Vermont Agency of Transportation

Research Advisory Committee

Project Quarterly Progress Reports

2015 – Q2

(01-01-2015 to 03-31-2015)

Improvement and Operation of the Vermont Travel Model

FINAL QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE: 0001052
SPR: 302

B. PRINCIPLE INVESTIGATOR(s): Jim Sullivan

C. START AND END DATE (per grant assignment): October 1, 2014 – September 30, 2015

D. ANTICIPATED COMPLETION DATE: September 30, 2015

E. PROJECT OBJECTIVES: The overall objectives of this project are to:

1. Maintain the Vermont Travel Model as a comprehensive predictor of travel behaviors of Vermonters
2. Respond to requests from VTrans staff and its contractors to query or run the model for specific applications

F. REPORT PERIOD: January 1st through March 31st , 2015

G. ACCOMPLISHMENTS THIS PERIOD:

- Improvement of the Model:
  - Continued the "halo" analysis recommended by the TMIP peer review panel by incorporating demographic characteristics of external northeastern U.S. Census urban areas (UAs) into the Model's external TAZs, and recommending internalizing one or more of those UAs in the Model
- Operation of the Model:
  - Assessed the impacts of construction closures of:
    - Bridge 33 over the Ottauquechee River along U.S. Route 4 in the Town of Killington
    - Bridges 2A and 2B, spanning Interstate 91 over State Route 30 and the West River in Brattleboro
    - Bridge 83, spanning Route 15 over Joe's Brook in Walden
    - The Stowe Street bridges (B46A, B46N, and B46S) spanning Interstate 89 and the I-89N off-ramp at Exit 10 over Stowe Street and Graves Brook in Waterbury
  - Documented the findings of each assessment in a technical memorandum

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 55%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Improvement of the Model:
  - Complete the "halo" analysis recommended by the TMIP peer review panel by incorporating demographic characteristics of external northeastern U.S. Census urban areas (UAs) into the Model's external TAZs, and recommending internalizing one or more of those UAs in the Model
- Operation of the Model:
  - Assess the impacts of construction closure of a segment of Route 9 in Searsburg for replacement of a culvert

Progress report prepared by: Jim Sullivan **Date Prepared:** April 13, 2015

Evaluation of Experimental Features
QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 352 Evaluation of Experimental Features

B. PRINCIPLE INVESTIGATOR(s):
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C. START AND END DATE (per grant assignment):
Ongoing

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: To evaluate experimental features and products on VTrans projects and installations. This includes installation or application, field monitoring and data collection, testing, photographic analysis and preparation of interim and final reports on the methods chosen. Publication or transmittal of experimental results will be sent to interested Agency units.

F. REPORT PERIOD: 1-1-15 to 3-31-15

G. ACCOMPLISHMENTS THIS PERIOD:

- Annual and seasonal visits to the following projects:
  - WP 2012-R-3: Assessment of 40" Wide Paving Skid Box
    - Conducted last winter site visit – Photos and rut readings will be collected.
  - WP 2013-R-3: 3M LPM 5000 Polyurea, Sherwin Williams' Smart Mark™ Hydro Thermoplastic, Swarcoplast Thin Film MMA 5090 Series Methyl Methacrylate, Epoplex LS65 Epoxy, and Ennis Waterborne Roadmarking Paint.
- Report and Update drafts completed:
  - WP 2008-R-2 - Assessment of TechCrete, a Concrete Repair Material and Joint Sealant (Final)

- WP 2011-R-1 - Assessment of Super-Slab, a Precast Concrete Slab in a Bridge Approach Application (Initial)
- WP 2012-R-2: Poly-Carb Flexogrid Bridge Deck Overlay System (Update)
- WP 2012-R-4: Assessment of Uretek Deep Injection Process (Initial)

- Reports published:
  - WP 1996-R-08: Cold In-Place Recycled Bituminous Pavement - Dorset-Danby, VT (Final)
  - WP 2009-R-03: Glomarc 90 Polyurea Pavement Markings (Final)
  - WP 2011-R-2: Wavetronix® SmartSensor Matrix™ Radar Stop Bar Detection (Final)
  - WP 2013-S-1: Assessment of Fiber Reinforced Polymer (FRP) Strips for Bridge Rehabilitation (Initial)

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: Email notifications. Reports and updates are available electronically through the following link: http://vtransplanning.vermont.gov/research/research/projects/completed

J. PERCENT COMPLETION OF TOTAL PROJECT: N/A

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Annual and seasonal visits to the following projects:
  - WP 2012-R-1 - Assessment of the Bridge Preservation LLC's BDM Waterproofing Membrane System
    - Site visit will be performed.
  - WP 2013-R-3: Pavement Marking Comparison, Brookfield-Montpelier, Interstate 89 Painted Markings:
    - Initial update/report will be drafted and published.
    - Spring retroreflectivity readings both wet and dry will attempted to be collected in April/May 2015.

- Final updates and reports for the following will be completed and published:
  - WP 2007-R-1: Reclaimed Stabilized Base with Cement (Final)
  - WP 2008-R-2 - Assessment of TechCrete, a Concrete Repair Material and Joint Sealant (Final)
  - WP 2011-R-1 - Assessment of Super-Slab, a Precast Concrete Slab in a Bridge Approach Application (Initial)

- WP 2011-R-4: 9.5 mm Highly Polymer Modified Thin Hot Mix Asphalt (HMA) Overlay (Update)
- WP 2011-R-5: Assessment of Jahn Permeable Mortar System In a Historic Bridge Abutment Application (Initial)
- WP 2011-R-6: Assessment of the Sterling Lloyd Eliminator Waterproofing Membrane System (Initial)
- WP 2012-R-2: Poly-Carb Flexogrid Bridge Deck Overlay System (Update)
- WP 2012-R-3: Assessment of 40" Wide Paving Skid Box
- WP 2012-R-4: Assessment of Uretek Deep Injection Process (Initial)
- WP 2013-R-3: Pavement Marking Comparison, Brookfield-Montpelier, Interstate 89 Painted Markings (Initial)

Progress report prepared by: Wendy Ellis
Date Prepared: 3-19-15

Porous Pavement Performance Evaluation in a Cold Weather Climate – Randolph Park and Ride

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 705 Porous Pavement Performance Evaluation in a Cold Weather Climate – Randolph Park and Ride

B. PRINCIPLE INVESTIGATOR(s):
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C. START AND END DATE (per grant assignment):
2008-2013

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: The objective of this research initiative is to examine the overall performance and pollutant removal efficiency of an experimental pervious Park and Ride located in the town of Randolph. This will be accomplished by documenting site characteristics such as soil permeability and frost susceptibility with reference to the water table, construction practices with special emphasis placed on grading, compaction and concrete placement, and the occurrence of any surface distresses including cracking and spalling. Infiltration efficiency will be monitored over time with respect to the pervious wearing course and underlying soils with consideration to winter maintenance practices and pressure washing activities. Pollutant removal will be assessed at varying depths within the basin as well as the incidence of bacterial growth at the interface of the basin and underlying soils.

F. REPORT PERIOD: January 1st, 2015 through March 31st, 2015

G. ACCOMPLISHMENTS THIS PERIOD: N/A

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: 90%

K. **ACTIVITIES PLANNED FOR NEXT QUARTER:** Final infiltration testing, chain drag and overall assessment will be conducted, all prior to any construction with regards to the re-design. Final report writing will begin and once all final data is collected and compiled, final data analysis will commence.

Progress report prepared by: Jason P. Tremblay
Date Prepared: April 15, 2015

Evaluation of Concrete Bridge Mix Designs for Control of Cracking

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 710 Evaluation of Concrete Bridge Mix Designs for Control of Cracking

B. PRINCIPLE INVESTIGATOR(s):
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C. START AND END DATE (per grant assignment):
2009 - 2015

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: Phase I: The objective of this research initiative is to examine a series of differing concrete mix designs in order to begin the process of selecting an optimum design for VTrans bare concrete bridge deck projects as well as other bridge projects. The desire is to lower the amount of cracking that is present on the bridge decks, possibly by using shrinkage control agents and/or by reducing the amount of cementitious material which would result in a reduction of needed mix water, based on the current water/cementious ratios. Laboratory testing of this type is needed in order to provide a basis for support for using shrinkage reducing admixtures and/or adjusting current mix designs.

Mixes will fall within three groups. The first group will be the control group, consisting of batches of normal high performance concrete (HPC), classes A and B. The second group will make use of two different methods of shrinkage control within the control mixes, a shrinkage reducing admixture and a shrinkage compensating cementitious admixture. The third group will make use of an optimized gradation of aggregate and other various alterations.

Phase II: The objective of this second phase of the research initiative is to examine a select few of the top performing mixes tested in the previous study, alter a few key variables in their design, and zero in on the ideal design for the Agency's needs. The first component to evaluate will be the amount of cement required. One mix will be chosen from the initial study and the cement content varied at four different values, 400, 475, 550, and 610 per cubic yard. Four batches of each of these will be produced and tested.

As part of the process it is desired to mix the concrete in larger test batches than during the first study, where mixes were batched in house in approximately 1.5 cubic foot quantities. As part of this phase, mixes will be batched in a three cubic yard quantity; a standard quantity known to replicate the consistency of full scale pours well, and be done by a local concrete producer.

F. REPORT PERIOD: January 1st, 2015 through March 31st, 2015

G. ACCOMPLISHMENTS THIS PERIOD: N/A. Holding a meeting was discussed but never occurred due to personnel changes.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES: The final report was distributed to stakeholders throughout the Agency.

J. PERCENT COMPLETION OF TOTAL PROJECT: 100% (phase I), all production, testing, data compilations, and basic analysis has been completed, along with a final report published and distributed. 10% (phase II), concrete mixer received and base mixes decided upon.

K. ACTIVITIES PLANNED FOR NEXT QUARTER: Further supplies will be purchased for phase II and test batch preparation began.

Progress report prepared by: Jason Tremblay
Date Prepared: April 15, 2015

Correlating M-E PDG with Vermont Conditions – Phase II

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 711 Correlating M-E PDG with Vermont Conditions – Phase II

B. PRINCIPLE INVESTIGATOR(s):

Chris Benda
Geotechnical Engineering Manager
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C. START AND END DATE (per grant assignment):
2010-2012

D. ANTICIPATED COMPLETION DATE: The funding has been extended into FFY '14, and it is anticipated the project will be complete by December 31, 2014 – Would like to extend completion date to July 2015.

E. PROJECT OBJECTIVES: Using the information gathered and work completed in Phase I, the first objective of this Phase is to determine the necessary beta-factors for calibration of the M-E PDG software by comparing in-situ pavement distresses with the software output. Both rutting and IRI will be compared at their present day values, along with their quantities over time. Using statistical methods along with NCHRP Report 1-40B *Local Calibration Guide*, a calibration and validation process will be developed and carried out to ascertain the adjustment factors to be used for pavement design in Vermont.

Continuing with the progress of the overall project, the second objective of this phase will be verification of the model. Using additional sites from the 2004 Layer Coefficient Study, in-situ values will be compared with predicted to insure the model is working correctly.

F. REPORT PERIOD: January 1, 2015-March 31, 2015

G. ACCOMPLISHMENTS THIS PERIOD:
We have continued verifying the input parameters for the 5 project sites and are working on refining the data to be as accurate as possible. This includes finalizing dates of data collection (IRI & rutting), completion dates of construction, traffic input parameters, and HMA as well as soil parameters. We are working on incorporating a new site – the Morristown alternate truck route

and are in the process of getting a WIM installed. Samples taken during the construction of that project were tested for resilient modulus values. Results have been analyzed.

H. PROBLEMS ENCOUNTERED (If any): Getting all of the data is turning out to be a little more time consuming than anticipated. Not necessarily a problem, but is pushing the completion date back.

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT:

87%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: We plan on implementing the Morristown site into PaveME beginning with soil data parameters. We are working with traffic research on developing accurate traffic values to use for sites without WIM data available. We are still waiting on getting dates IRI and rutting measurements were taken and will then update the results of the IRI and rutting values predicted from the other 5 sites.

Progress report prepared by: Marcy Meyers **Date Prepared:** 4-16-2015

Life-Cycle Determination of Preventative Maintenance Treatments

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 713 Life-Cycle Determination of Preventative Maintenance Treatments

B. PRINCIPLE INVESTIGATOR(s):
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C. START AND END DATE (per grant assignment):
2009-2017

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: Preventative maintenance treatments, intended to arrest minor deterioration, retard progressive failures, and reduce the need for corrective maintenance, has the potential to both improve quality and reduce expenditures. The life cycle and associated cost-effectiveness of these treatments may vary significantly based upon the selected treatment, functional classification, traffic demand, condition of the roadway prior to application, constructability, and environmental conditions.

The primary intent of this research initiative is to determine the life expectancy and associated costs of preventative maintenance treatments currently used in the State of Vermont. This will be completed by evaluating the constructability, performance and cost effectiveness of all treatments encompassed within the study. The treatments will include paver placed surface treatments, micro-surfacing (Type I and II), chip seal, hot-in-place recycling, and standard mill and fill treatments.

F. REPORT PERIOD: 1-1-15 to 3-31-15

G. ACCOMPLISHMENTS THIS PERIOD:

- Cracking and rutting updates were corrected.

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: None.

J. PERCENT COMPLETION OF TOTAL PROJECT: 70%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Work on reporting requirements – Initial report should be started.
- Begin annual site visits.

Progress report prepared by: Wendy Ellis
Date Prepared: 3-19-15

Evaluation of Skid Resistance of Bare Concrete Bridge Decks

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 715 Evaluation of Skid Resistance of Bare Concrete Bridge Decks

B. PRINCIPLE INVESTIGATOR(s):

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C. START AND END DATE (per grant assignment):
2010-2012

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: The objective of this research initiative is to examine different concrete surface finishing techniques currently in place on bare bridge decks in order to determine which methodologies lead to the greatest skid resistance. Two differing methods of skid resistance testing will be performed, including the use of a British Pendulum Tester as well as a locked wheel skid test. The Structures Section has comprised a list of fifteen bridges that will be tested around the state, 32 years or younger, with five or more different surface finishing techniques used among them. Analysis of the skid resistance data will help lead to the selection of an optimal concrete surface finish thereby increasing the overall safety of the traveling public.

The analysis of these finishing techniques will also include other factors, such as cost, long term durability, quality assurance, construction feasibility and probability of success.

F. REPORT PERIOD: January 1st, 2015 through March 31st, 2015

G. ACCOMPLISHMENTS THIS PERIOD: None; draft report has been reviewed in house and sent to Wayne Symonds for Structures review, as they were the originators of the solicitation. Awaiting comments for finalization. It has been decided that further review will take place within Research and the project finalized.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. **PERCENT COMPLETION OF TOTAL PROJECT:** 95%, all data collected; data analysis and draft report finished.

K. **ACTIVITIES PLANNED FOR NEXT QUARTER:** Final report will be finalized and published.

Progress report prepared by: Jason Tremblay
Date Prepared: April 15, 2015

Assessment of Design Parameters and Construction Requirements for Full Depth Reclamation Projects with Cement

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 718 Assessment of Design Parameters and Construction Requirements for Full Depth Reclamation Projects with Cement

B. PRINCIPLE INVESTIGATOR(s):
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C. START AND END DATE (per grant assignment): January 12, 2011 – July 12, 2012

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: The objectives of this research initiative include examining alternative means and methods for assessing performance characteristics of the reclaimed stabilized base material; this data would then be used to develop acceptance criteria and to validate design assumptions with an overall objective of optimizing VTrans' RSB pavement design model.

F. REPORT PERIOD: 1-1-15 to 3-31-15

G. ACCOMPLISHMENTS THIS PERIOD:
- The final report was Published.

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: 100%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:
None

Progress report prepared by: George W. Colgrove III, Research Administrator
Date Prepared: 1-5-15

Use of Piles in Slope Stabilization
QUARTERLY REPORT

A. **PROJECT NUMBER AND TITLE:** Use of Piles in Slope Stabilization
SPR: 719

B. **PRINCIPAL INVESTIGATOR(s):** Callie Ewald, Chris Benda and Mandar Dewoolkar

C. **START AND END DATE (per grant assignment):** February 1, 2011 through March 31, 2012. Extended through August 2015

D. **ANTICIPATED COMPLETION DATE:** August 2015

E. **PROJECT OBJECTIVES:** The primary objective of this research is to provide the Agency with design guidance for reinforcing unstable slopes with steel H-Piles and to gap design software omissions. The primary design tool used by the Agency does not consider every aspect of failure in the piles and does not account for soil stiffness. A second objective of the research is to evaluate the suitability of using the Borehole shear Test (BST) apparatus as an aid in establishing soil parameters for analysis. The BST is a test that is performed in the field which determines effective shear strength parameters of the in-situ soil. Due to the high expense and length of time required for laboratory testing, this device could be of significant benefit in slide mitigation activity. A site in Cornwall, VT has been identified to conduct a field investigation and testing program.

F. **REPORT PERIOD:** January 1, 2015 through March 31, 2015

G. **ACCOMPLISHMENTS THIS PERIOD:** Survey was completed by the VTrans survey section to capture the river at the toe of slope as well as the field beyond. Cross sections were cut and are currently being updated and evaluated in the modeling program Slide to come up with a remediation in Cornwall. Worked on the literature section of the report and retrieved updated inclinometer and well log readings in the field.

H. **PROBLEMS ENCOUNTERED (If any):** The movement in the inclinometer is reading much deeper than originally anticipated. This adds an additional level of complexity to the modeling and will require additional survey and modeling.

I. **TECHNOLOGY TRANSFER ACTIVITIES**: None

J. **PERCENT COMPLETION OF TOTAL PROJECT:** 80%

K. **ACTIVITIES PLANNED FOR NEXT QUARTER:** Fine-tune the working model for the slide in Cornwall and develop a remediation that increases the factor of safety of the slope. Work on the report and finish by the end of August.

Progress report prepared by: Callie Ewald
Date Prepared: May 1, 2015

Verification of Abutment and Retaining Wall Design Assumptions

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 720 Verification of Abutment and Retaining Wall Design Assumptions

B. PRINCIPAL INVESTIGATOR(s):

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Christopher C. Benda, P.E.
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C. START AND END DATE (per grant assignment): October 1, 2013 – December 31, 2013.

D. ANTICIPATED COMPLETION DATE: May 30, 2014

E. PROJECT OBJECTIVES: The primary objective of this research is to verify that the backfill and drainage details currently used on cast-in-place concrete cantilevered retaining walls and bridge abutments on VTrans projects perform as expected, i.e. will provide zero pressure head differential on both faces of the wall, and that the backfill has the engineering properties assumed in the design. A second objective is to find the most cost effective backfill details. Included in this objective is developing selection guidelines, soil parameters, drainage details and construction specifications that will allow the use of backfill materials with greater fines content than that currently specified.

F. REPORT PERIOD: 2015 Q2

G. ACCOMPLISHMENTS THIS PERIOD:

The final project report was submitted.

H. PROBLEMS ENCOUNTERED (If any): No significant problems to report.

I. **TECHNOLOGY TRANSFER ACTIVITIES**: A manuscript based on this research was published in print in the journal of Transportation Research Record. We found out that it was printed during Q2. The full citation is:

Gomez, B. W., Dewoolkar, M. M., Lens, J. E., and Benda, C. C. (2014), "Effects of fines content on hydraulic conductivity and shear strength of granular structural backfill", *Transportation Research Record*, No. 2462, 1-6.

J. **PERCENT COMPLETION OF TOTAL PROJECT:** 100%

K. **ACTIVITIES PLANNED FOR NEXT QUARTER:** None.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER:
None.

Progress report prepared by: Mandar Dewoolkar
Date Prepared: April 15, 2015

Evaluation of Load Characteristics of I-89 Bridges 58 N&S, Richmond – Phase II

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:

SPR: 721 Evaluation of Load Characteristics of I-89 Bridges 58 N&S, Richmond

B. PRINCIPLE INVESTIGATOR(s):

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Eric M. Hernandez, Ph.D.
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C. START AND END DATE (per grant assignment): June 1, 2011 – December 31, 2012

D. ANTICIPATED COMPLETION DATE: *August 2013. This extension was approved by VTrans as a no-cost extension.*

E. PROJECT OBJECTIVES:

The objective of this research initiative is to instrument bridge number 58 (north) on Interstate 89 in the town of Richmond, in an effort to determine its load bearing capabilities. Currently AASHTO distribution factors are used to determine load ratings on the bridges, which lead to possibly conservative estimates, thus restricting some overweight load passage. Accurate determination of the load bearing characteristics would allow for as-tested values to be used in lieu of the AASHTO distribution factors and therefore lead to a more accurate load rating. In addition, due to questions pertaining to the original design plans it is currently unknown what grade of steel was used in the stringers; a separate concurrent project will be undertaken to determine this accurately.

Determination of the load bearing characteristics of this bridge will be done through the use a series of remain-in-place strain and/or displacement gauges installed on three of the bridges stringers; one near and abutment, one near a pier, and one in a negative moment region. The system will be capable of recording continuous load data, thus displaying characteristics over a wide range of traffic types and streams. Instrumentation plans specifics, as well as all work, will be done through a consultant, selected through a request for proposal (RFP) process. Special attention will be paid to the data when a known heavyweight vehicle or load will be traversing the bridge and in conjunction with nearby weigh in motion (WIM) stations. Information will be used in an effort to determine whether or not special care need be taken when overweight loads cross the bridge, and to possibly revise bridge load ratings.

F. REPORT PERIOD: Jan 01, 2015 to March 31, 2015

G. ACCOMPLISHMENTS THIS PERIOD:

- Final report was submitted.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 100%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

Progress report prepared by: Eric M. Hernandez, Ph.D.

Date Prepared: March 15th 2015

Designing Porous Concrete to Resist Damage from Deicing Salts and Freeze-Thaw
QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 730 Designing Porous Concrete to Resist Damage from Deicing Salts and Freeze-Thaw

B. PRINCIPAL INVESTIGATOR(s):

Dr. Mandar Dewoolkar
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(802)656-1942

Dr. Edwin R. Schmeckpeper, Associate Professor
Dr. Adam F. Sevi, Assistant Professor
Civil and Enviornmental Engineering
Norwich University

C. START AND END DATE (per grant assignment): June 1, 2012 – December 31, 2014.

D. ANTICIPATED COMPLETION DATE: August 31, 2015

E. PROJECT OBJECTIVES: The scope of this research is to: (1) evaluate in the laboratory porous concrete mixes for their resistance to deicing chemicals; (2) quantify the effects of sand addition on the resistance to deicing salts; (3) quantify the effects of fly ash replacement on resistance to deicing salts; (4) evaluate various chemical admixtures to determine if they improve resistance of porous concrete to deicing salts; and (5) determine how curing time affects resistance to deicing salts.

F. REPORT PERIOD: 2015 Q1

G. ACCOMPLISHMENTS THIS PERIOD:

(a) 1st Month: The testing program is progressing. The samples are continued to be tested for freeze-thaw cycles at Norwich.
(b) 2nd Month: The testing program is progressing. The samples are continued to be tested for freeze-thaw cycles at Norwich.
(c) 3rd Month: The testing program is progressing. The samples are continued to be tested for freeze-thaw cycles at Norwich. Data from both Universities were combined and analyzed. Data are being processed.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 96%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: Freeze-Thaw testing at UVM and Norwich will continue. Analysis is expected to progress significantly.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER: About $1,000

Progress report prepared by: Mandar Dewoolkar

Date Prepared: April 15, 2015

Prediction and Mitigation of Scour for Vermont Bridges
QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 731 Prediction and Mitigation of Scour for Vermont Bridges

B. PRINCIPAL INVESTIGATOR(s):

Mandar Dewoolkar, Ph.D., P.E.
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1942.

C. START AND END DATE (per grant assignment): June 1, 2012 – May 31, 2015.

D. ANTICIPATED COMPLETION DATE: August 31, 2015

E. PROJECT OBJECTIVES: Successfully mitigating scour related problems associated with bridges is dependent on engineers' ability to reliably estimate scour potential, design effective scour prevention and countermeasures, design safe and economical foundation elements accounting for scour potential, and design reliable and economically feasible monitoring systems. The specific objectives of this research are to: (1) conduct an extensive literature review on methods to estimate scour potential, methods of monitoring, design methodologies, and countermeasures, and summarize the results in a summary document and make recommendations on specific methodologies that would be adaptable for Vermont; (2) develop a methodology for semi-empirically linking rapid geomorphic assessments (RGA) to observed bridge scour as a predictive tool; and (3) instrument select test sites with relatively low-cost passive sensors that will actively yet remotely communicate excessive scour.

F. REPORT PERIOD: 2015 Q2: January 2015 to March 2014

G. ACCOMPLISHMENTS THIS PERIOD:

a. 1st Month (January 2014): Continuing to expand and update the comprehensive bridge database. Identified all damaged bridges through online inspection photos. Continued to work on the specific stream power measurements. Assessed the relationships of individual components of RGA data to VTrans' bridge data. A new Senior Design team of Mechanical and Electrical Engineers was identified to work on the second version of the scour sensor.
b. 2nd Month (February 2014): Analyzed the available resources from Irene, to determine significance in variable to determine bridge vulnerability. Visually

characterized bridges damaged for use in analysis. The Senior Design team began performing literature review.

c. 3rd Month (March 2014): Began writing a report on the bridge scour damage and vulnerability from Irene. Including analysis of all available bridge and stream information. The Senior Design team began assessing various sensing technologies that might be appropriate for scour/erosion sensing.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 70%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: The review of countermeasure and bridge design alternatives will continue. Work on the stream power/geomorphic tool for characterizing stream vulnerability will continue. Report writing is underway, and will continue to expand.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER: $10,000

Progress report prepared by: Mandar Dewoolkar
Date Prepared: April 15, 2015

Pavement Marking Comparison Study

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 732 Pavement Marking Comparison Study

B. PRINCIPLE INVESTIGATOR(s):
Wendy Ellis
Research Technician V
Vermont Agency of Transportation
2178 Airport Rd., Unit B
Berlin, VT 05641
Telephone: (802) 828-6918
Fax: (802) 828-2792

C. START AND END DATE (per grant assignment): January 1, 2013 – September 30, 2018

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: The objectives of this research initiative include examining and evaluating the reflective and durable characteristics of recessed and surface applied pavement markings in both wet and dry conditions and to classify durable tapes into performance categories based on their durability and adhesion capabilities.

F. REPORT PERIOD: 1-1-15 to 3-31-15

G. ACCOMPLISHMENTS THIS PERIOD:

- Sent retroreflectometer out for calibration.
- WP 2013-R-3: Pavement Marking Comparison, Brookfield-Montpelier, Interstate 89 Painted Markings:
  - Completed a winter site visit March 11th to take photographs and notes regarding the present condition.
  - Outline was completed for initial report.
- WP 2013-R-4: Pavement Marking Comparison Study – Berlin, VT - US Route 302 Inlaid Pavement Marking Tape, Preformed Thermoplastic, and Bike Lane Markings:
  - None.

H. PROBLEMS ENCOUNTERED (If any): None

I. **TECHNOLOGY TRANSFER ACTIVITIES:** None

J. **PERCENT COMPLETION OF TOTAL PROJECT:** 25%

K. **ACTIVITIES PLANNED FOR NEXT QUARTER:**

- Initial draft update/report will be completed and published.
- Spring retroreflectivity readings both wet and dry will attempted to be collected in AprilMay 2015.
- Meet with project managers to discuss WP 2013-R-4 and attend preconstruction meeting for this project if occurs during this quarter.

Progress report prepared by: Wendy Ellis
Date Prepared: 3-19-15

Long-Term & Short-Term Measures of Roadway Snow & Ice Control Performance

QUARTERLY REPORT

A. **PROJECT NUMBER AND TITLE:** RSCH016
SPR: 733

B. **PRINCIPLE INVESTIGATOR(s):** Jim Sullivan

C. **START AND END DATE (per grant assignment):** April 1, 2013 – March 31, 2015

D. **ANTICIPATED COMPLETION DATE:** March 31, 2016

E. **PROJECT OBJECTIVES:** The objectives of this project are to improve the performance of RSIC activities by the VTrans fleet by developing a plan for implementation of new performance measures. Long-term, seasonal measures will be developed which implement a time-to-normal approach. A short-term measure will be pilot-tested, utilizing real-time thermal image processing.

F. **REPORT PERIOD:** January 1st through March 31st , 2015

G. **ACCOMPLISHMENTS THIS PERIOD:**

- Attended and presented at a meeting of the Technical Advisory Committee for the project and at a meeting of the Tri-State Maintenance and Operations meeting
- Installed, tested, and troubleshot thermal infrared camera equipment on a plow truck in the Colchester district garage.
- Collected thermal imagery for 1-2 winter snow events.
- Began development of the draft project report

H. **PROBLEMS ENCOUNTERED:**

- Speed data collection at RWIS stations was not possible due to malfunctioning field equipment and malfunctioning data-servers
- Testing, troubleshooting and field inspection for installation of thermal infrared camera equipment was not completed in time to collect thermal video imagery in a winter storm during 2014. A new end date of 3/31/2015 for the project was established at no additional cost. No effort was incurred from April 1, 2014 to October 1, 2014. The remaining budget was to be used between October 1, 2014 and March 31, 2015 to accomplish the originally defined scope.
- Excessive field modification of the thermal infrared camera equipment was required to affix the camera equipment to the plow truck, and final

modifications were completed in late February 2015. Between that time and March 31st, there were no significant winter storms in the Colchester district, so the collection of imagery for 5-6 storms was not possible. A new end date of 3/31/2016 for the project is established at no additional cost, to allow the team one more winter to complete the collection of thermal video imagery. No effort will be incurred from April 1, 2015 to December 31st, 2015. The remaining budget will be used between January 1, 2016 and March 31, 2016 to accomplish the originally defined scope.

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 90%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- None

Progress report prepared by: Jim Sullivan **Date Prepared:** April 13, 2015

Statewide Analysis of Guardrails, Curves and Crashes

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 736

B. PRINCIPLE INVESTIGATOR(s): Brian H. Y. Lee

C. START AND END DATE (per grant assignment): 1 Mar 2013 – 30 Dec 2014

D. ANTICIPATED COMPLETION DATE: 31 Dec 2014

E. PROJECT OBJECTIVES:

This research project focuses on the placement of guardrails and the location of curves, both with respect to crash incidents. Since guardrails and curves are often co-located (i.e., many guardrails are placed along curves and many curves have guardrails), it is highly likely that these two road features are correlated in space and confound each other's relationship with crashes. Both guardrails and curves may vary in their attributes by location (e.g., guardrails in size, material, offset; curves in radii, length, pavement material) and can relate to crashes in positive and negative ways. In this project, both guardrails and curves are considered together in a single, holistic statewide study, while maintaining the ability to discuss each of these issues separately.

There are two project objectives:

Objective 1: Develop guidelines that will inform road engineers about contexts in which the use of guardrails to help prevent crashes is appropriate. This would include taking into account of the site conditions, the users, and the types of facilities and guardrails.

Objective 2: Determine curve characteristics that are highly correlated with crashes to help identify locations where safety interventions may be warranted. Similar to Objective 1, this would include taking into account of the site conditions, the users, the types of facilities, and the presence of different interventions.

F. REPORT PERIOD: 1 Jan 2015 through 31 Mar 2015

G. ACCOMPLISHMENTS THIS PERIOD:

- Submitted draft report
- Made final project presentation at VAOT (on Thu 26 Feb 2015)

H. PROBLEMS ENCOUNTERED (If any):

N/A

I. TECHNOLOGY TRANSFER ACTIVITIES:

N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 95%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Receive comments & edit report as needed

Progress report prepared by: Brian H. Y. Lee **Date Prepared:** 6 April 2015

Quantifying the Vulnerability of Vermont Bridges to Seismic Loading
QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 737 Quantifying the Vulnerability of Vermont Bridges to Seismic Loading

B. PRINCIPAL INVESTIGATOR(s):

Mandar Dewoolkar, Ph.D., P.E.
Associate Professor
School of Engineering - University of Vermont
(802) 656 1942

Eric Hernandez, Ph.D.
Assistant Professor
School of Engineering - University of Vermont
(802) 656-3331

C. START AND END DATE (per grant assignment): May 15, 2013 – May 31, 2016.

D. ANTICIPATED COMPLETION DATE: May 31, 2016

E. PROJECT OBJECTIVES: The overarching objective of this research is to assist the Agency in establishing a methodology for the seismic assessment of their inventory of bridges; that is, to provide a rational basis for ranking their bridges according to their seismic vulnerability in consideration of variations in seismicity, foundation, terrain, and geologic conditions, and structure type, age and importance. The specific objectives are to: (1) review and update Agency's bridge inventory; (2) conduct a thorough literature review on seismic vulnerability ranking of bridges; (3) develop an appropriate seismic vulnerability ranking system for Vermont bridges and slopes associated with bridges; (4) assign and validate the rankings by conducting thorough seismic analysis of select bridge sites; and (5) prepare training materials and final report to assist Agency personnel in the upkeep of the inventory and rating system for retrofitted and new bridges.

F. REPORT PERIOD: 2015 Q2

G. ACCOMPLISHMENTS THIS PERIOD:

a. 1st Month (January 2015) – Continued working with SAP2000 2-D and 3-D finite element structural models for analysis of the predominant multi-span bridge type in Vermont, consisting of steel girders with concrete deck. This included researching and obtaining published recommendations for non-linear bearing performance properties to be used in the modeling.

b. 2nd Month (February 2015) – Researched background literature on methods and parameters used for probabilistic seismic hazard modeling provided by the United States Geological Survey for the region, to support decision making in the overall vulnerability ranking recommendations to be developed. Continued with structural model analyses.
c. 3rd Month (March 2015) – Continued structural modeling of the steel girder type bridges. Began investigating established structural damage indices to be considered in the structural damage vulnerability quantification process.

H. PROBLEMS ENCOUNTERED (If any): None to date.

I. TECHNOLOGY TRANSFER ACTIVITIES: None in this quarter.

J. PERCENT COMPLETION OF TOTAL PROJECT: 58%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: Continue detailed seismic analysis of representative bridge types and developing a framework for quantifying seismic bridge modeling results in terms of performance metrics including damage indices. Begin detailed evaluation of soil considerations including liquefaction and flow potential as part of the overall bridge seismic vulnerability evaluations. Prepare for and attend a project TAC meeting, preferably to be held in this quarter.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER (Q3, April-June)
a. April 2015 $3,500
b. May 2015 $3,500
c. June 2015 $3,500

Progress report prepared by: Mandar Dewoolkar
Date Prepared: April 15, 2015

High Speed Ground Penetrating Radar (GPR) for Road Pavement and Bridge Structural Inspection and Maintenance

Quarterly Report

A. PROJECT NUMBER AND TITLE:

SPR: RSCH017-738
High Speed Ground Penetrating Radar (GPR) for Road Pavement and Bridge Structural Inspection and Maintenance

B. PRINCIPLE INVESTIGATOR(s):

Tian Xia
Associate Professor
School of Engineering
University of Vermont

C. START AND END DATE (per grant assignment):

05/01/2014-06/30/2016

D. ANTICIPATED COMPLETION DATE:

06/30/2016

E. PROJECT OBJECTIVES:

The overarching objective of this research is the development of a systematic methodology of employing GPR, including instruments, subsequent data processing and interpretation that can be used regularly as part of a roadway pavement and bridge evaluation program. Test methodologies and procedures that are suitable for Vermont environmental and infrastructural conditions will be explored and evaluated. Moreover we will implement and improve a high speed GPR system that allows driving speed roadway and bridge deck inspection with leveraged inspection resolution. We will investigate the strengths and limitations of GPR to determination the correct implementation both in terms of operation and data assessment, and the range of road conditions for which usage is worthwhile. We will work with VTrans closely to make GPR a suitable tool to facilitate transportation infrastructure survey, maintenance, repair and rehabilitation in Vermont and beyond. To ensure the successful accomplishment of the project, we will fulfill the following research objectives in two phases.

<u>Phase 1 (Year 1):</u>

- **Objective 1:** Review and evaluate current roadway pavement and bridge deck inspection methods employed by VTrans, and gather the available structural as-built plans. Also available GPRs systems and their functionalities will be reviewed.
- **Objective 2:** Develop and improve a high performance high resolution GPR that allows surveying at highway speeds.
- **Objective 3:** Apply GPR for roadway pavement profile inspections.
- **Objective 4:** Apply GPR for bridge deck inspections.

Phase 2 (Year 2):

- **Objective 5:** To inspect seasonal changes and deicing salt effects on pavement and bridge deck condition.
- **Objective 6:** Data registration method will be implemented to facilitate database development and data management. Integration with VTrans Automatic Road Analyzer (ARAN).
- **Objective 7:** Develop systematic GPR inspection flow and procedures applicable for maintenance and rehabilitation decision making.
- **Objective 8:** Identify and recommend areas for further study to improve inspection accuracy and effectiveness.

F. REPORT PERIOD:

01/16/2015 – 04/15/2015

G. ACCOMPLISHMENTS THIS PERIOD (broken down by month):

In this project quarter, three accomplishments have been made: (1) An automatic asphalt pavement thickness estimation method is developed; (2) 3D asphalt pavement GPR scan are performed at two selected test sites on UVM campus; (3) Continuous asphalt pavement condition monitoring at three test spots are conducted.

1. Asphalt Pavement Thickness Estimation Method (01/16/2015-02/15/2015)

Asphalt pavement thickness measurement is important for pavement quality evaluation. Traditional destructive measurement methods are slow, expensive and inefficient. In this project, GPR based non-destructive measurement method is developed. Specifically, a 3-step signal processing method is implemented as described below:

Step 1: Stack every 5 GPR A-Scan traces to calculate average value to increase the signal to noise ratio.

Step 2: Remove the DC offset in A-Scan trace.

Step 3: Top and bottom surface of asphalt pavement identification using Hilbert Transform.

In our GPR system, Hilbert Transform is implemented to extract the pulse envelope that measures the signal power. The Hilbert Transform of signal $s(t)$ can be considered as the convolution of $s(t)$ with the function $h(t) = \frac{1}{\pi t}$, which can be expressed as

$$\hat{s}(t) = \mathcal{H}\{s\} = h(t) * s(t) = \int_{-\infty}^{\infty} s(\tau)h(t-\tau)d\tau = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{s(\tau)}{t-\tau} d\tau \quad (1)$$

To eliminate the singularities, such as $\tau = t$ and $\tau = \pm\infty$, Hilbert Transform is defined using the Cauchy principal value. Correspondingly, the Hilbert Transform of $s(t)$ is given by

$$\hat{s}(t) = \mathcal{H}\{s\} = -\frac{1}{\pi}\lim_{\varepsilon\downarrow 0}\int_{\varepsilon}^{\infty} \frac{s(t+\tau)-s(t-\tau)}{\tau} d\tau \quad (2)$$

Applying Hilbert transform to GPR signal $s(t)$, the analytic signal is obtained as

$$s_a(t) = s(t) + i\hat{s}(t) \quad (3)$$

where $\hat{s}(t)$ is the direct output of the Hilbert Transform of $s(t)$. The magnitude of $s_a(t)$ equals

$$|s_a(t)| = \sqrt{s(t)^2 + \hat{s}(t)^2} \quad (4)$$

$|s_a(t)|$ is the envelope of $s(t)$, which facilitates the signal power characterization.

Figure 1 demonstrates signal power characterization using Hilbert transform. The signal in Figure 1(a) is a GPR A-Scan waveform produced from two scatters. In the A-Scan waveform, the first pulse is the antennas' direct coupling, while the second and third pulses are the reflection signal from the 1st and 2nd scatters correspondingly. As the transmitting pulse signal is the Ricker wavelet (the second order derivatives of Gaussian function), the backscattering pulse from each object or layer interface shows three peaks. Figure 1(b) shows the waveform produced by the Hilbert transform where the three peaks become much more discernible.

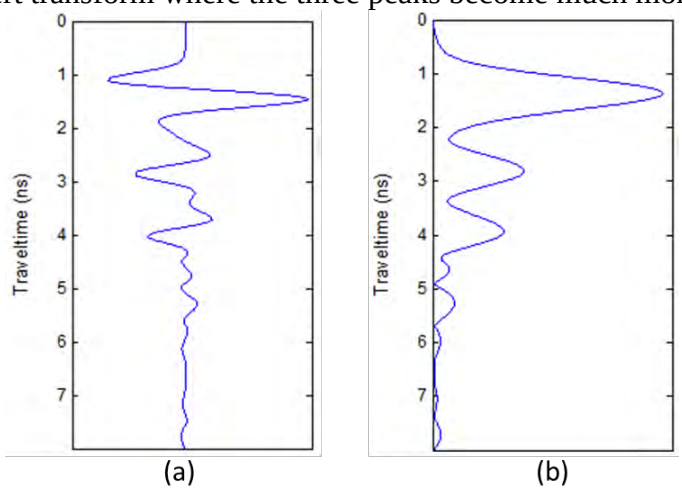


Figure 1 Hilbert transform for signal power characterization: (a) GPR A-Scan trace; (b) GPR A-Scan envelope.

Figure 2 demonstrates the GPR asphalt pavement inspection scenery. The 1st echo in the A-Scan trace the antenna directly coupling signal, the 2nd echo is the air-ground reflection signal, and the 3rd echo is the asphalt bottom surface reflection signal. Thus, upon the Hilbert Transform processed B-Scan image, the 2nd and 3rd signal peaks are extracted. The time instance for the 2nd signal peak is t_1, and the time instance for the 3rd signal peak is t_2.

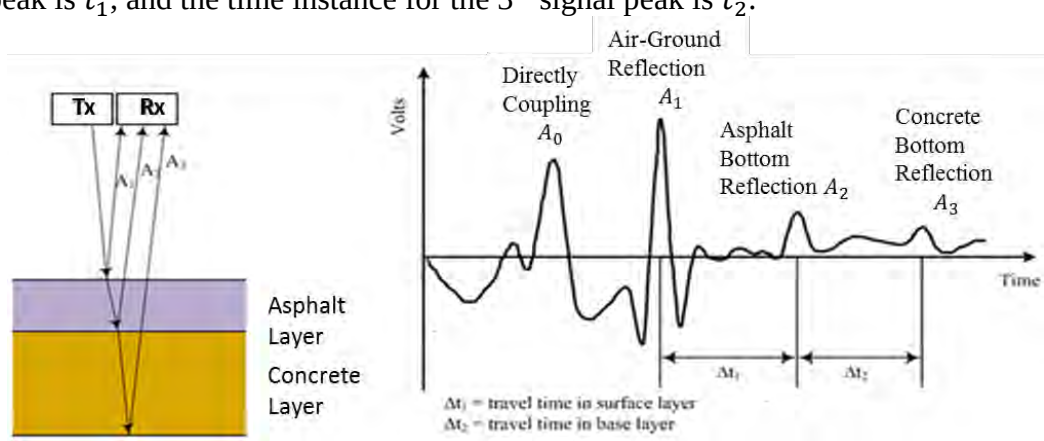


Figure 2 GPR Asphalt Pavement Test Scenery

Step 4: Asphalt pavement thickness calculation.

The two-way travel time of radar incident signal between the air-ground surface and the pavement bottom surface equals $\Delta t = t_2 - t_1$, and the one-way travel time is $\Delta t/2$. Substituting the dielectric constant of asphalt ε into equation $V = V_c/\sqrt{\varepsilon}$, where V_c is the speed of light in air. Using $V = d/(\frac{\Delta t}{2})$, the depth of the asphalt pavement d can be calculated.

2. 3D Asphalt Pavement GPR Inspection (02/16/2015-03/15/2015)

Two test sites on UVM campus are selected for 3D asphalt pavement GPR inspection. The first test site is an on-campus driveway which is shown in Figure 3(a). During GPR inspection, parallel scans of 7 lines of are performed, the scan lines are 1.5 feet apart from each other. The second test site is a load zone of an on-campus parking lot as shown in Figure 3(b). During GPR inspection, parallel scans of 5 lines are performed, the scan lines are 1 foot apart from each other. To accurately monitor and control the position and direction of each GPR scan line, a geophysical coordinate map is placed on ground for reference, which is shown in Figure 3(c).

(a)

(b)

(c)

Figure 3 Asphalt Pavement Test Sites on UVM Campus

For highway construction, the asphalt pavement is normally more than 4 inches thick. However, for the on-campus driveway and parking lot construction, thickness of asphalt pavement is less than 3 inches. Theoretically, high frequency GPR signal can produce high range resolution high while low penetrating depth, while low frequency GPR signal has deeper penetrating depth but at the cost of low range resolution. In this experiment, in order to achieve a high range resolution for thin asphalt layer measurement, the high frequency 2.3 GHz Mala CX GPR system in our lab is utilized as the test device.

Figure 4 plots the B-Scan image for one scan line at the first test site. In the image, the air-ground interface and asphalt pavement bottom surface are marked respectively. The thickness of the asphalt pavement on this scan line is relatively even and smooth. Combining all 7 scan lines, the thickness map for the first test site is plotted in Figure 5. The horizontal axis in this figure specifies GPR travel distance in the scan direction, while the vertical axis is specifies the width of the scanning area. The color-to-thickness mapping is shown on the right. From the thickness map, it is observed that at the center portion of this on-campus driveway, the asphalt pavement thickness is smaller than that the border portion. We think this is because this driveway has a single lane, most traffic loads utilize the center portion of the road, which cause the center portion of the pavement to be thinner.

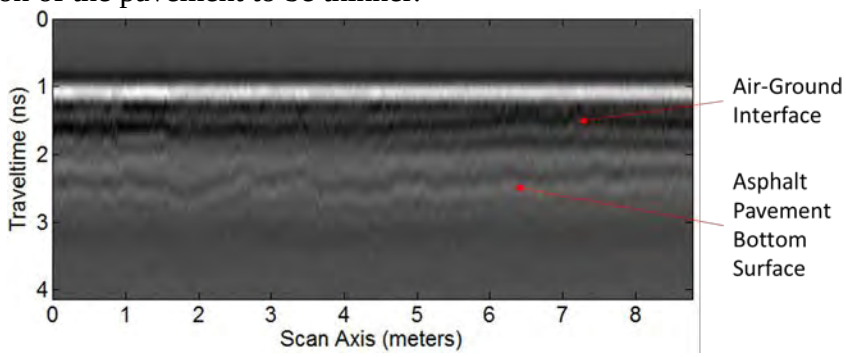


Figure 4 B-Scan Image for One Scan Line on the 1st Test Site

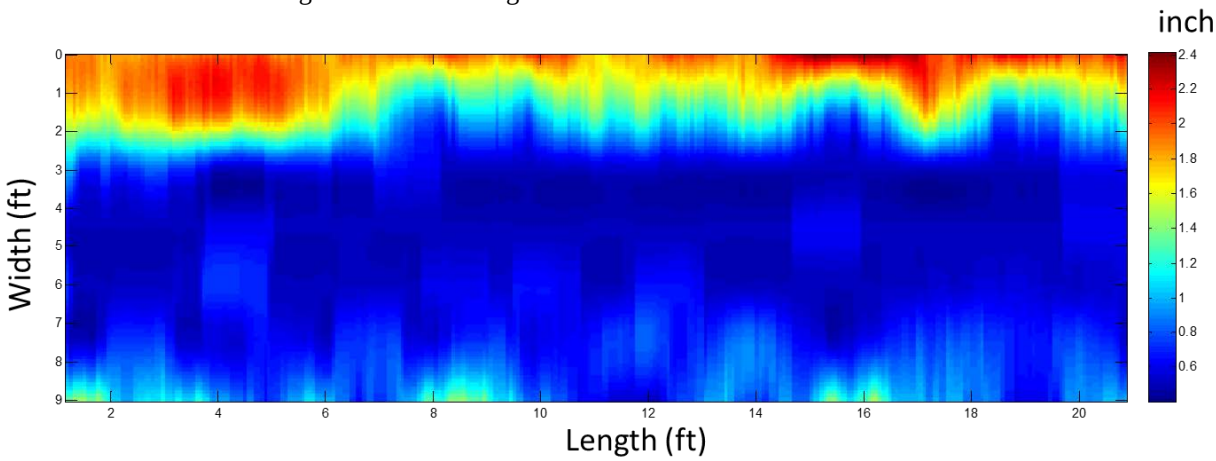


Figure 5 Asphalt Pavement Thickness Map for the 1st Test Site

Figure 6 plots the B-Scan image for the 2nd GPR scan line on the second test site. The air-ground interface and asphalt pavement bottom surface are marked in the B-Scan image respectively. The thickness of the asphalt pavement on this scan line decreases from the starting point to the ending point. Combining all 5 scan lines, the thickness map for this test site is plotted in Figure 7. The color-to-thickness mapping is shown on the right of this figure. From the thickness map, it is observed that one region (middle left in Figure 7) of this test site has very thin asphalt pavement. This observation is consistent with our visual check on this test site, which shows there is a pit on this portion.

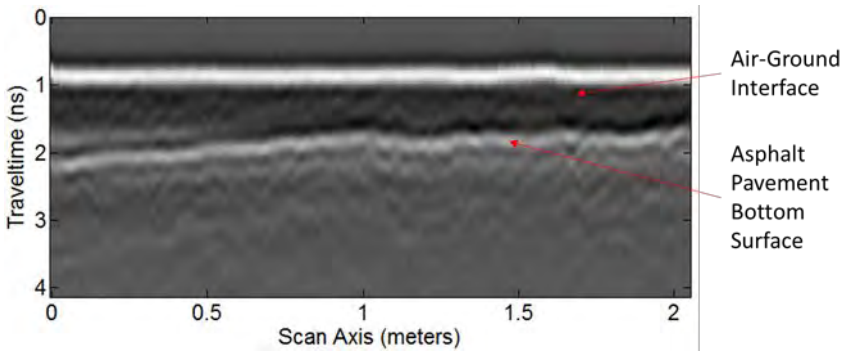


Figure 6 B-Scan Image for One Scan Line on the 2nd Test Site

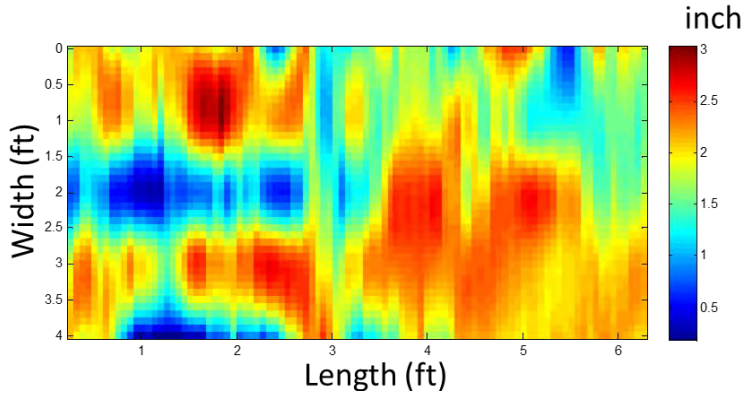


Figure 7 Asphalt Pavement Thickness Map for the 2nd Test Site

3. Asphalt Pavement Dielectric Constant Monitoring (03/16/2015-04/15/2015)

The winter in Vermont is quite long and cold, so the snow and ice are accumulated in the asphalt pavement during the winter. Also, water sinks under the asphalt pavement after raining. When pavement moisture changes, the dielectric constant of the asphalt pavement will be different. In this study, we explore GPR's capability to measure the dielectric constant of the asphalt pavement which can be utilized to assess asphalt moisture condition and road water drainage property.

In the experiment, three spots on a 2nd on-campus test sites are marked and selected for measurement, which are depicted in Figure 8. The 1st test spot is located at the border of the road pavement. The 2nd test spot is located at the center portion of the road. This spot has a pit where water is accumulated. The 3rd test spot is also located at the center portion of the asphalt pavement. Two weeks of successive GPR tests on these 3 spots are performed. The dielectric constant for these 3 spots are calculated and recorded after each test. Note, the dielectric constant of water is much higher than the pavement, therefore a higher dielectric constant indicates a higher degree moisture.

Figure 8 Asphalt Pavement Dielectric Constant Monitoring Test Spots

The calculated dielectric constants for 3 test spots are summarized in Table 1. The weather and temperature for each test date are recorded. The dielectric constant curves versus test date for 3 test spots are plotted in Figure 9. The 1st test spot is at the border of the asphalt pavement and close to a soil region. The water underneath the pavement can easily flow to the soil region. Therefore, the dielectric constant of this test spot is relatively small after the raining than other 2 test spots. The 2nd test spot is a pit in this asphalt pavement region, where water accumulates heavily during the raining, and the dielectric constant of this test spot is affected significantly. The 3rd test spot is a normal asphalt pavement region with no obvious defect, i.e. cracks, its dielectric constant is relatively stable comparing with other 2 test spots.

Table 1 Dielectric Constant of Asphalt Pavement for Two Weeks Duration

Weather	Partly Cloudy	Partly Cloudy	Mostly Cloudy	Partly Cloudy	Sun	Cloudy	Partly Cloudy	Partly Cloudy	Cloudy	Cloudy	Mostly Cloudy	Sunny
Temperature (Celsius)	3	0	8	18	5	3	5	7	6	8	7	16
Raining Before Test	Yes	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes	No
Date	31-Mar	1-Apr	2-Apr	3-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr
Spot 1	6.9206	6.3098	6.6024	4.585	4.076	4.585	4.8508	4.6506	3.1478	3.3393	4.8508	4.8508
Spot 2	5.6929	5.6929	6.2918	6.9206	7.5793	8.6236	7.9199	7.2462	6.2918	6.9206	7.2462	7.2462
Spot 3	5.9886	5.4047	5.6929	6.2918	6.3393	6.3393	5.6929	5.6929	5.4047	5.4047	5.4047	5.9886

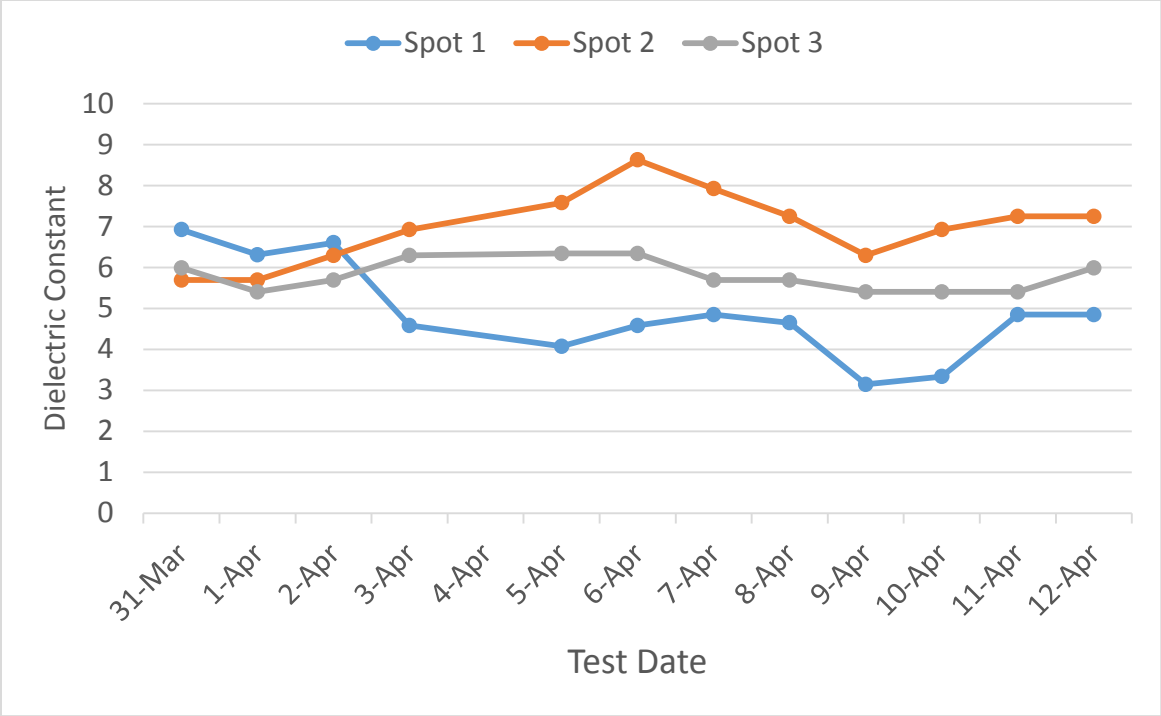


Figure 9 Dielectric Constant of 3 Test Spots

I. TECHNOLOGY TRANSFER ACTIVITIES:
N/A.

J. PERCENT COMPLETION OF TOTAL PROJECT:
Percent completion of total project is estimated to be around 60%. We expect much more accomplishments in the following quarters.

K. ACTIVITIES PLANNED FOR NEXT QUARTER:
- More field tests will be conducted either on UVM campus or on spots recommended by VTrans.
- More advanced data processing algorithms will be implemented for result analysis.
- Contact VTrans to identify a road segment or a bridge segment to perform field test. Some traffic control might needed from Vtrans.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER (April 2015 – July 2015, beak down into monthly estimates):
- $12,000 will be spent to cover research personnels' (two faculty investigators, one Post-doctor, and one Ph.D. student) summer salary.

Progress report prepared by: **Tian Xia**

Date Prepared: **04/15/2015**

Cost-Effective and Rapid Concrete Repair Techniques

Quarterly Report FFY2015 Q2

A. PROJECT NUMBER AND TITLE:
RSCH017-739
Cost-Effective and Rapid Concrete Repair Techniques

B. PRINCIPAL INVESTIGATOR(s):
Dryver Huston
Professor
School of Engineering
University of Vermont

C. START AND END DATE (per grant assignment):
05/01/2014-04/30/2015

D. ANTICIPATED COMPLETION DATE:
04/30/2015 (No cost extension application may be pending.)

E. PROJECT OBJECTIVES:
The intent of this project is to identify concrete repair practices that work best for the climate and infrastructure conditions in Vermont. Concrete is a principal component of many transportation structures. While highly durable, a variety of processes degrade and damage concrete. Replacement is expensive. Many cases warrant repair instead of replacement. Since many damage processes are progressive, early and properly timed repairs can reduce costs. Overall lifetime cost of ownership approach to selection and design of repairs has merit, but requires good information about costs and outcomes. There is a possibility that proper timing and application of repairs can be of great benefit to maintenance activities – including lifetime costs and rapid techniques that allow for expedited designs of repairs and minimizing repair times. Realizing the advantages of concrete repair requires effective execution of damage identification, damage assessment, repair design, repair, and post-repair assessment.

<u>Phase 1:</u>
This is a proposed one-year single-phase effort. Included in this Phase is Objective 5 which will be to develop a Phase II effort aimed at bringing the best practices into field evaluations.

- **Objective 1:** Assess present practices of concrete repair – The objective is to identify repair practices for concrete transportation infrastructure in Vermont and neighboring states. This will include the processes damage identification, damage assessment, repair design, repair, and post-repair assessment.
- **Objective 2:** Develop flow chart of decision-making and options for repair practice and evaluation – This will create a guide with recommendations for maintenance personnel and engineers, with an emphasis on cost-effective procedures that minimize imposing additional burdens on inspection and maintenance personnel.

- **Objective 3:** Develop procedures for integrating repair options and decisions into asset management – This will aid in reducing lifetime costs of ownership and assist in statewide maintenance planning.
- **Objective 4:** Recommend areas for further study and tech transfer to make cost effective repairs –This will be an effort to identify topics of importance to Vermont and achievable within present resource constraints.
- **Objective 5:** Describe a future Phase II effort that would take the procedures that seem to work the best and apply them in the field – This will result in a test plan for a Phase II effort.

F. REPORT PERIOD:

1/16/2015 – 4/15/2015

G. ACCOMPLISHMENTS THIS PERIOD (broken down by month):

a. 1st Month (January 16 – February 15, 2015)

The main activity this month involved developing a concrete repair decision flow chart chart. The first step was to down select topics for detailed analysis. The selected topics include: fascia, walls, columns, expansion joints. The flow chart allows the user to select the specific structural elements of interest and type of damage. It allows the user to input factors about the damage including: type of damage, location of damage, extent of damage, and prognosis. Figure 1 shows the expansion joint and fascia decision tree. Figure 2 shows a close-up view of the procedure section for expansion joints.

b. 2nd Month (February 16 – March 15, 2015)

The activity this month focused on acquiring and assembling into an electronic database various concrete repair technical manuals, codes, recommendations and reports. These included: Army TM 5-600 Bridge Inspection Maintenance, and Repair; Iowa DOT Bridge Maintenance Manual; ACI 546.1 R-80 Guide for Repair of Concrete Bridge Superstructures; ACI Concrete Repair Manual; Georgia DOT Bridge Structure Maintenance and Rehabilitation Repair Manual; and Wisconsin DOT Structure Inspection Manual. Activity also focused on developing a graphical user interface (GUI) interface for the flow chart and algorithm, Figure 3, Figure 4 and Figure 5.

c. 3rd Month (March 16, 2015 – April 15, 2015)

The activity this month included linking the repair data files with the repair options in the flow chart GUI. The user can select a repair type and the GUI pops up the pertinent documents for examination. At this point the algorithm helps to provide the proper repair method for a certain structural element and damaged type, including encasement, patching, composite wrapping, preventative paint, and electro chemical corrosion extraction. The next step was to begin to build a decision-making tree within the GUI, Figure 6. The following step was to use data from Vtrans bridge inspection and repair reports (provided by J.B. McCarthy) to create electronic input versions of these documents, Figure 7, Figure 8 and Figure 9.

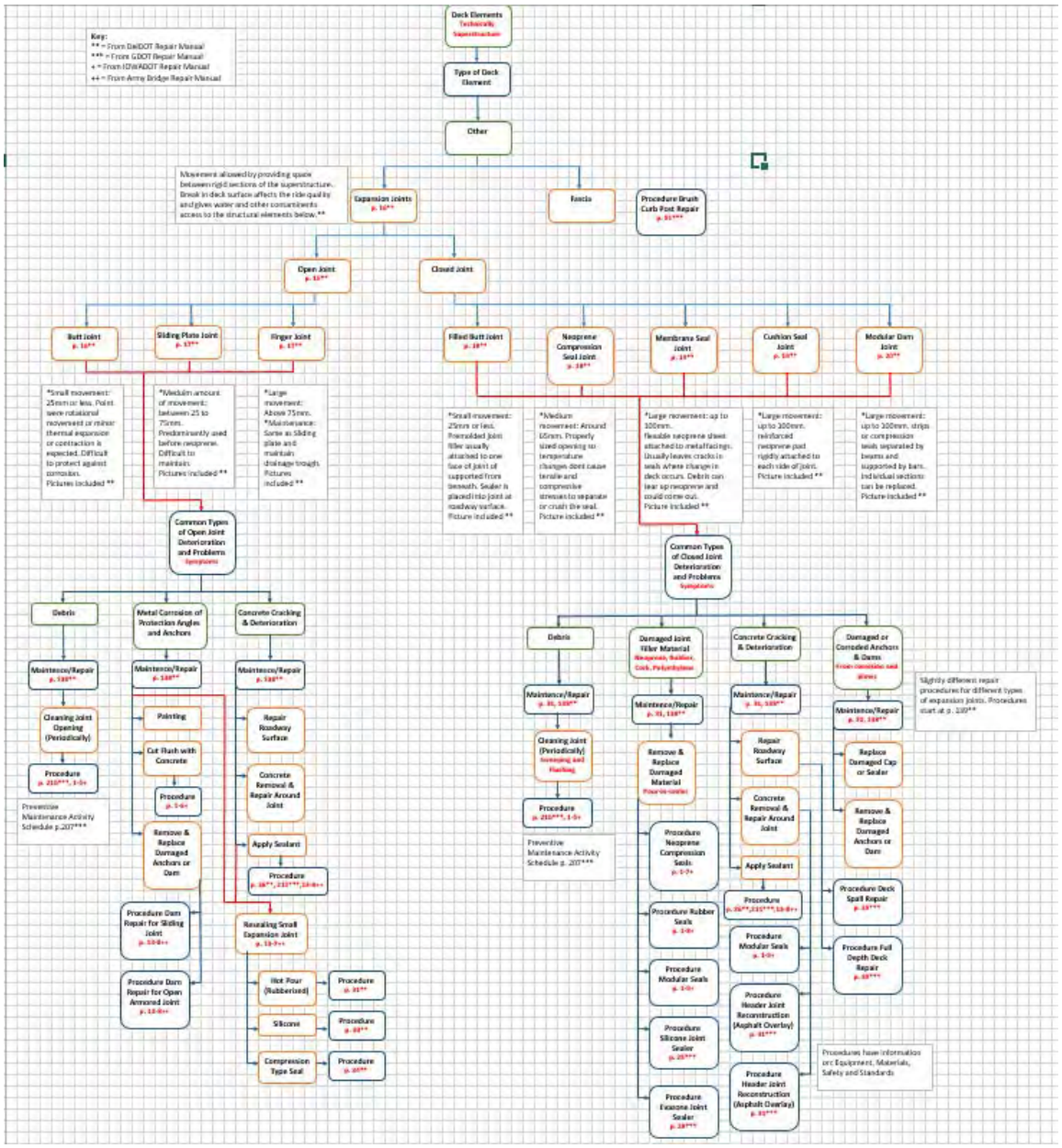


Figure 1 Expansion joint and fascia decision tree

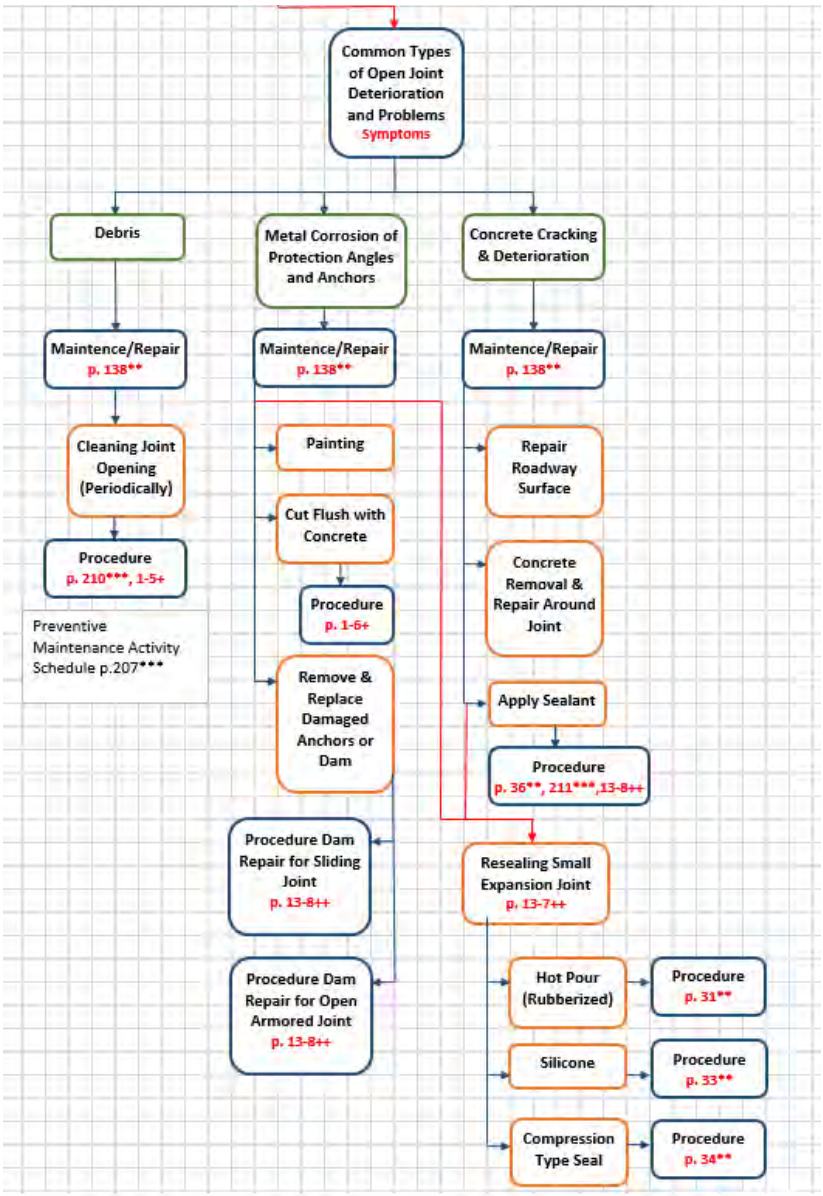


Figure 2 Closeup of procedure section

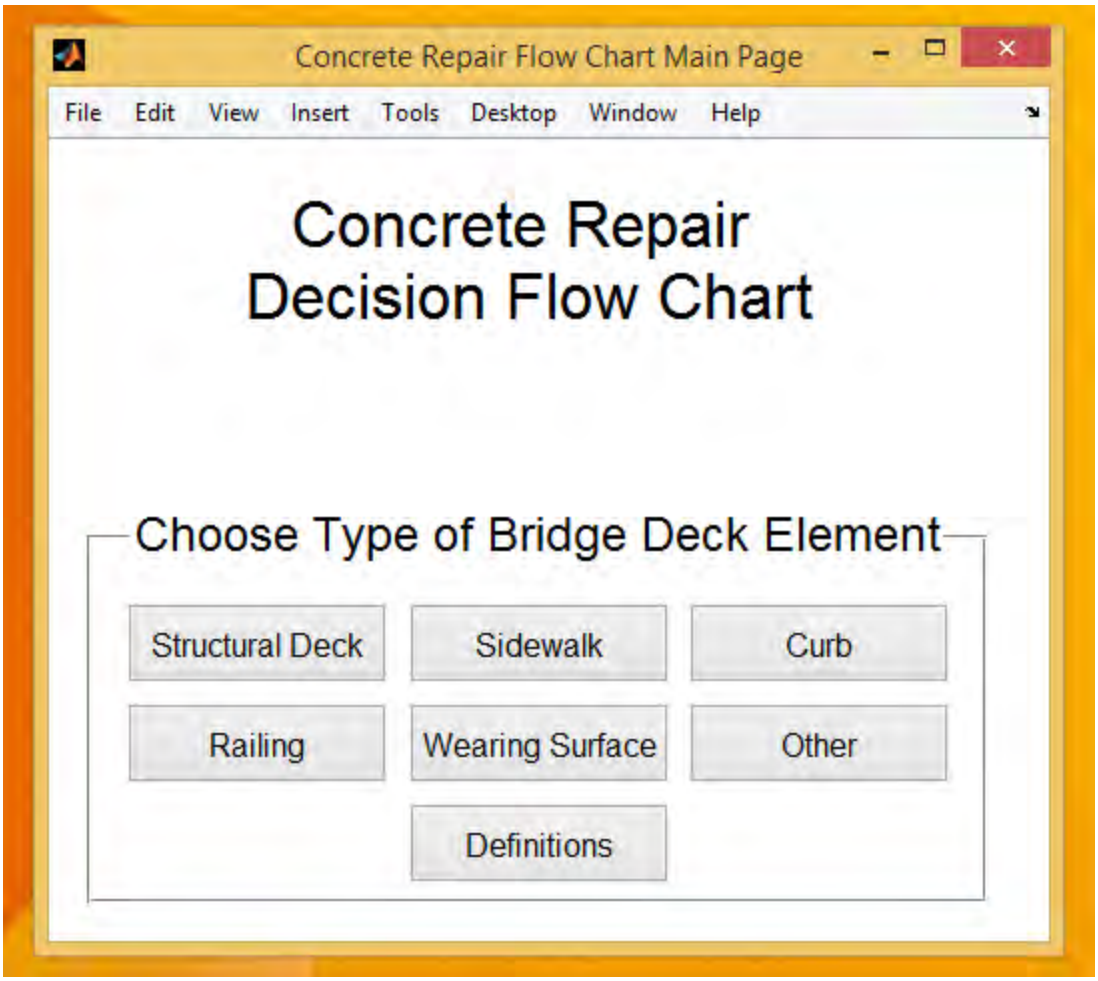


Figure 3 Screen shot of Concrete Repair Decision Flow Chart GUI main page, with user friendly features including definitions of terms in current GUI page

Figure 4 Screen shot of particular bridge deck element GUI (going through flowchart), enables picking type of damage to element to select proper repair procedure.

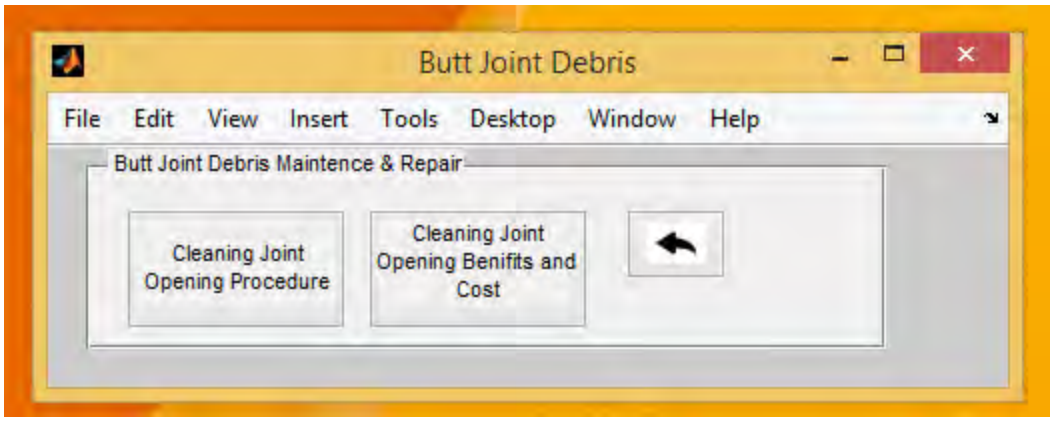


Figure 5 Screen shot of particular bridge deck element GUI (going through flowchart) with particular damage, user can pick correct repair procedure (links to repair procedures from list of data files) and determine benefits associated to repair and estimated cost of repair.

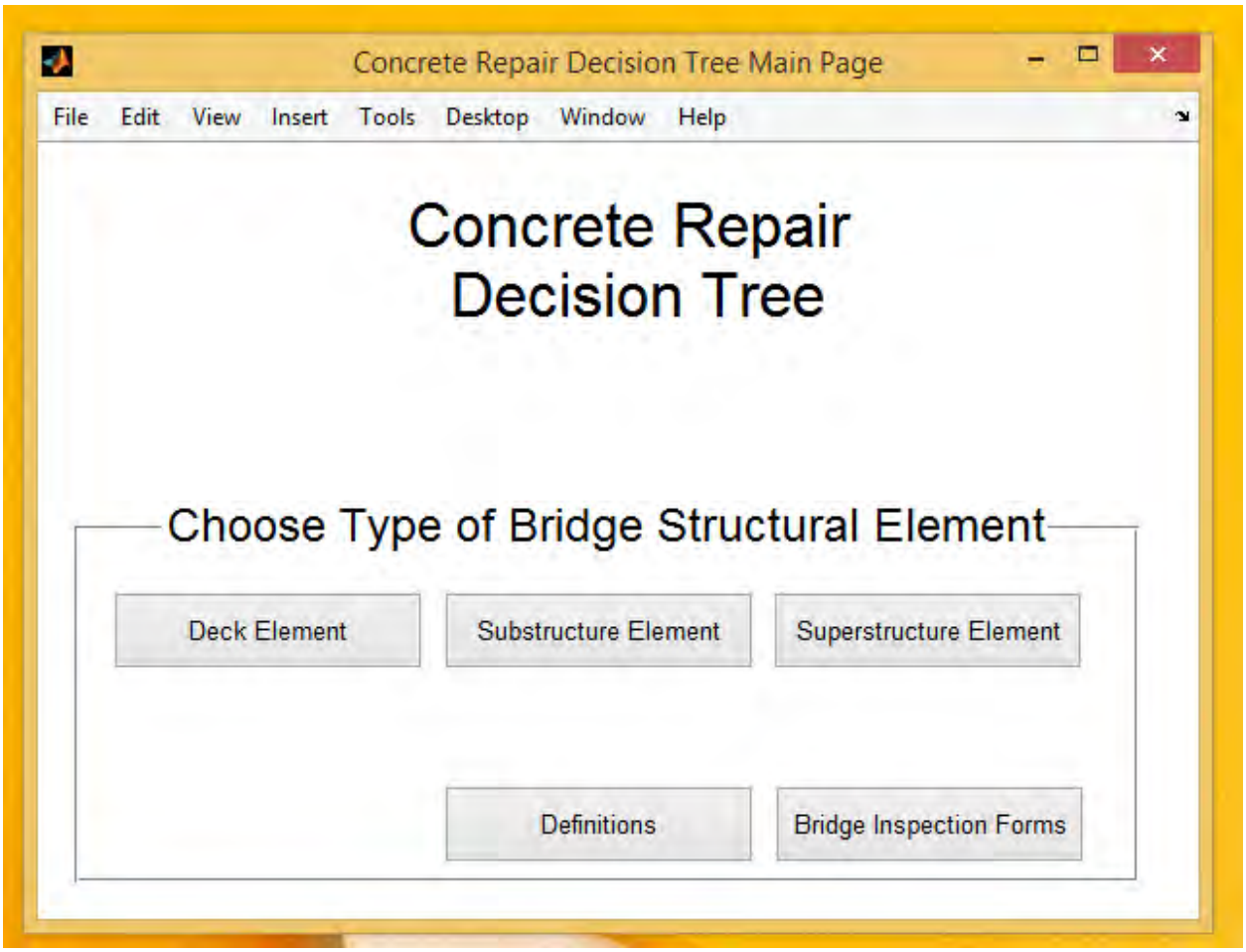


Figure 6 Screen shot of Concrete Repair Decision Tree GUI. In final GUI Flow chart will be incorporated into this GUI, and link to Bridge Inspection GUI that exports inspection data to an excel spreadsheet.

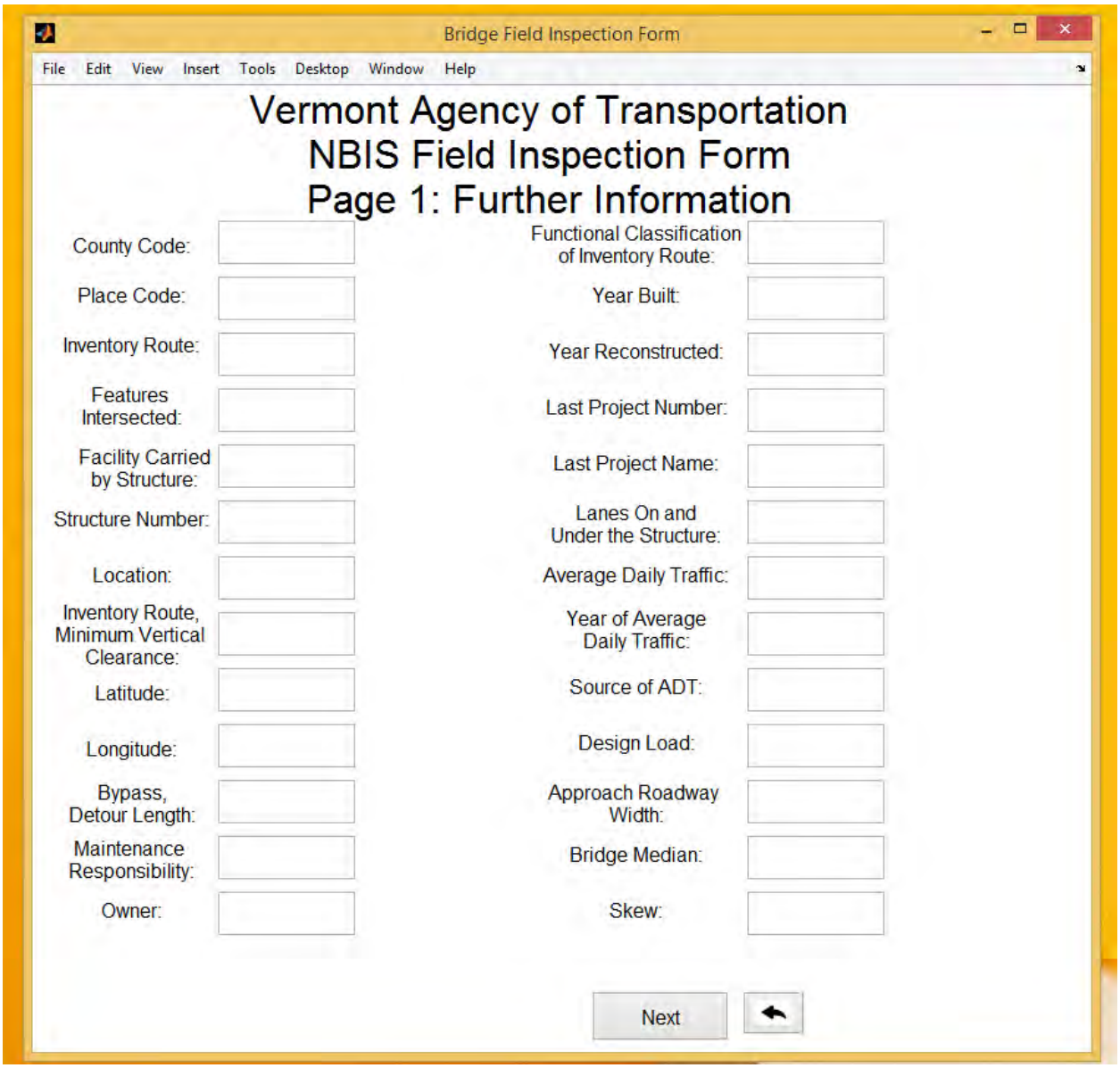
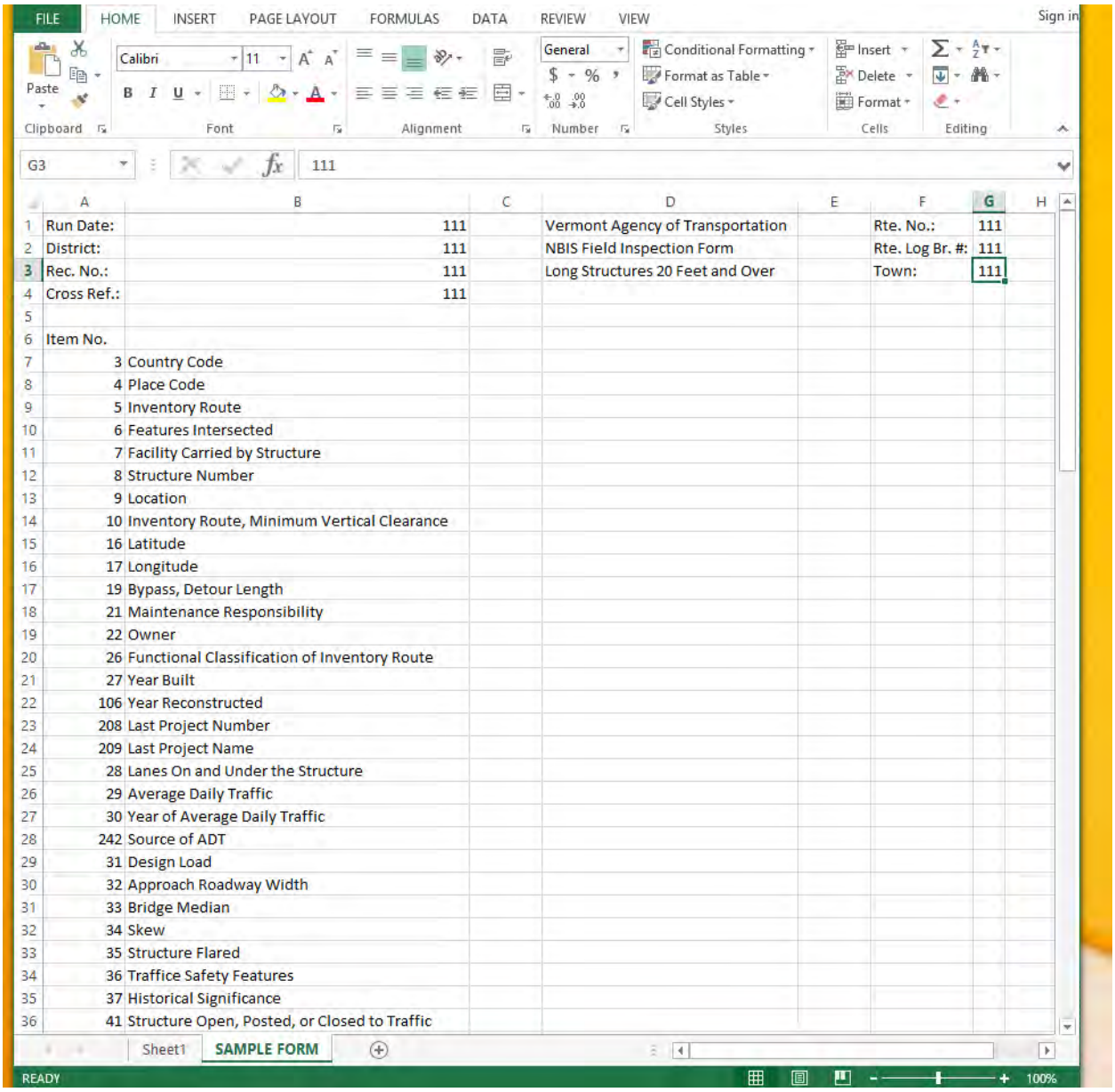


Figure 7 Bridge Inspection Form GUI, an electronic version of the VTrans NBIS Field Inspection Form that exports data to an excel spreadsheet.



	A	B	C	D	E	F	G
1	Run Date:	111		Vermont Agency of Transportation		Rte. No.:	111
2	District:	111		NBIS Field Inspection Form		Rte. Log Br. #:	111
3	Rec. No.:	111		Long Structures 20 Feet and Over		Town:	111
4	Cross Ref.:	111					
5							
6	Item No.						
7	3	Country Code					
8	4	Place Code					
9	5	Inventory Route					
10	6	Features Intersected					
11	7	Facility Carried by Structure					
12	8	Structure Number					
13	9	Location					
14	10	Inventory Route, Minimum Vertical Clearance					
15	16	Latitude					
16	17	Longitude					
17	19	Bypass, Detour Length					
18	21	Maintenance Responsibility					
19	22	Owner					
20	26	Functional Classification of Inventory Route					
21	27	Year Built					
22	106	Year Reconstructed					
23	208	Last Project Number					
24	209	Last Project Name					
25	28	Lanes On and Under the Structure					
26	29	Average Daily Traffic					
27	30	Year of Average Daily Traffic					
28	242	Source of ADT					
29	31	Design Load					
30	32	Approach Roadway Width					
31	33	Bridge Median					
32	34	Skew					
33	35	Structure Flared					
34	36	Traffice Safety Features					
35	37	Historical Significance					
36	41	Structure Open, Posted, or Closed to Traffic					

Figure 8 Screen shot of exported data from Bridge Inspection GUI

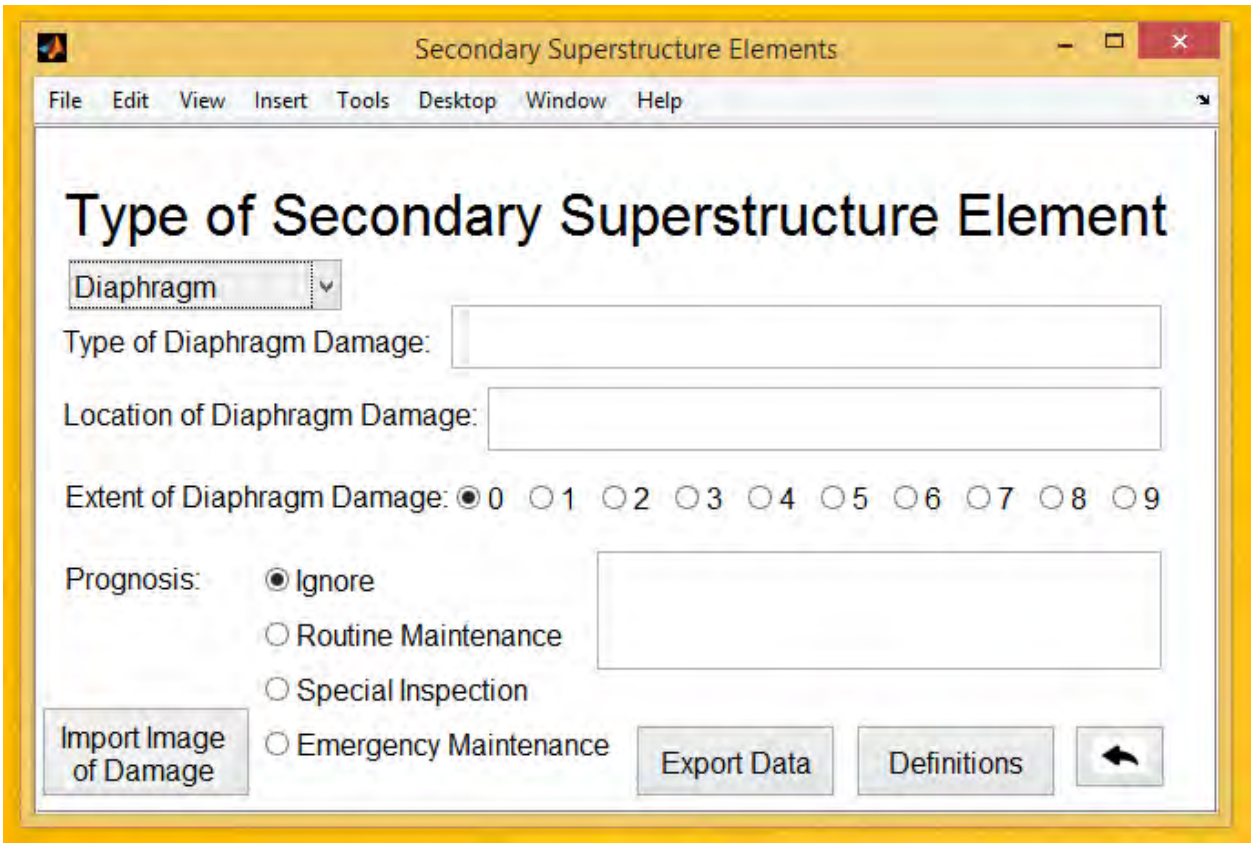


Figure 9 Assessment of bridge structure GUI , assessment of damage and prognosis, exports data to an excel spreadsheet can upload an image of structural damage.

H. PROBLEMS ENCOUNTERED (If any):

No major problems were encountered. Due to the initial slow start of the project, a request for a no-cost extension to the project may be forthcoming. The post doctoral researcher who has been working on the project (D. Burns) will be leaving at the end of this quarter. His duties will likely be replaced by an engineering graduate student on wages.

I. TECHNOLOGY TRANSFER ACTIVITIES:

There were no major technology transfer activities this quarter. D. Huston attended the American Concrete Institute Convention in Kansas City, MO (April 11-13, 2015) and participated in the Concrete Repair Education, and Alkali Silica Reactivity technical committees.

J. PERCENT COMPLETION OF TOTAL PROJECT:

Percent completion of total project is estimated to be around 75%.

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Visit additional damaged bridge sites with Vtrans maintenance personnel. This may included the use of nondestructive test equipment, such as ground penetrating radar.
- Continue with decision-making flow chart development.
- Present draft flow chart to Vtrans personnel for comment and feedback.

- Conduct technology transfer activities related to concrete repair with the State of New York and possibly Maine and New Hampshire Departments of transportation.
- Introduce triage decision-making, and the framework for cost estimation into the algorithm.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER (April 16, 2015 – June 15, 2015) (pending approval of no-cost extension):

- $4,500 combined salary and fringe benefits for student on wages Jonathan Razinger
- $75 for travel to bridge sites
- $100 for supplies

Progress report prepared by: **Dryver Huston**

Date Prepared: **4/15/2015**

Using Remote Data Collection to Identify Bridges and Culverts Susceptible to Blockage During Flooding Events

QUARTERLY REPORT

A. PROJECT NUMBER: RSCH017
SPR: 740

B. PRINCIPLE INVESTIGATOR(s): Jim Sullivan

C. START AND END DATE (per grant assignment): July 1, 2014 - June 30, 2016

D. ANTICIPATED COMPLETION DATE: June 30, 2016

E. PROJECT OBJECTIVES: This project will consist of three phases and has nine objectives:

- Phase I: Project kick-off
  - Objective 1: Assemble the team
  - Objective 2: Select stream field sites
  - Objective 3: Finalize the project work plan
- Phase II: Flight operations and data collection
  - Objective 3: Collect stereo imagery for field sites under a variety of conditions
  - Objective 4: Process imagery to extract 2D orthophoto mosaics and 3D surface models
  - Objective 5: Develop, test, and assess feature-extraction capabilities
  - Objective 6: Integrate the data with Geographic Information System (GIS) software
  - Objective 7: Test field-based data transmission approaches
- Phase III: Reporting
  - Objective 8: Summarize the methodology and findings
  - Objective 9: Present the results

F. REPORT PERIOD: January 1st through March 31st , 2015

G. ACCOMPLISHMENTS THIS PERIOD:

- Capitalizing on synergies between this project and other projects funded by the U.S. DOT, more stereo imagery was collected at Great Brook in Plainfield, Vermont
- The imagery from these data collection efforts was processed into 3D surface models, and feature-extraction capabilities were tested.

- Due to these synergies, minimal oversight was required of the Principal Investigators (PIs) on the project, resulting in effort allocations for the quarter that are below the budgeted levels.

H. PROBLEMS ENCOUNTERED (if any):

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 5%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Synergies between this project and other projects funded by the U.S. DOT will allow more test sites to be selected and more imagery to be collected throughout the next quarter in consultation with the project advisors from VTrans and ANR

Progress report prepared by: Jim Sullivan **Date Prepared:** April 13, 2015

Personal Transportation Plan Pilot Program (PTP3), Phase 1

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
RSCH017-741: Personal Transportation Plan Pilot Program (PTP3), Phase 1

B. PRINCIPLE INVESTIGATOR(s): Brian H. Y. Lee

C. START AND END DATE (per grant assignment): 1 Jun 2014 – 30 Sep 2015

D. ANTICIPATED COMPLETION DATE: 30 Sep 2015

E. PROJECT OBJECTIVES:

The Personal Transportation Plan Pilot Program (PTP3) is a collaboration between VAOT, the University of Vermont (UVM), and the Vermont Statewide Independent Living Council (SILC, www.vtsilc.org). The **primary objective** of the entire project is to:

> Improve the mobility of Vermonters with disabilities by creating a personal transportation planning tool that would be used by the target population as well as their families, friends, and other caretakers to match existing transportation resources with their travel needs.

The long-term objective of this effort is to create a planning tool that would be used by transportation-disadvantaged Vermonters from across the entire state. There will be online and paper/telephone versions of this tool where users can answer a list of questions concerning the schedules and locations of various activities in their lives and be interactively guided to information about existing transportation resources that could help meet their travel needs.

The PTP3 project will include at least four phases: I) Pre-Program Assessment, II) Pilot Program Development, III) Pilot Program Implementation, and IV) Post-Program Evaluation. The research work in this current project only concerns Phase I of this pilot program. The following are the **Phase I objectives**. Other phases of this pilot program are outside of this proposed scope of work.

1. Phase I: Pre-Program Assessment
   a. Objective 1: Identify mobility needs
   b. Objective 2: Measure abilities to meet mobility needs
   c. Objective 3: Inform the subsequent phases

F. REPORT PERIOD: 1 January 2015 to 31 March 2015

G. ACCOMPLISHMENTS THIS PERIOD:

- Solicited feedback on survey format from beta testers, including UVM's Universal Design Tech Lab and users with various physical impairments, particularly those who are blind or visually impaired
- Conducted editing of the full draft based on feedback from beta testers, focusing on both format and content

H. PROBLEMS ENCOUNTERED (If any): We discovered a few software compatibility issues between the survey platform that we are using and some accessibility programs. We worked with the beta testers and the UVM Design Tech Lab to find feasible solutions for these problems.

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 40%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Conduct survey
- Perform data analysis with survey results
- Continue drafting report

Progress report prepared by: Samantha Tilton **Date Prepared:** 02 April 2015

The changing risk of extreme event impacts on Vermont transportation infrastructure

Quarterly Report

A. Project number and title: 742: The changing risk of extreme event impacts on Vermont transportation infrastructure
SPR: RSCH015

B. **Principal Investigator:** Arne Bomblies, UVM School of Engineering

C. **Start and End date**: 1/15/15 – 1/15/17

D. **Anticipated completion date:** 1/15/17

E. Project objectives:

a. The generation of a map of change factors associated with precipitation changes from climate change that can be easily applied to current design methodology.
b. Precipitation time series for model simulations will be generated using a stochastic, data-driven approach.
c. Generate a report on the nature of climate change impacts on extreme flows in Vermont.

F. **Report period:** 1/15/15 – 4/15/15

G. Accomplishments this period:

a. January 2015: Graduate student Cam White and PI Bomblies began by laying the groundwork for the data-driven model generation. This included collection of meteorologic data for Burlington and region-wide using a gridded "reanalysis" data set and extracting time series.
b. February 2015: We developed a computer code to generate realizations of precipitation based on the past observations. Concurrently, Cam began working on becoming familiar with the Mad River Valley hydrology model, which will be intensively used later in the project.
c. March 2015: Similar to February, progress in March was centered on advancing the ability to generate future precipitation scenarios based on past observed changes, and getting the hydrology model ready for use (i.e. Cam becoming familiar with it) once the precipitation model nears completion. Currently, we are continuing to work on the conditional probabilities of daily minimum and maximum temperatures as they relate to rainfall. This task will continue in Q3. It is important because the daily temperature minima and maxima are dependent on whether or not it rains on a particular day, and the model cannot have unrealistic combinations of temperature and precipitation. The changes over the years (e.g. more precip as rain recently) are also being characterized. In general, we are well underway to completing up to Task 1.6 as initially proposed. We still have to address Tasks 1.2 and 1.5, but for that we are 2-3 months ahead of schedule in completion of Task 1.6.

H. **Problems encountered**: No problems have been encountered.

I. **Technology transfer activities**: None.
J. **Percent completion of total project**: 15%
K. **Activities planned for next quarter**:
    a. By the end of next quarter, we anticipate completion of the Markov Chain Monte Carlo model required to generate nonstationary climate input for our hydrological modeling. This task requires significant computer programming, and will constitute the bulk of the effort for Q3 (April – June).
    b. We also will pursue the potential covariates of North Atlantic Oscillation, El Niño, Pacific Decadal Oscillation and other teleconnection indices to determine their role in the Vermont precipitation climatology. This will involve literature review as well as significant exploration of long data sets from meteorological stations.
    c. We will conduct trial runs of the generated meteorological data as input to the hydrology model. This is partly a head start for Task 2.1.
    d. Cam will complete his three spring 2015 courses by the middle of May.
L. **Estimated budget amount spent next quarter**: $7300.

Progress report prepared by: Arne Bomblies

Date prepared: April 13, 2015

Demonstration and Purchase of PG Binder Testing Equipment
QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 905 Demonstration and Purchase of PG Binder Testing Equipment

B. PRINCIPAL INVESTIGATOR(s):

George W. Colgrove III, Research and Development
and
Troy Lawson, Asphalt & Hot Mix Unit, Materials Lab

C. START AND END DATE (per grant assignment): December 15, 2013 – September 30, 2014.

D. ANTICIPATED COMPLETION DATE: June 30, 2015

E. PROJECT OBJECTIVES: Materials and Research initiated an effort to procure the same PG Binder lab equipment that it acquired earlier in a Pooled Fund Project. The Pooled Fund project was a New England wide project where the New England states would use the same testing equipment to unify the testing processes and for comparisons. With the pooled fund project terminating early, this effort was initiated to complete the equipment acquisition.

F. REPORT PERIOD: 2015 Q2

G. ACCOMPLISHMENTS THIS PERIOD:
No activity has been completed in this period.

Wireless equipment for the MMA lab has been identified and is awaiting purchase

H. PROBLEMS ENCOUNTERED (If any):
No problems have been encountered in this period.

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: 95%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

A Research Update will be produced to summarize the effort in obtaining and installing the new PG Binder.

Progress report prepared by: George Colgrove
Date Prepared: April 14, 2015

Pavement Performance and Annualized Cost Study

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 921 Pavement Performance and Annualized Cost Study

B. PRINCIPLE INVESTIGATOR(s):

Wendy Ellis
Research Technician V
Vermont Agency of Transportation
2178 Airport Rd., Unit B
Berlin, VT 05641
Telephone: (802) 828-6918
Fax: (802) 828-2792

C. START AND END DATE (per grant assignment):
ongoing

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: To collect performance data from a comprehensive array of pavement rehabilitation techniques for the purpose of monitoring effectiveness and costs. The evaluation is centered upon those projects which have rehabilitated existing pavements with reclaimed base stabilization, cold recycled bituminous concrete, milling followed by overlay, and overlays. Projects have been selected from distinct microclimates representing the range of Vermont weather conditions. This project is vital to the ongoing success of our paving program. Findings from this study will be used to determine the most cost effective treatment based upon various factors including daily traffic, underlying soils and pavement profile, and roadway condition prior to any rehabilitation efforts.

F. REPORT PERIOD: 1-1-15 to 3-1-15

G. ACCOMPLISHMENTS THIS PERIOD:

- 2015 new projects were chosen and added to the project.
- The 2015 field data collection schedule was completed.
- The IRI and Rutting request for Asset Management was completed.
- Cracking and rutting spreadsheets were updated.

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: N/A

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Preconstruction site visits will be conducted in April/early May for new projects.
  - This should include Moretown-Duxbury because the portion included in the study was not constructed in 2014.
- Annual site visits will be started.

Progress report prepared by: Wendy Ellis
Date Prepared: 3-19-15

An Assessment of Culvert Replacements Modified for Fish Passage

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 969 An Assessment of Culvert Replacements Modified for Fish Passage

B. PRINCIPLE INVESTIGATOR(s):
Wendy Ellis
Research Technician V
Vermont Agency of Transportation
2178 Airport Rd., Unit B
Berlin, VT 05641
Telephone: (802) 828-6918
Fax: (802) 828-2792

C. START AND END DATE (per grant assignment):
2008-2013

D. ANTICIPATED COMPLETION DATE: *If different from the END DATE in paragraph C., the reason must be given.*

E. PROJECT OBJECTIVES: With over 50 modified culverts previously installed throughout the State of Vermont, the objective of this research project is to determine the effectiveness of fish passage restoration. An examination of representative fish passage structures will define the character, durability and stability of the constructed habitats and improved connectivity up and downstream of the culvert. In addition, the research project will evaluate the cost-effectiveness of these types of structures, including the timing of the natural bed load accumulation in the structure.

F. REPORT PERIOD: 1-1-15 to 3-31-15

G. ACCOMPLISHMENTS THIS PERIOD:

- Cost data was collected.
- Notes/observations were collected from the town of Warren.

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: 90%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Final report will be drafted and published.

Progress report prepared by: Wendy Ellis
Date Prepared: 3-19-15