE
ROCK DURABILITY TESTING MEMO (REVISION 1)

This memorandum provides the results of durability testing undertaken on rock samples from the Canal Road dip slide site on Pender Island, BC. We have also summarized the suitability for re-use of both rock types based on the lab results. A previous version of this memorandum was issued on August 25, 2022. Since issuance, additional samples have been collected and analysed for durability. This memorandum summarises both the original results and the results of the additional samples.

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

1. BACKGROUND

Following the atmospheric river events of November 2021, the BC Ministry of Transportation and Infrastructure (MoTI) identified possible worsening of a known active landslide and is now proposing to stabilize this approximately 300 m long segment of Canal Road on South Pender Island, BC.

This section of Canal Road is located approximately 3 km from the Pender Canal Bridge, immediately to the east of the Mt. Norman Access Road and bordering the Beaumont-Gulf Islands National Park Reserve. The road is located at the crest of a steep slope, with an average slope angle of about 40° down to ocean (north). Bedrock or colluvium is exposed on the upslope (south) side of the road. Crown land and private property are located downslope of the slide and Parks Canada (Mt Norman) on the upslope (south) side.

Thurber has undertaken geotechnical investigations and provided recommendations for the road realignment; these deliverables have been provided separately. Two bedrock types have been identified at the site: a conglomerate of the De Courcy Formation and a siltstone/shale which may be from the Cedar District Formation or may be a siltstone lens of the De Courcy Formation.

The proposed future road realignment will require blasting into bedrock and will produce a significant surplus of blast-rock material. MoTI requested that Thurber conduct durability analysis

on the two rock types to assess suitability for reuse as structural backfill, riprap, or pavement gravels.

The civil design team (McElhanney) is developing quantity estimates for the rock excavation separately.

2. SAMPLE COLLECTION

On July 21, 2022, Maggie Cramb, EIT of Thurber visited the Canal Road site to collect rock samples for durability testing. Samples of both rock types were collected by breaking off outcrop fragments using a rock hammer. Approximate locations of sample collection are shown on Figure 1 (attached).

At request of MoTI, On September 13, 2022, Jessica Dhami, GIT of Thurber returned to the site accompanied by Alex Hutter, GIT of MoTI, to collect additional samples of the conglomerate. A hand operated hammer drill, rock hammer, and mallet were used to collect conglomerate samples at six discrete locations along the outcrop. Each sample was approximately 18 to 19 L in volume (one 5-gallon pail). Sample locations were marked in the field and surveyed by McElhanney Ltd. Locations of each sample are shown on Figure 1 (attached).

3. LABORATORY TESTING

3.1 Initial Samples

Samples collected in July were sent to our Edmonton Asphalt and Advanced Aggregate Laboratory for testing. The *Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus* (ASTM D6928-17) test was run on both rock types.

3.2 Secondary Samples

Samples collected in September were sent to Golder Associates Inc.'s (Golder) laboratory in Burnaby, BC for analysis. Due to the small sample size, samples 3 and 4 as well as samples 5 and 6 were combined to obtain volumes required for ASTM testing. *Testing Rock Slabs to Evaluate Soundness of Riprap by Use of Sodium Sulfate or Magnesium Sulfate* (ASTM D5240) was run on samples 1, 2, and 3/4, sample 5/6 did not have any rock slabs large enough for testing. *Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus* (ASTM D6928-17) and *Specific Gravity And Absorption of Rock For Erosion Control* (ASTM D6473) were run on all samples.

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4. LABORATORY RESULTS

Laboratory results are presented in Table 1 below.

Table 1. Summary of laboratory results for durability testing.

		Magnesium Sulphate Soundness (ASTM D5240) Loss (%)	Micro-Deval (ASTM D6928) Loss Factor (%)	Specific Gravity (ASTM D6473) (Dry Basis)	Specific Gravity (ASTM D6473) (SSD Basis)	Apparent Specific Gravity (ASTM D6473)	Absorptivity (ASTM D6473) (%)
July Samples	Siltstone	-	90.7	-	-	-	-
	Conglomerate	-	29.3	-	-	-	-
September Samples	Sa.1	2.0	12.2	2.579	2.613	2.670	1.32
	Sa.2	4.3	19.5	2.515	2.574	2.673	2.36
	Sa.3/4	0.8	22.9	2.577	2.620	2.691	1.66
	Sa.5/6	-	21.2	2.478	2.547	2.662	2.79

5. MATERIAL RE-USE SUITABILITY

To determine material suitability for re-use as aggregate or riprap, we have compared laboratory results to requirements in Sections 202 and 205 of the *2020 Standard Specifications for Highway Construction Volume 1 of 2* (BC MoTI) (Standard Specs).

5.1 Re-Use as Aggregate

Based on the initial Micro-Deval testing, the siltstone material does not meet the criteria for re-use as any aggregate type. The conglomerate material may be suitable for use as Surfacing Aggregate, 25 mm or 50 mm Base Course, Subbase Aggregates, or Bridge End Fill, all of which have maximum Micro-Deval loss factors of ≤ 25% or ≤ 30%. Sa. 1 also meets the criteria for 75 mm Base Course which has a Micro-Deval loss factor of ≤ 17%.

5.2 Re-Use as Riprap

Based on the initial Micro-Deval testing, the siltstone material does not meet the criteria for re-use as Riprap. The allowable values for use as Riprap, as stated in Table 205-A of the Standard Specs are summarized in Table 2.

Table 2. Allowable values for Riprap from Table 205-A of the Standard Specs.

Property	Allowable Value
Specific Gravity	≥ 2.50
Absorption	≤ 2%
Soundness by use of Magnesium Sulphate	≤ 10%
Micro-Deval Abrasion Loss Factor	≤ 20%

Based on the results received from Golder, the conglomerate meets the allowable value for Specific Gravity except for Sa. 5/6 which marginally fails with a value of 2.478 (Dry Basis) but passes for SDD basis and Apparent Specific Gravity. Samples Sa.1 and Sa. 4/3 meet the criteria for absorptivity, while Sa. 2 and Sa. 5/6 have results above the minimum allowable value. Two of the samples, Sa. 1 and Sa. 2 have Micro-Deval loss factors within the allowable value, while Sa. 3/4 and Sa. 5/6 both have results higher than the allowable value. All samples are within the allowable value for Soundness by Magnesium Sulphate.

6. CONCLUSION

The siltstone is not suitable for re-use as either Aggregate or Riprap. The conglomerate durability results are acceptable for use as most Aggregate types and on the margin of acceptability for use as Riprap. Since material re-use is not proposed for this project, the results should be provided to any future users of the material to assess acceptability of the product.

The conglomerate appears visually, relatively uniform across the site. Variability within the laboratory results is likely a reflection of variability within the conglomerate, and not representative of discrete regions within the rock. Therefore, we consider averaging the laboratory results for the conglomerate across all samples would be acceptable to represent the material as a whole and inform any future users.

Regardless of the results of durability testing, blast rock is considered acceptable for reuse as embankment fill.

7. CLOSURE

We trust this provides you sufficient information for your needs at this time. If you have any questions or would like to discuss these recommendations, please contact us.

Attachments:

- Statement of Limitations and Conditions
- Figure 1 - Rock Sample Location Plan
- Thurber Lab Test Reports
- Golder Lab Reports

Thurber Engineering Ltd.
Permit to Practice #1001319

2022.11.04
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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.

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Pender Island - Canal Road Slide
Rock Sample Location Plan

0 10 20 m

Notes:
2021 base imagery obtained from CRD

FIGURE 1

Client: BC MoTI
File No: 33450

Date: October 27, 2022
Drawn by: JBD

THURBER ENGINEERING LTD.

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P: 780 438 1460 F: 780 437 7125

TEST REPORT

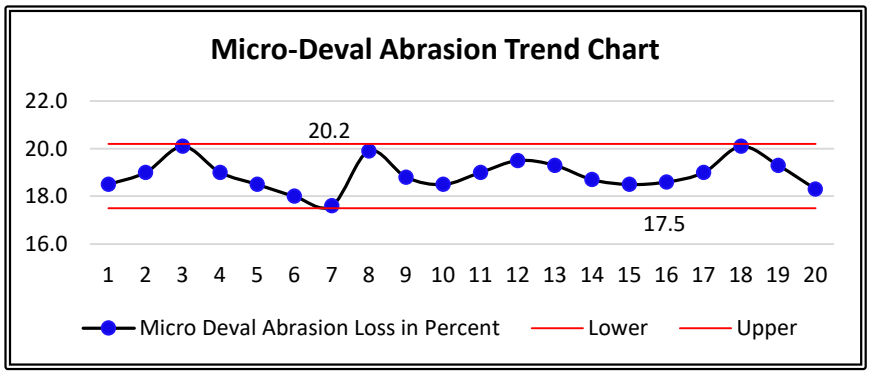
Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus

Client :	BC MOTI	Sampling Date :	July 21, 2022
Project :	Pender Island-Canal Road	Receiving Date :	July 26, 2022
Project No :	33450-20.22	Testing Date :	August 4, 2022
Series No :	N/A	Source :	N/A
Material Type :	Conglomerate	Standard :	ASTM D6928-17

Sample Test Report	
Description	Result
Grading Used	**8.2**
% Loss of Fines	**29.3**

Calibration Aggregate Test Report	
Description	Result
% Loss of Fines	**19.5**
% Mean Loss	**18.9**

Sample : Reference Material (MTO-RM CA2)



Comments :

Tested By : NR

Reviewed By:

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TEST REPORT

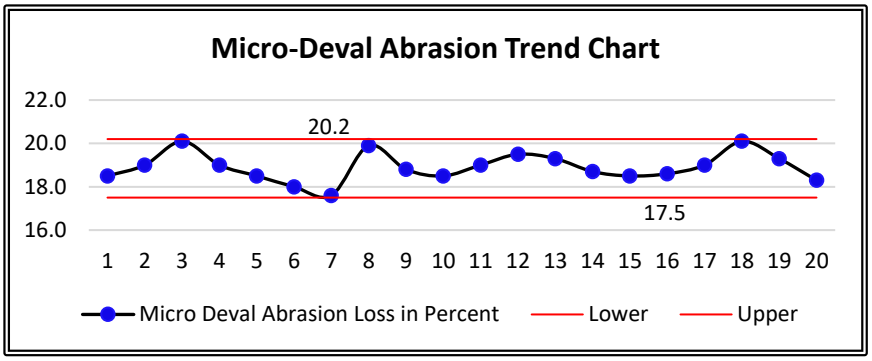
Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus

Client :	BC MOTI	Sampling Date :	July 21, 2022
Project :	Pender Island-Canal Road	Receiving Date :	July 26, 2022
Project No :	33450-20.22	Testing Date :	August 4, 2022
Series No :	N/A	Source :	N/A
Material Type :	Siltstone/Shale	Standard :	ASTM D6928-17

Sample Test Report	
Description	Result
Grading Used	**8.2**
% Loss of Fines	**90.7**

Calibration Aggregate Test Report	
Description	Result
% Loss of Fines	**19.5**
% Mean Loss	**18.9**

Sample : Reference Material (MTO-RM CA2)



Comments :

Tested By : NR

Reviewed By:

GOLDER
MEMBER OF WSP

EVALUATION OF DURABILITY OF ROCK FOR EROSION CONTROL USING MAGNESIUM SULFATE

ASTM D5240

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400717, Easting: 483466	Date received:	September 19, 2022
Sample ID:	SA1	Sampled by:	Client
Date tested:	October 3 - 12, 2022	Tested by:	FF/KS

1.0. OBJECTIVE AND METHOD

The objective of this laboratory test was to evaluate the resistance to breakdown of rock samples upon repeated exposure to magnesium sulfate solution. This report comprises a testing service only.

Individual rock samples were reviewed to enable the selection of a sample suitable for the preparation of slab specimens that satisfy the requirements of ASTM D5240. Since much of the bulk rock material submitted testing was found to be too weak to produce the required number of specimens per clause 8.2.1 and 8.2.2 of the ASTM D5240, only a single slab specimen 65 ± 5 mm thick was cut using a water-cooled diamond saw; it was larger than 125 mm in length and width. The single specimen was prepared, and labelled as "1".

The test was conducted such that the specimen was subjected to five cycles of immersion and drying. The immersion portion of each cycle consisted of storing the specimen in a solution of magnesium sulfate for 16 hours, followed by 8 hours of drying in an oven at 110°C. The specimen was left in the oven when the test was interrupted.

The condition of the slab specimen was evaluated before and after the five cycles through macroscopic and microscopic examination using a binocular microscope with magnifications up to 50x. Observations were made of material dislodgement, pre-existing cracks, and newly developed deterioration. At each inspection, a photo and inspection log were generated for the specimen. The mass of the slab specimen was determined both prior to and at the end of the test procedure, and the percent loss by mass was calculated.

2.0. QUANTITATIVE ANALYSIS

The individual percent loss for the single specimen, by mass, is given in Table 1.

Table 1: Percent Mass Loss

Specimen ID	Measured Mass Loss *(%)*
1	2.0

The sample remained intact and did experience some loss of material. The percent loss was 2.0%.

3.0. QUALITATIVE ANALYSIS

The specimen was examined macroscopically and microscopically before and after the test.

3.1. Summary of Initial Observations

The specimen was a clastic sedimentary rock with grain size ranging from fine sand to gravel. The sample was moderately competent and exhibited oxidation/rusty staining on the weathered surfaces.

Description of the slab is provided below.

Slab 1: Dark grey, grey, buff-brown, locally rusty brown on weathered surface, fine to medium grained poorly sorted lithic sandstone. The sample has one 4 cm-thick layer of coarse pebbly sandstone. The matrix is silty. Sand grains have various shapes and lithological composition (volcanics, sandstone, coal, chert, minor carbonate, many rusty clasts) and range from angular to subrounded. The sample can be scratched with a steel knife with various degrees of effort (generally medium effort, locally harder, locally softer). Minor debris comes off upon touch. Locally the sample is porous and vuggy, with the pores/vugs visible under the microscope. Locally the vugs are coated with iron oxide. Reaction to HCl is localized to the carbonate grains. No response to the magnet was observed. The sample shows fractures and hairline fractures. Face I shows fractures and hairline fractures at random orientations, Face II shows fractures along the boundary between the fine sandstone and the gravelly sandstone.

3.2. Observation of Individual Specimens

Specimen ID	Initial Observation	Final Observation after 5 Cycles
1	Sample shows fractures and hairline fractures. Face I shows fractures and hairline fractures at random orientations. Face II shows fractures along the boundary between the fine sandstone and the gravelly sandstone.	Sample remained intact. One large piece came off and some fine-grained material dislodged upon touch. Face I some clasts came off from the gravelly layer. Face II no significant change.

3.3. Summary of Deterioration

The specimen remained intact and experience some material loss. The slab became more fragile with material loss upon slight touch. Fractures became wider and deeper. One cm-size chip detached form one edge.

4.0. OVERALL SUMMARY

The specimen was a grey, rusty brown, poorly sorted sandstone moderately weathered. Some loss of material and moderate deterioration was observed.

The data contained in this report pertain to the samples provided for testing and are not applicable to material from other locations or trial periods.

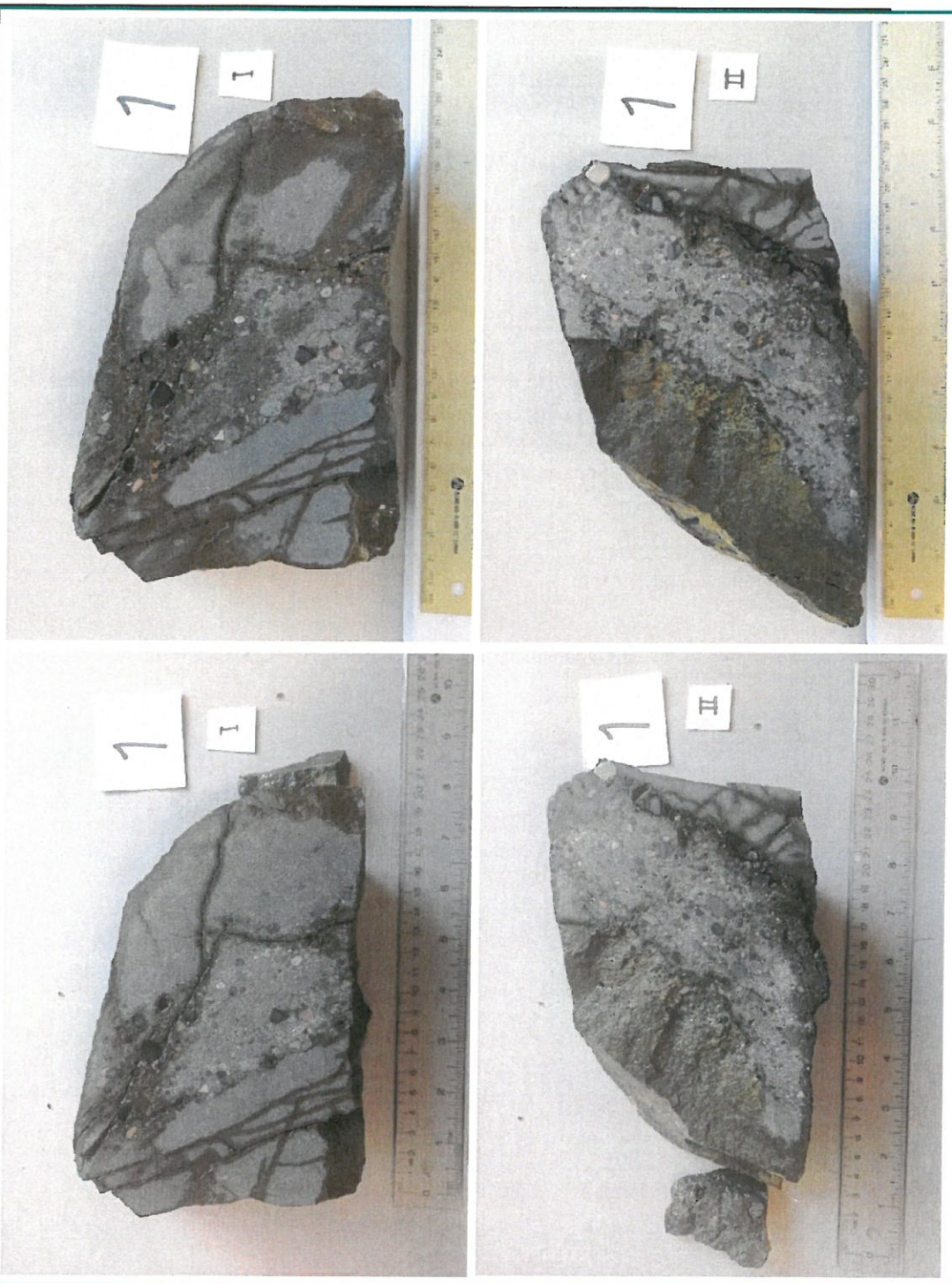
Reported by: F. Furlanetto, Ph.D., P.Geo.

Reviewed by: _____
F. Shrimer, P.Geo.

APPENDIX A: SPECIMEN SURFACE PHOTOGRAPHS

Photo 1.

Slab 1 prior to soundness cycles (upper photos) and after cycles (lower photos).



GOLDER
MEMBER OF WSP

EVALUATION OF DURABILITY OF ROCK FOR EROSION CONTROL USING MAGNESIUM SULFATE

ASTM D5240

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400716, Easting: 483445	Date received:	September 19, 2022
Sample ID:	SA2	Sampled by:	Client
Date tested:	October 3 - 12, 2022	Tested by:	FF/KS

1.0. OBJECTIVE AND METHOD

The objective of this laboratory test was to evaluate the resistance to breakdown of rock samples upon repeated exposure to magnesium sulfate solution. This report comprises a testing service only.

Individual rock samples were selected to produce slab specimens that satisfy the requirements of ASTM D5240. Bulk rock specimens submitted for this test were too weak and brittle to meet the minimum number of specimens required per clause 8.2.1 and 8.2.2 of the ASTM D5240 standard. Slab specimens 65 ± 5 mm thick were cut using a water-cooled diamond saw, with most specimens larger than 125 mm in length and width. Three lab specimens were prepared and labelled as 2A, 2B, 2C.

The test was conducted such that the specimens were subjected to five cycles of immersion and drying. The immersion portion of each cycle consisted of storing the specimens in a solution of magnesium sulfate for 16 hours, followed by 8 hours of drying in an oven at 110°C. Specimens were left in the oven when the test was interrupted.

The condition of each slab specimen was evaluated before and after the five cycles through macroscopic and microscopic examination using a binocular microscope with magnifications up to 50x. Observations were made of material dislodgement, pre-existing cracks, and newly developed deterioration. At each inspection, a photo and inspection log was generated for each specimen. The mass of each slab specimen was measured prior to and at the end of the test, and the percent loss by mass was calculated for each specimen. In cases of specimens breaking into smaller sub-specimens during testing, the largest remaining piece of the slab was used for mass loss calculations.

2.0. QUANTITATIVE ANALYSIS

The individual percent losses by mass for the specimens are summarized in Table 1.

Table 1: Percent Mass Loss

Specimen ID	Measured Mass Loss *(%)*
2A	5.6
2B	1.5
2C	5.8
Total	**4.3**

All samples remained intact and experienced some loss of material. The cumulative average percent loss by mass for the three specimens was 4.3 %.

3.0. QUALITATIVE ANALYSIS

Each specimen was examined macroscopically and microscopically before and after the test.

3.1. Summary of Initial Observations

The specimens are clastic sedimentary rocks with grain sizes ranging from sand to coarse gravel. They range in colour from brownish-grey, grey, and dark grey to buff and beige, with some rust-coloured zones. Some samples broke during preparation. The samples are weakly to moderately weathered and exhibit oxidation/rusty staining on the weathered surfaces.

Descriptions of the slabs are provided below.

Slab 2A: Light brownish grey, grey, beige, reddish orange, dark grey conglomerate. Reddish brown on the weathered surface. Pebble clasts are subrounded and have various shapes (some are subprismatic, some are oval, some are flattened). Grain size ranges from 2 mm to 4 cm. The sandy matrix is rust coloured, and the sand grains are angular to subangular. The lithological composition of the clasts includes volcanic, metamorphic, quartz, sandstone, siltstone, chert. Grains have a limonite-hematite coating. The sample can be scratched with a steel knife. Reaction to HCl is absent and no magnet response was observed. A few pits and vugs are visible under the microscope. The sample is fractured. Face I shows one fracture and one pit (a gravel clast that was removed during sample preparation), and one piece of slab is about to come off. Face II shows a few shallow pits.

Slab 2B: Light brownish grey, grey, beige, sand-supported conglomerate. Light rusty brown on weathered surface. Pebble clasts are subangular to subrounded and have various shapes (some are subprismatic, some are oval, some are flattened). Grain size ranges from a few mm to 5.5 cm, and average 1 cm. The sandy matrix is rust coloured, and the sand grains are angular to subangular. The lithological composition of the clasts includes volcanic, granitic, metamorphic, quartz, sandstone, siltstone, and chert. Grains have a limonite-hematite coating. The sample can be scratched with a steel knife. Reaction to HCl is absent and no magnet response was observed. The sample is fractured and a few pits and vugs are visible.

Face I shows a few pits and a couple of small fractures around the gravel clasts. Face II shows three discontinuous fractures and a few pits, and one gravel clast about to detach.

Slab 2C: Light brownish grey, grey, beige, reddish orange, dark grey, sand-supported conglomerate. Reddish brown on weathered surfaces. Pebble clasts are subrounded and have various shapes (some are subprismatic, some are oval, some are flattened). Grain size ranges from 2 mm to 4 cm, and average 4-5 mm. The sandy matrix is rust coloured, and the sand grains are angular to subangular. The lithological composition of the clasts includes volcanic, metamorphic, quartz, sandstone, siltstone and chert. Grains have a limonite-hematite coating. The sample can be scratched with a steel knife. Reaction to HCl is absent and no magnet response was observed. A few pits and vugs are visible under the microscope. Sample is fractured. Face I shows few pits (a result of gravel clasts that came off during sample preparation). Face II shows few shallow pits and three fractures.

3.2. Observation of Individual Specimens

Specimen ID	Initial Observation	Final Observation after 5 Cycles
2A	Few pits and vugs are visible under the microscope. Sample is fractured. Face I shows one fracture and one pit (a gravel clast came off during sample preparation), and one piece of slab is about to come off. Face II shows a few shallow pits.	Sample remained intact. The edges of the slab are more rounded. Minor material loss and some fine-grained material dislodges upon touch. Both faces became more porous and substantially rougher. Some gravel clasts came off.
2B	Sample is fractured and few pits and vugs are visible. Face I shows few pits and a couple of small fractures running around the gravel clasts. Face II shows three discontinuous fractures and a few pits, and one gravel clast about to detach.	Sample remained intact. Some gravel clasts came off, and the cracks around the pebbles became wider. Face II became more porous and rougher.
2C	Few pits and vugs are visible under the microscope. Sample is fractured. Face I shows few pits (as result of gravel clasts that came off during sample preparation). Face II shows few shallow pits and three fractures.	Sample remained intact. Some debris can be dislodged upon touch. The edges of the slab are rounded, and the overall porosity is much higher. The sample exhibits a more intense rusty color on the edges. Face I became more porous and rougher. The sandy matrix eroded, and the gravel clasts stand out. The fractures became wider and deeper. Face II one triangular piece came off from the right side. The surface is rougher and more porous. The gravel clasts stand out against the more eroded sandy matrix. Many gravel clasts came off.

3.3. Summary of Deterioration

All specimens remained intact and experienced variable material loss. The slabs became significantly more porous and more brittle, with material loss upon slight touch, and the edges became rounded.

The gravelly samples experienced differential loss, with the sandy matrix more degraded and the coarse clasts standing out or absent.

4.0. OVERALL SUMMARY

The specimens were brownish grey, grey, rusty brown, beige, and dark grey poorly sorted sandstone and conglomerate. The samples were weakly to moderately weathered and showed pits and fractures.

Some loss of material and moderate deterioration was observed.

The data contained in this report pertain to the samples provided for testing and are not applicable to material from other locations or trial periods.

Reported by: F. Furlanetto, Ph.D., P.Geo.

Reviewed by: _____
F. Shrimer, P.Geo.

APPENDIX A: SPECIMEN SURFACE PHOTOGRAPHS

Photo 1.

Slab 2A prior to soundness cycles (upper photos) and after cycles (lower photos).

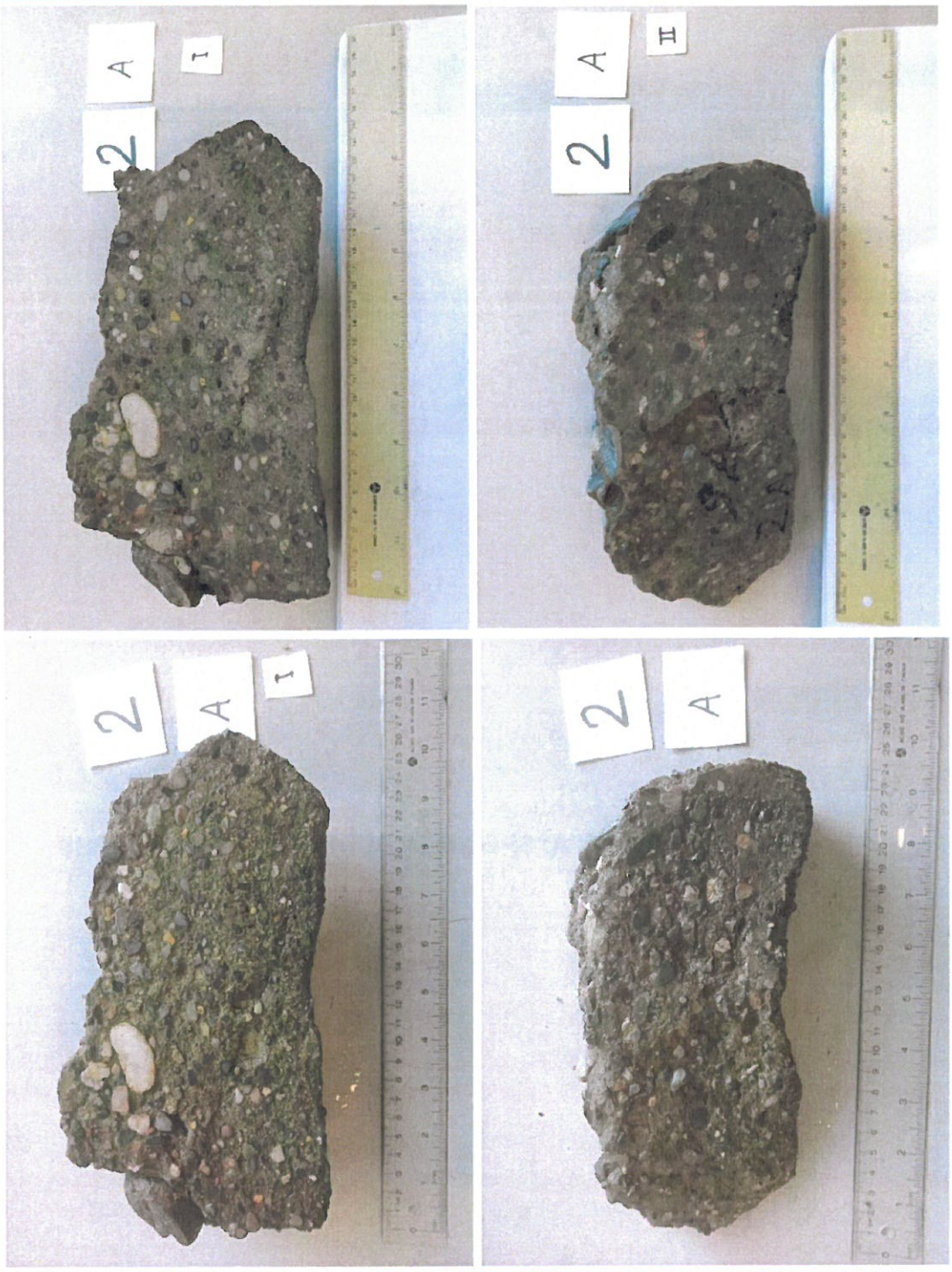


Photo 2.

Slab 2B prior to soundness cycles (upper photos) and after cycles (lower photos).

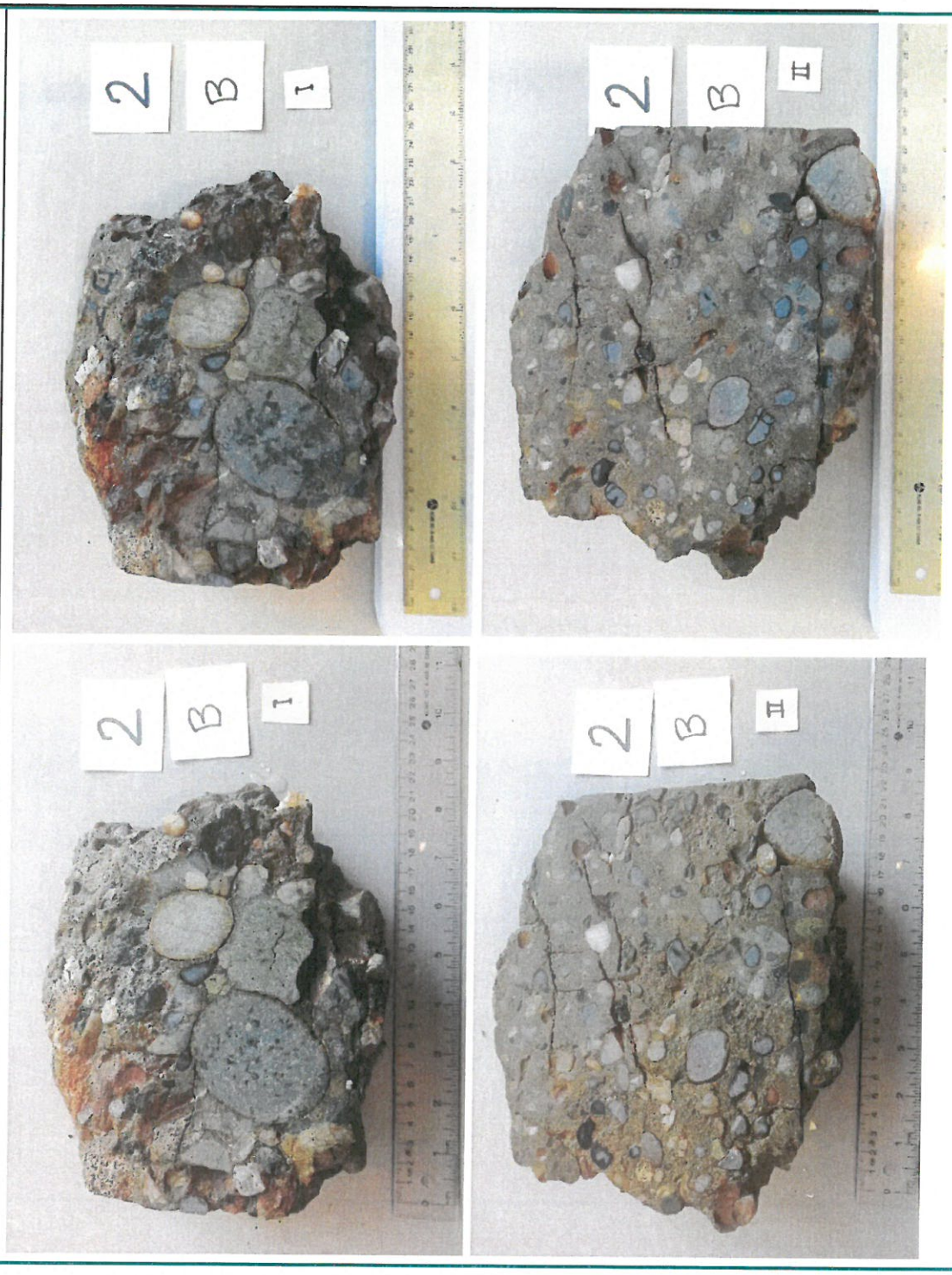
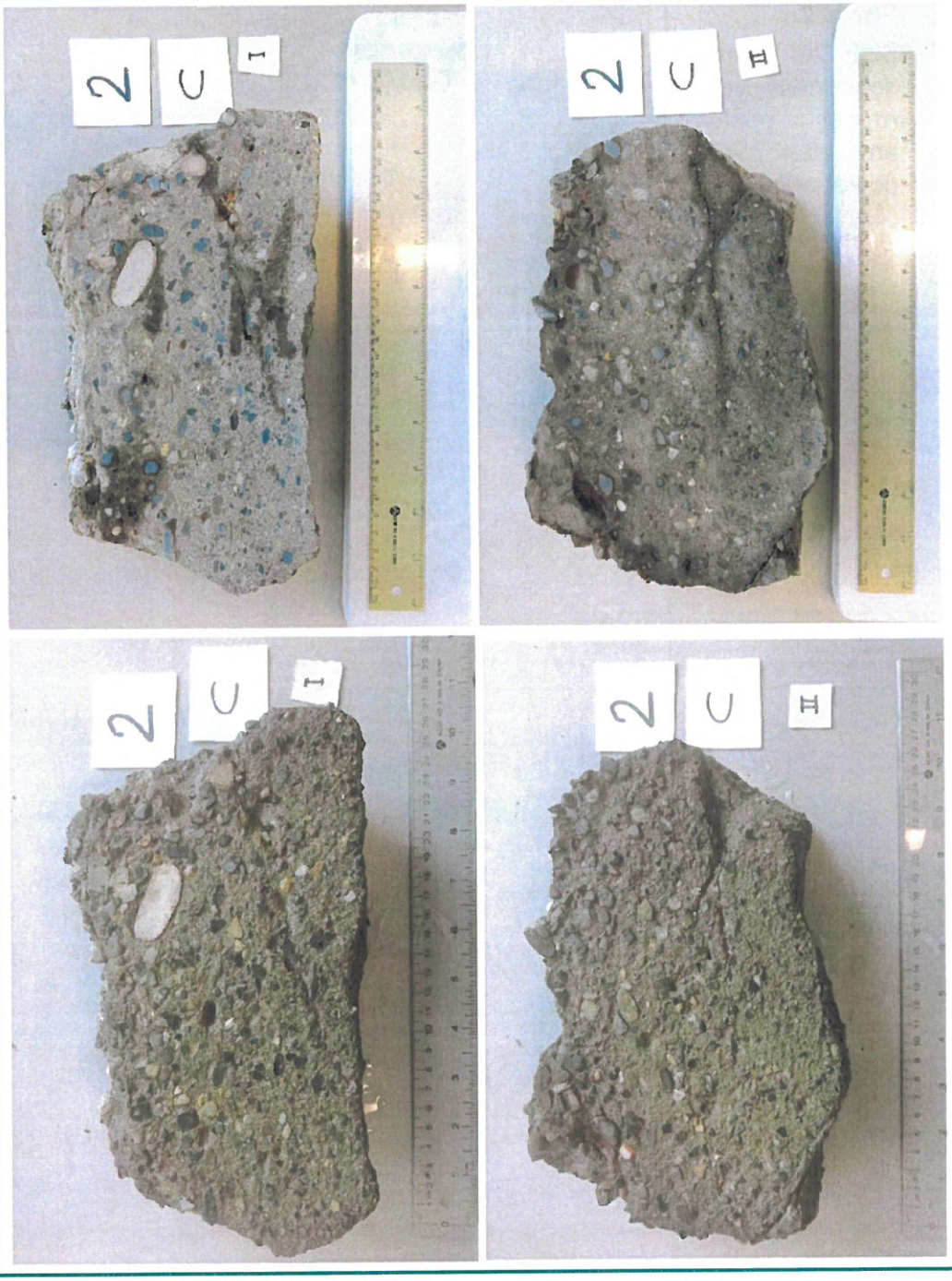


Photo 3.

Slab 2C prior to soundness cycles (upper photos) and after cycles (lower photos).



GOLDER
MEMBER OF WSP

EVALUATION OF DURABILITY OF ROCK FOR EROSION CONTROL USING MAGNESIUM SULFATE

ASTM D5240

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400715, Easting: 483429 & Northing: 5400717, Easting: 483412	Date received:	September 19, 2022
Sample ID:	SA3 and SA4 Combined	Sampled by:	Client
Date tested:	October 3 - 12, 2022	Tested by:	FF/KS

1.0. OBJECTIVE AND METHOD

The objective of this laboratory test was to evaluate the resistance to breakdown of rock samples upon repeated exposure to magnesium sulfate solution. This report comprises a testing service only.

Individual rock samples were selected to enable the preparation of slab specimens that satisfy the requirements of ASTM D5240. Some of the bulk rock specimens that were submitted for testing were too weak to be able to produce a sufficient number of specimens as required by clause 8.2.1 and 8.2.2 of the ASTM D5240 standard. Slab specimens 65 ± 5 mm thick were cut using a water-cooled diamond saw, with most specimens larger than 125 mm in length and width. Four laboratory specimens were prepared and labelled as “3/4A”, “3/4B”, “3/4C”, and “3/4D”.

The test was conducted such that the specimens were subjected to five cycles of immersion and drying. The immersion portion of each cycle consisted of storing the specimens in a solution of magnesium sulfate for 16 hours, followed by 8 hours of drying in an oven at 110°C. Specimens were left in the oven when the test was interrupted.

The condition of each slab specimen was evaluated before and after the test through macroscopic and microscopic examination using a binocular microscope with magnifications up to 50x. Observations were made of material dislodgement, pre-existing cracks, and newly developed deterioration. At each inspection, a photo and inspection log were generated for each specimen. The mass of each slab specimen was determined both prior to and at the end of the test procedure, and the percent loss by mass was calculated for the individual specimens. In cases of specimens breaking into smaller sub-specimens during testing, the largest remaining piece of the slab was used for mass loss calculations.

2.0. QUANTITATIVE ANALYSIS

The individual percent losses by mass for the specimens are summarized in Table 1.

Table 1: Percent Mass Loss

Specimen ID	Measured Mass Loss *(%)*
3/4A	0.8
3/4B	0.4
3/4C	0.3
3/4D	1.4
Total	**0.8**

All samples remained intact and experienced minimal loss of material. The cumulative average percent loss by mass for the five specimens was 0.8 %.

3.0. QUALITATIVE ANALYSIS

Each specimen was examined macroscopically and microscopically before and after the test.

3.1. Summary of Initial Observations

The specimens are clastic sedimentary rocks with grain size ranging form sand to cobble. They are all dark grey, grey, buff, beige, and brownish grey poorly-sorted pebbly sandstone and conglomerate. The samples are weakly to moderately weathered and exhibit slight oxidation/rusty staining on the weathered surfaces.

Descriptions of the slabs are provided below.

Slab 3/4A: Dark grey, grey, beige, and brownish grey, medium-grained pebbly sandstone. Rusty brown on weathered surface. The sand grains are angular to sub-angular and have variable shapes. The pebble clasts are subrounded to rounded. The lithological composition of the grains comprises chert, quartz, volcanic, minor carbonate grains and a trace of shale/schist. The sample can be scratched with steel knife with effort, locally with minor effort, locally cannot be scratched. Reaction to HCl is localized on the carbonate grains, and no response to magnet was observed, except for some rare gravel clasts where there was a very weak attraction. The sample is pitted from grains that came off during sample preparation and shows a few fractures. Face I shows a few pits and one curved hairline fracture.

Slab 3/4B: Dark grey, grey, beige, and brownish grey, medium-grained pebbly sandstone. Rusty brown on weathered surface. The sand grains are angular to sub-angular and have varying shapes. The pebble clasts are subrounded to rounded. The lithological composition of the grains comprises chert, quartz, volcanic, minor carbonate grains and a trace of shale/schist. The sample can be scratched with steel knife with effort, locally with minor effort, locally cannot be scratched. Reaction to HCl is localized on the carbonate grains, and no response to magnet was observed, except for some rare gravel clasts where there was a very weak attraction. The sample is pitted as a result of grains that were removed during

sample preparation and shows a few fractures. Face I shows a few pits, a few hairline fractures, and two small and one long fractures. Face II shows two small hairline fractures.

Slab 3/4C: Dark grey, grey, beige, and brownish grey, medium-grained pebbly sandstone. Rusty brown on weathered surfaces. The sand grains are angular to sub-angular and have varying shapes. The pebble clasts are subrounded to rounded. The lithological composition of the grains comprises chert, quartz, volcanics, minor carbonate grains and a trace of shale/schist. The sample can be scratched with steel knife with effort, locally with minor effort, locally cannot be scratched. Reaction to HCl is localized on the carbonate grains, and no response to magnet was observed, except for some rare gravel clasts where there was a very weak attraction. The sample is pitted as a result of the removal of grains during sample preparation and shows a few fractures. Face I shows a few pits. Face II shows the large rounded pebble clasts with microcracks.

Slab 3/4D: Grey, dark grey, light grey, greenish grey, brownish grey on weathered surface conglomerate. Matrix-supported. Clasts are subrounded to subangular and have various shapes and sizes up to 5 cm. The sand grains of the matrix are angular to subangular. The lithological composition of the clasts includes volcanic, siltstone, sandstone, chert, quartz, altered and weathered granitoids. The sample can be scratched with steel knife with variable effort. No response to the application of HCl was observed. Magnetis response was localized only on one volcanic clast of basaltic composition and was otherwise absent. The sample is pitted and fractured. Minor debris came off upon touch. Face I of the slab shows a few pits near the edges and hairline fractures, some around the harder clasts, some softer grains were fractured. Face II is pitted and shows abundant fractures, many going around the larger and harder clasts, and some fractured softer clasts.

3.2. Observation of Individual Specimens

Specimen ID	Initial Observation	Final Observation after 5 Cycles
3/4A	Sample is pitted (from grains that came off during sample preparation) and shows a few fractures. Face I shows a few pits and one curved hairline fracture.	Sample remained intact. Minimal loss of debris upon touch. Face I the top right corner became more porous and one new hairline fractured developed. Face II loss of material from the edges of the polished face, and the edges became rounded and more porous. Loss of some gravel clasts.
3/4B	Sample is pitted (from grains that came off during sample preparation) and shows a few fractures. Face I shows few pits, few hairline fractures, two small and one long fractures. Face II shows two small hairline fractures.	Sample remained intact. No change.
3/4C	Sample is pitted (from grains that came off during sample preparation) and shows a few fractures. Face I shows few pits. Face II shows the large rounded pebble clasts with microcracks.	Sample remained intact. No change.
3/4D	Sample is pitted and fractured. Minor debris came off upon touch. Face I of the slab shows a few pits near the edges and hairline fractures, some around the harder clasts, some softer grains were fractured. Face II is pitted and shows abundant fractures, many going around the larger and harder clasts, and some fractured softer clasts.	Sample remained intact. Some debris coming off upon touch. Both faces became slightly more porous, and some gravel clasts came off. The cracks around the larger pebbles became wider and deeper.

3.3. Summary of Deterioration

All specimens remained intact and experienced minimal material loss. Two slabs did not undergo any change. Two slabs became slightly more fragile with material loss upon slight touch. Few new hairline fractures developed and some increase in porosity was observed.

The coarser-grained conglomeratic samples experienced differential erosion with the sandy matrix more degraded and the coarse clasts standing out or absent. Some slabs became more porous, and the edges became rounded.

4.0. OVERALL SUMMARY

The specimens were brownish grey, grey, rusty brown, beige, and dark grey poorly sorted sandstone and conglomerate. The samples were weakly to moderately weathered and showed pits and fractures.

Minimal loss of material and minor deterioration was observed.

The data contained in this report pertain to the samples provided for testing and are not applicable to material from other locations or trial periods.

Reported by: F. Furlanetto, Ph.D., P.Geo.

Reviewed by: _____
F. Shrimer, P.Geo.

APPENDIX A: SPECIMEN SURFACE PHOTOGRAPHS

Photo 1.

Slab 3/4A prior to soundness cycles (upper photos) and after cycles (lower photos).

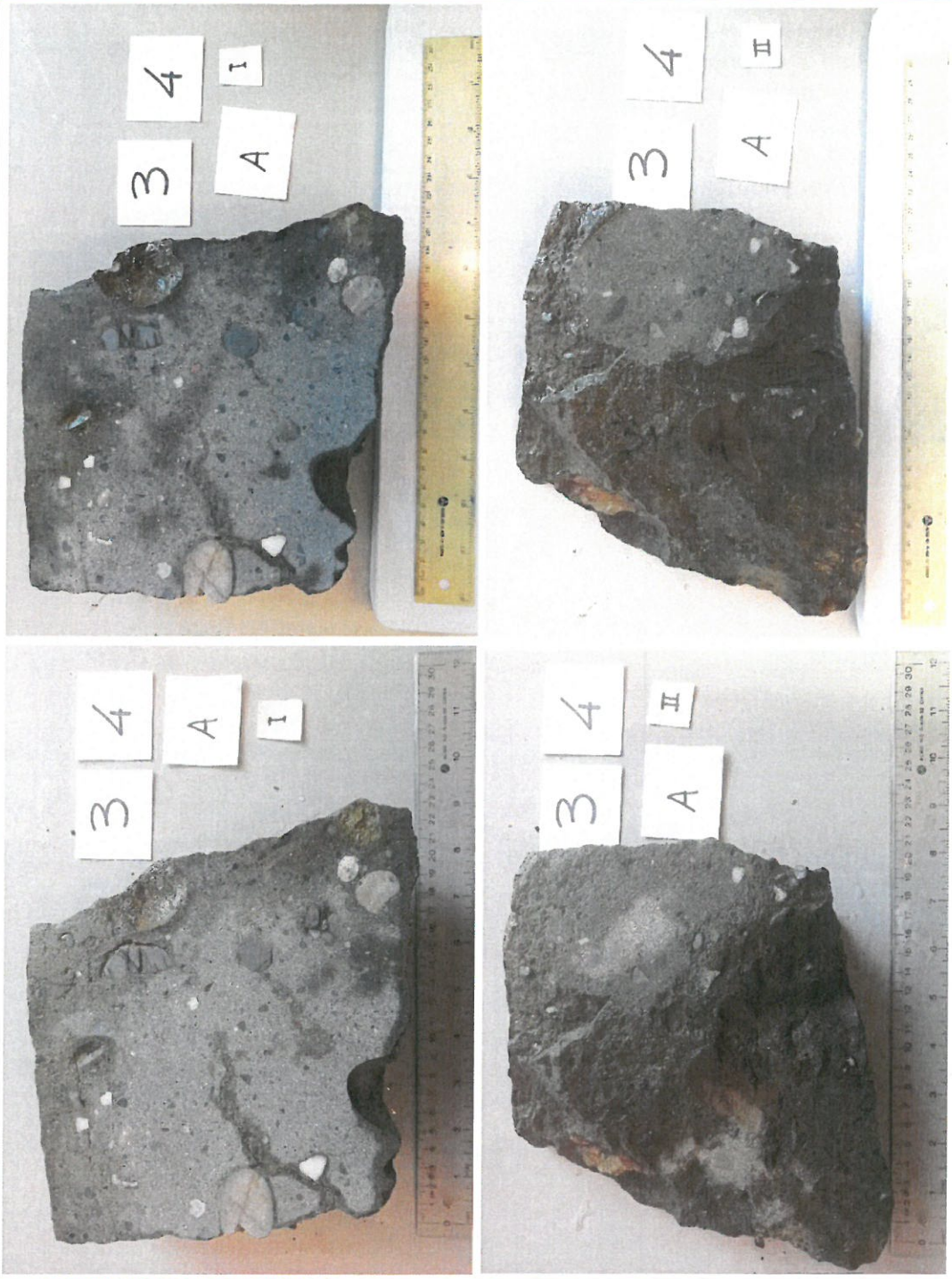


Photo 2.

Slab 3/4B prior to soundness cycles (upper photos) and after cycles (lower photos).

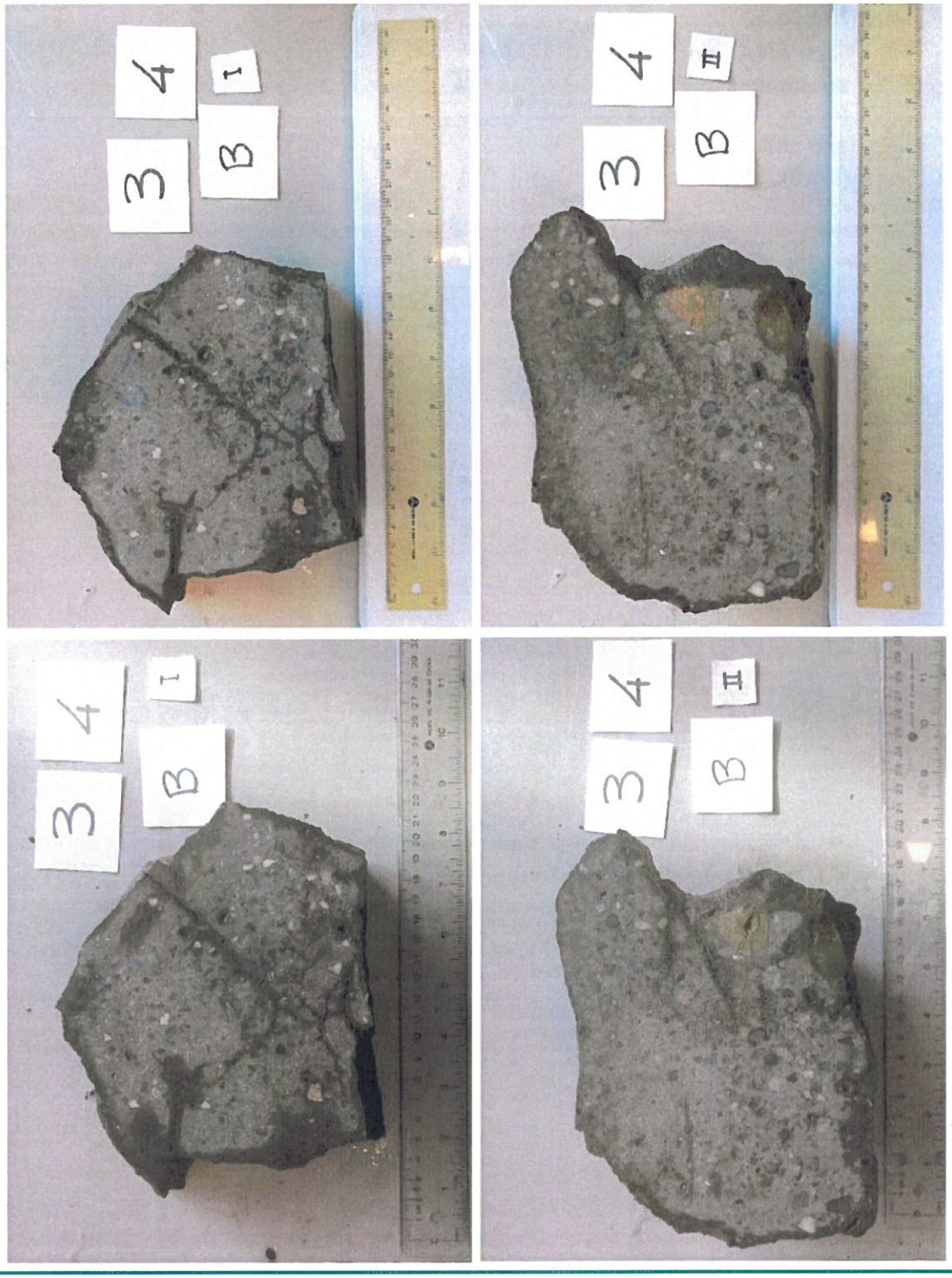


Photo 3.

Slab 3/4C prior to soundness cycles (upper photos) and after cycles (lower photos).

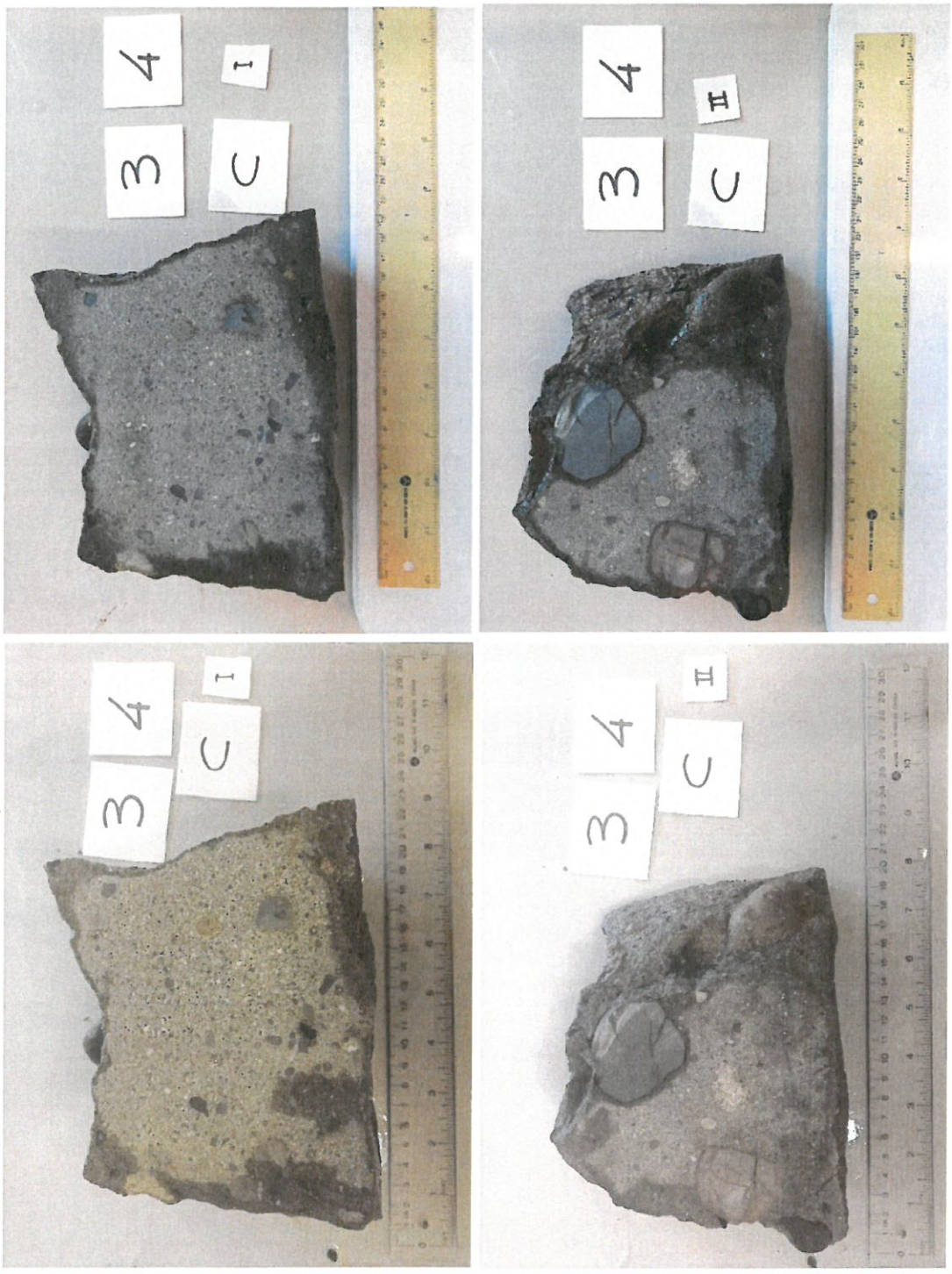
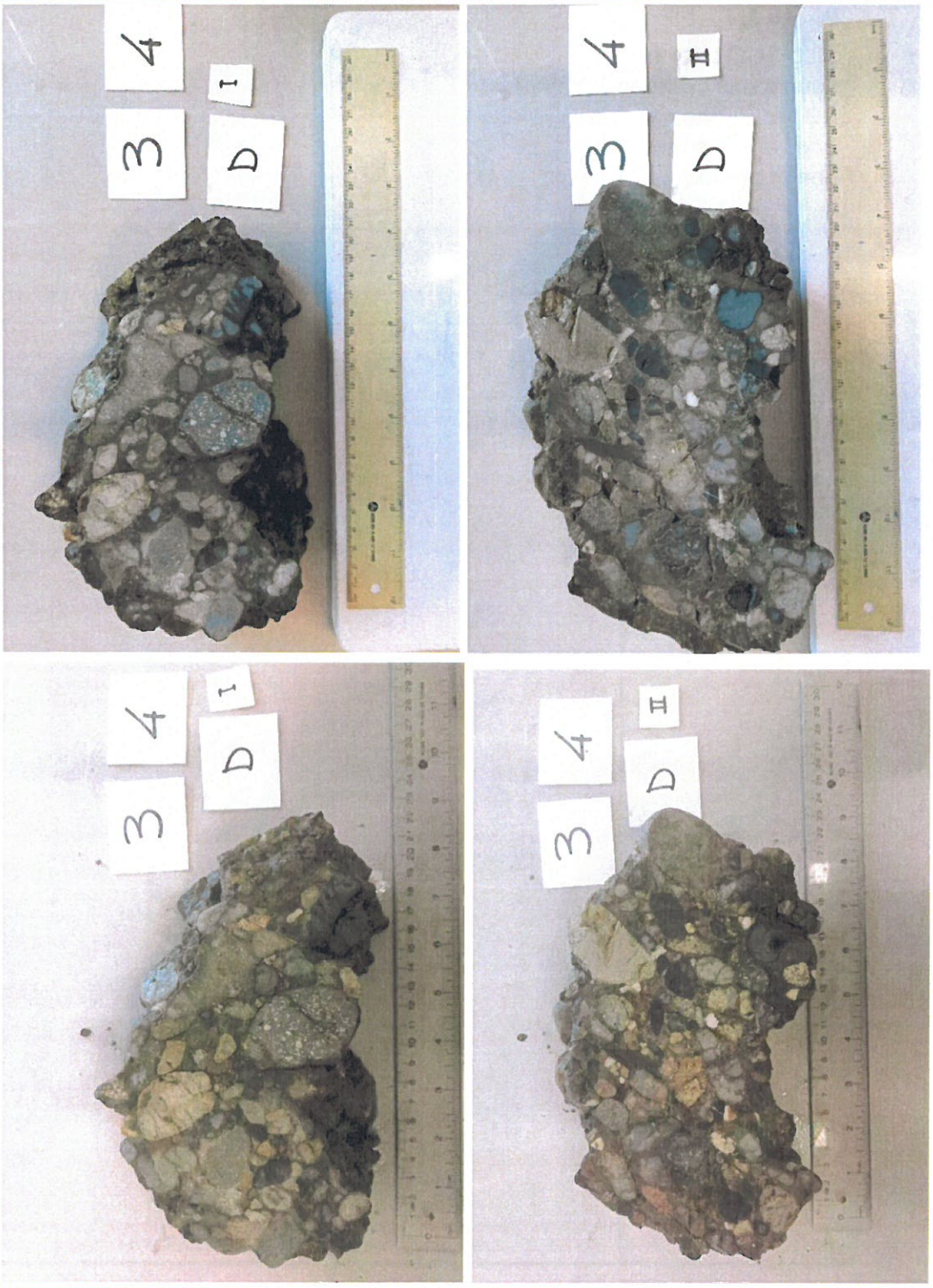


Photo 4.

Slab 3/4D prior to soundness cycles (upper photos) and after cycles (lower photos).



GOLDER
MEMBER OF WSP

RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS

ASTM D6928

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400717, Easting: 483466	Date Sampled:	September 13, 2022
Sample ID:	SA1	Sampled by:	Client
Date tested:	October 3, 2022	Tested by:	KS

Grading	**Section 8.2** 19 x 16 mm, 16 x 12.5 mm, and 12.5 x 9.5 mm Sieve Fractions
Loss at Conclusion of Test (%)	**12.2**

Notes:
Sample laboratory crushed to minus 19 mm prior to testing.
MTO RM CA2 Reference Aggregate loss was 13.0 %, tested on October 3, 2022. Valid range is between 11.4 - 14.8 %.

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT

Notice: The test data given herein pertain to the sample provided and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

GOLDER
MEMBER OF WSP

RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS

ASTM D6928

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400716, Easting: 483445	Date Sampled:	September 13, 2022
Sample ID:	SA2	Sampled by:	Client
Date tested:	October 3, 2022	Tested by:	KS

Grading	**Section 8.2** 19 x 16 mm, 16 x 12.5 mm, and 12.5 x 9.5 mm Sieve Fractions
Loss at Conclusion of Test (%)	**19.5**

Notes:
Sample laboratory crushed to minus 19 mm prior to testing.
MTO RM CA2 Reference Aggregate loss was 13.0 %, tested on October 3, 2022. Valid range is between 11.4 - 14.8 %.

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT

Notice: The test data given herein pertain to the sample provided and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

GOLDER
MEMBER OF WSP

RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS

ASTM D6928

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400715, Easting: 483429 Northing: 5400717, Easting: 483412	Date Sampled:	September 13, 2022
Sample ID:	SA3 and SA4 Combined	Sampled by:	Client
Date tested:	October 3, 2022	Tested by:	KS

Grading	**Section 8.2** 19 x 16 mm, 16 x 12.5 mm, and 12.5 x 9.5 mm Sieve Fractions
Loss at Conclusion of Test (%)	**22.9**

Notes:
Sample laboratory crushed to minus 19 mm prior to testing.
MTO RM CA2 Reference Aggregate loss was 13.0 %, tested on October 3, 2022. Valid range is between 11.4 - 14.8 %.

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT

GOLDER
MEMBER OF WSP

RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS

ASTM D6928

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400713, Easting: 483390 Northing: 5400710, Easting: 483362	Date Sampled:	September 13, 2022
Sample ID:	SA5 and SA6 Combined	Sampled by:	Client
Date tested:	October 3, 2022	Tested by:	KS

Grading	**Section 8.2** 19 x 16 mm, 16 x 12.5 mm, and 12.5 x 9.5 mm Sieve Fractions
Loss at Conclusion of Test (%)	**21.2**

Notes:
Sample laboratory crushed to minus 19 mm prior to testing.
MTO RM CA2 Reference Aggregate loss was 13.0 %, tested on October 3, 2022. Valid range is between 11.4 - 14.8 %.

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT

Notice: The test data given herein pertain to the sample provided and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

GOLDER
MEMBER OF WSP

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D6473

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400717, Easting: 483466	Date Sampled:	September 13, 2022
Sample ID:	SA1	Sampled by:	Client
Date tested:	October 4, 2022	Tested by:	KS

Specimen ID	Mass (g)	Specific Gravity (Dry Basis)	Specific Gravity (SSD Basis)	Apparent Specific Gravity	Absorption (%)
1	1511.9	2.553	2.592	2.657	1.53
2	1937.6	2.605	2.634	2.683	1.11
AVERAGE		**2.579**	**2.613**	**2.670**	**1.32**

Note: Insufficient amount of sample provided for testing; minimum five rock specimen requirement could not be met.

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT

Notice: The test data given herein pertain to the sample provided and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

GOLDER
MEMBER OF WSP

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D6473

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400716, Easting: 483445	Date Sampled:	September 13, 2022
Sample ID:	SA2	Sampled by:	Client
Date tested:	October 4, 2022	Tested by:	KS

Specimen ID	Mass (g)	Specific Gravity (Dry Basis)	Specific Gravity (SSD Basis)	Apparent Specific Gravity	Absorption (%)
1	1159.5	2.438	2.518	2.650	3.27
2	1848.5	2.564	2.610	2.689	1.81
3	1472.4	2.570	2.614	2.688	1.71
4	1104.4	2.489	2.555	2.665	2.65
AVERAGE		**2.515**	**2.574**	**2.673**	**2.36**

Note: Insufficient amount of sample provided for testing; minimum five rock specimen requirement could not be met.

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT

Notice: The test data given herein pertain to the sample provided and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

GOLDER
MEMBER OF WSP

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D6473

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400715, Easting: 483429 Northing: 5400717, Easting: 483412	Date Sampled:	September 13, 2022
Sample ID:	SA3 and SA4 Combined	Sampled by:	Client
Date tested:	October 4, 2022	Tested by:	KS

Specimen ID	Mass (g)	Specific Gravity (Dry Basis)	Specific Gravity (SSD Basis)	Apparent Specific Gravity	Absorption (%)
1	1360.0	2.599	2.631	2.685	1.23
2	2303.7	2.544	2.595	2.682	2.02
3	2245.2	2.632	2.656	2.697	0.92
4	1227.7	2.632	2.656	2.696	0.91
5	1551.5	2.479	2.559	2.695	3.24
AVERAGE		**2.577**	**2.620**	**2.691**	**1.66**

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT

GOLDER
MEMBER OF WSP

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D6473

Client:	Ministry of Transportation and Infrastructure	Project No.:	20396349
Project:	Canal Road, Pender Island	Phase No.:	22009
Location ID:	Northing: 5400713, Easting: 483390 Northing: 5400710, Easting: 483362	Date Sampled:	September 13, 2022
Sample ID:	SA5 and SA6 Combined	Sampled by:	Client
Date tested:	October 4, 2022	Tested by:	KS

Specimen ID	Mass (g)	Specific Gravity (Dry Basis)	Specific Gravity (SSD Basis)	Apparent Specific Gravity	Absorption (%)
1	1130.3	2.487	2.552	2.661	2.64
2	1297.8	2.460	2.540	2.675	3.26
3	1645.3	2.518	2.573	2.664	2.18
4	1871.8	2.447	2.525	2.653	3.16
5	2034.2	2.475	2.543	2.655	2.73
AVERAGE		**2.478**	**2.547**	**2.662**	**2.79**

Reported by: K. Scribner

Reviewed by: _____
S. John, AScT