Vermont Agency of Transportation

Research Advisory Committee

Project Quarterly Progress Reports

2014 – Q4

(7-01-2014 to 9-30-2014)

Evaluation and Advancement of VTrans Bridge Deterioration Model

QUARTERLY REPORT

A. PROJECT NUMBER (EA Number): TAMP001-001

B. PRINCIPLE INVESTIGATOR(s): Dr. Eric Hernandez

C. START AND END DATE (per grant assignment): April 17, 2014 – December 31, 2014

D. ANTICIPATED COMPLETION DATE: October 17, 2014

E. PROJECT OBJECTIVES: The primary goal of this project is to evaluate and advance the VTrans' Bridge Deterioration Model (BDM). The objective of the BDM is to estimate when a bridge will fall into the "structurally deficient" category based on previous inspection results for nearly 2,600 bridges documented in the VTrans' Bridge Inventory System (BIS).

F. REPORT PERIOD: July 1st through September 30th , 2014

G. ACCOMPLISHMENTS THIS PERIOD:

- Completed the development of the bridge deterioration models, using a Markov Chain process with a Regression Method (like Florida) and a Weibull Method (like New York)
- Delivered the model files for the preliminary enhanced BDM in MATLAB and presented findings and recommendations on the BDM to VTrans
- Began writing the draft-final project report

H. PROBLEMS ENCOUNTERED (if any): The timeline in the proposal assumed a notice-to-proceed date of March 1, 2014. Since the NTP was not received until April 17, 2014, the timeline is revised as follows:

- Draft Final Report: A draft of the final report will be delivered to VTrans on September 24, 2014. VTrans will be given 15 working days to review and comment on the final product. The final product delivery date for the report, with VTrans comments incorporated, is October 17, 2014.
- Preliminary BDM: The preliminary enhanced BDM, including all supporting electronic files, spreadsheets, databases, & macros, along with all computer codes or languages necessary to run the model, will be delivered by August 29, 2014. With the preliminary BDM, UVM will provide a description (1-2 pages) of the process necessary to perform analyses using the enhanced BDM.
- Final Presentation: UVM shall coordinate a presentation to VTrans to present findings and recommendations at a date that is convenient to VTrans staff near or following delivery of the Final Report.

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 90%

K. ACTIVITIES PLANNED FOR NEXT REPORTING PERIOD:

- Complete and deliver the draft-final project report

Progress report prepared by: Jim Sullivan **Date Prepared:** October 15, 2014

Improvement and Operation of the Vermont Travel Model

FINAL QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE: 0001051
SPR: 302

B. PRINCIPLE INVESTIGATOR(s): Jim Sullivan

C. START AND END DATE (per grant assignment): October 1, 2013 – September 30, 2014

D. ANTICIPATED COMPLETION DATE: September 30, 2014

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: July 1st through September 30th , 2014

G. ACCOMPLISHMENTS THIS PERIOD:

- Improvement of the Model:
  - Completed the re-assessment of centroid connectors locations and resolution of TAZs
  - Completed testing the validity of leaving the trip matrices asymmetrical, particularly for NHB travel, since NHB trips do not necessarily return to their origin daily
  - Completed writing the final-draft report for Year 6 of the project
- Operation of the Model:
  - Operated the Model in support of efforts by Parsons Brinckerhoff Freight and Logistics Consulting Services to prepare a statewide rail plan for Vermont: estimated the market share of rail compared to automobile passenger travel in Vermont, and estimated VMT growth for intercity travel in Vermont.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 100%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- None

Progress report prepared by: Jim Sullivan **Date Prepared:** October 16, 2014

Evaluation of Experimental Features
QUARTERLY REPORT

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

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 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: 7-1-14 to 9-30-14

G. ACCOMPLISHMENTS THIS PERIOD:

- Installations: WP 2013-R-3: Pavement Marking Comparison Study - Brookfield-Montpelier, Interstate 89 Painted Markings
    - All markings associated with this project were applied along I-89 SB in conjunction with Brookfield-Montpelier IM 089-1(61) paving project including: 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. Retroreflectivity readings were measured on Day 1, Week 1, Week 2, Week 3, and Week 4 following installation. All readings and associated comments and observations concerning the application will be summarized in the initial update.
- Annual and seasonal visits to the following projects:
    - WP 2005-R-1: Fine Graded 75 Gyration Superpave Mix

- WP 2005-R-2: 50 Gyration Superpave Mix
- WP 2011-R-2: Wavetronix® SmartSensor Matrix™ Radar Stop Bar Detection
- WP 2011-R-6: Assessment of the Sterling Lloyd Eliminator Waterproofing Membrane System
- WP 2012-R-2: Poly-Carb Flexogrid Bridge Deck Overlay System
- WP 2012-R-3: Assessment of 40" Wide Paving Skid Box
- WP 2013-R-3: Pavement Marking Comparison, Brookfield-Montpelier, Interstate 89 Painted Markings
- WP 2013-S-1: Assessment of Fiber Reinforced Polymer (FRP) Strips for Bridge Rehabilitation – FRP stripes are installed. An analysis of the stripes will be made in the winter.
- Bridge in a Backpack? – Bridge is completed. Need to make a site visit to take measurements.

- Report and Update drafts completed:
  - WP 2009-R-03: Glomarc 90 Polyurea Pavement Markings (Interim, Final)
  - WP 2005-R-1: Fine Graded 75 Gyration Superpave Mix (Initial and 2 Updates)
  - WP 2010-R-1: Assessment of AASHTO M324 Type II vs Type IV Crackfillers. (Initial and 2 updates)
  - Investigative Report: Assessment of Extendo-Pave, a Polymer Crumb Rubber Crack Fill vs Standard Type II and Type IV Crack Fill (Final)

- Reports published:
  - WP 2009-R-03: Glomarc 90 Polyurea Pavement Markings (Initial)

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: Email notifications. Reports and updates are available electronically through the following link: http://vtransengineering.vermont.gov/sections/materials_and_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 2008-R-2 - Assessment of TechCrete, a Concrete Repair Material and Joint Sealant

- WP 2011-R-1 - Assessment of Super-Slab, a Precast Concrete Slab in a Bridge Approach Application
- WP 2011-R-3 - Pedestrian Hybrid Beacon Crosswalk System (PHB) or High-Intensity Activated Crosswalk (HAWK)
- WP 2011-R-5 - Assessment of Jahn Permeable Mortar System In a Historic Bridge Abutment Application
- WP 2012-R-1 - Assessment of the Bridge Preservation LLC's BDM Waterproofing Membrane System
- WP 2013-R-3: Pavement Marking Comparison, Brookfield-Montpelier, Interstate 89 Painted Markings – Month 2, 3, and 4 readings will be collected.

- Final updates and reports for the following will be completed and published:
  - Experimental and control crackfill along VT Route 25 (Final)
  - WP 2005-R-1: Fine Graded 75 Gyration Superpave Mix (Initial and 2 Updates)
  - WP 2007-R-1: Reclaimed Stabilized Base with Cement (Final)
  - WP 2009-R-1: Ennis Paint Duraset Methyl-Methacrylate (MMA) (Initial and Final)
  - WP 2009-R-03: Glomarc 90 Polyurea Pavement Markings (Interim and Final)
  - WP 2010-R-1: Assessment of AASHTO M324 Type II vs Type IV Crackfillers. (Initial and 2 updates)
  - WP 2011-R-1: Assessment of Super-Slab, a Precast Concrete Slab in a Bridge Approach Application (Initial)
  - 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 2013-R-3: Pavement Marking Comparison, Brookfield-Montpelier, Interstate 89 Painted Markings

Progress report prepared by: Wendy Ellis
Date Prepared: 10-15-14

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):
Jason P. Tremblay, P.E.
Research Engineer
Vermont Agency of Transportation
One National Life Drive
Montpelier, VT 05633
Telephone: (802) 828-2553

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: July 1st, 2014 through September 30th, 2014

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. Once all data is collected and compiled, data analysis and report writing will commence.

Progress report prepared by: Jason P. Tremblay
Date Prepared: October 15, 2014

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):
Jason Tremblay, M.S., P.E.
Research Engineer
Vermont Agency of Transportation
One National Life Drive
Montpelier, VT 05633
Telephone: (802) 828-6945

C. START AND END DATE (per grant assignment):
2009 - 2012

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: July 1st, 2014 through September 30th, 2014

G. ACCOMPLISHMENTS THIS PERIOD: The concrete mixer for phase II has been purchased and received. The draft report has been re-reviewed, with additions and corrections to be made identified.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 98% (phase I), all production, testing, data compilations, and basic analysis has been completed, along with a partial draft report.

K. ACTIVITIES PLANNED FOR NEXT QUARTER: The phase I final report will be finalized and published. Equipment and supplies will be purchased for phase II and test batch preparation began.

Progress report prepared by: Jason Tremblay
Date Prepared: October 15, 2014

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
Construction and Materials Bureau
Vermont Agency of Transportation
One National Life Drive
Montpelier, VT 05633
Telephone: (802) 828-6910

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.

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: July 1, 2014-September 30, 2014

G. ACCOMPLISHMENTS THIS PERIOD:
Addison traffic data was verified by Traffic Research and other input parameters have been validated. We've began updating the models for Fairfax-Fairfield-St. Albans, Lyndon, Moretown, and Richmond using updated traffic data and material properties. Accurate traffic data and material parameters are proving to be very important parameters.

H. PROBLEMS ENCOUNTERED (If any): Preliminary results from the Fairfax-Fairfield-St. Albans, Lyndon, Moretown, and Richmond sites are not predicting rutting and IRI values as well as Addison. Having a varied distribution of results may affect the accuracy of the calibration. Input parameters still need to be verified, which could affect the results.

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT:

87%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: We plan on verifying all input data for the remaining models. We anticipate performing a brief literature review of other states calibration factors and generating VT specific calibration factors based on our updated models.

Progress report prepared by: Marcy Meyers **Date Prepared:** 10-15-2014

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):
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):
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: 7-1-14 to 9-30-14

G. ACCOMPLISHMENTS THIS PERIOD:

- All remaining annual site visits were completed.

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.

Progress report prepared by: Wendy Ellis
Date Prepared: 10-16-14

Evaluation of Effectiveness of Centerline Rumble Stripes on Rural Roads

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE:
SPR: 714 Evaluation of Effectiveness of Centerline Rumble Stripes on Rural Roads

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):
2009-2014

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

E. PROJECT OBJECTIVES: The primary objective of this research directly aimed at increasing the safety of the traveling public, one of the Agency's four primary goals, through the use and implementation of centerline rumble stripes. The evaluation will include an assessment of the overall durability and resistance to wear characteristics of the centerline rumble stripes in terms of preexisting pavement and climatic conditions as well as winter maintenance practices. Ease of installation will also be documented along with the design of the rumble stripes in conjunction with the adjacent pavement markings. The stripes will be installed on two projects in summer of 2009. One location will be on preexisting pavement on US 4 in Mendon-Killington and another on new pavement on VT 105 in Sheldon-Enosburg.

These experimental rumble stripes are intended to alert drivers that they have crossed into the path of oncoming traffic. However, there are several concerns that have not yet been adequately studied according to a recent report from the National Cooperative Highway Research Program (NCHRP) including roadside noise complaints, pavement condition, drivers reacting to the left, striping visibility, increased wear from winter maintenance practices, limited after data, lack of widely accepted guidelines, and affect of water, snow, and ice accumulation. This study seeks to address these concerns and draw associated future implementation recommendations for the State of Vermont as well as perform a cost benefit analysis.

F. REPORT PERIOD: 7-1-14 to 9-30-14

G. ACCOMPLISHMENTS THIS PERIOD

- Worked on completing report.

H. PROBLEMS ENCOUNTERED (If any): None.

I. TECHNOLOGY TRANSFER ACTIVITIES: None.

J. PERCENT COMPLETION OF TOTAL PROJECT: 95%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Complete rough draft of the final report and publish.

Progress report prepared by: Wendy Ellis
Date Prepared: 10-16-14

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

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: 7-1-14 to 9-30-14

G. ACCOMPLISHMENTS THIS PERIOD:

- Report is in review.
- 2014 field testing was completed in Elmore-Morristown, STP 2937 (1).
    - Elmore-Morristown:
        - 2 – 1000' test sections were constructed. One lane examined 3 different mixing speeds (40 fpm, 60 fpm, and 80 fpm) and the other lane will look at different number of microcracking cycles (passes).
        - Within each lane moisture readings were taken and soil samples were collected for use in pH testing to determine the presence of cement.

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: 95%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- The final report will be distributed to TAC members for their review.
- The final report will be published.
- All 2014 data will analyzed. Results will be distributed to the TAC and pertinent Agency personnel.

Progress report prepared by: Wendy Ellis
Date Prepared: 10-16-14

Project Title
QUARTERLY REPORT

A. **PROJECT NUMBER AND TITLE:** Use of Piles in Slope Stabilization
SPR: RSCH014-719

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 May 2014 – Extending to December

D. **ANTICIPATED COMPLETION DATE:** December 2014

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:** July 15, 2014 through October 15, 2014

G. **ACCOMPLISHMENTS THIS PERIOD:** Continued monitoring of the inclinometers installed during Phase II boring investigation. Conducted slide modeling with new inclinometer data. Began writing sections of the report. Specifically a section entitled "Cornwall as a Case Study" and the literature review section.

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

I. **TECHNOLOGY TRANSFER ACTIVITIES**: None

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

K. **ACTIVITIES PLANNED FOR NEXT QUARTER:** Provide a draft report by the end of the year. Develop a remediation for the slide in Cornwall to provide to the District.

Progress report prepared by: Callie Ewald
Date Prepared: October 15th, 2014

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):

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

Christopher C. Benda, P.E.
Soils and Foundations Engineer
Vermont Agency of Transportation
Program Development/Materials and Research
(802) 828-6910

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: 2014 Q4

G. ACCOMPLISHMENTS THIS PERIOD:

a. 1st Month (July 2014) – Worked on the final report.
b. 2nd Month (August 2014) – Worked on the final report.
c. 3rd Month (September 2014) – Submitted the final report draft to VTrans for review.

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

I. TECHNOLOGY TRANSFER ACTIVITIES: A manuscript based on this research has been tentatively accepted by the journal of Transportation Research Record.

J. PERCENT COMPLETION OF TOTAL PROJECT: 99.9%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: Finalize the final report.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER:
None.

Progress report prepared by: Mandar Dewoolkar
Date Prepared: October 14, 2014

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):

Jason P. Tremblay, MS, EI
Research Engineer
Materials and Research Section
Vermont Agency of Transportation
1 National Life Drive
Montpelier, VT 05633
Phone: 802-828-6945
Fax: 802-828-2792

Eric M. Hernandez, Ph.D.
Assistant Professor
College of Engineering and Mathematical Sciences
School of Engineering
University of Vermont
301 Votey Hall, 33 Colchester Ave.
Burlington, VT, 05405

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: July 01, 2014 to September 30, 2014

G. ACCOMPLISHMENTS THIS PERIOD:

- All field activities and computational work related to this project have been completed.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 99%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Submit final report.

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

Date Prepared: Oct 15th 2014

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
Associate Professor
School of Engineering - University of Vermont
(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: December 31, 2014

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: 2014 Q3

G. ACCOMPLISHMENTS THIS PERIOD:

(a) 1st Month (April 2014): The testing program is progressing. The samples are continued to be tested for hydraulic conductivity, void content, compressive strength and Freeze-Thaw cycles at UVM and Norwich.
(b) 2nd Month (May 2014): The testing program is progressing. The samples are continued to be tested for hydraulic conductivity, void content, compressive strength and Freeze-Thaw cycles at UVM and Norwich.
(c) 3rd Month (June 2014): Some new specimens were made. The testing program is progressing. The samples are continued to be tested for hydraulic conductivity, void content, compressive strength and Freeze-Thaw cycles at

UVM and Norwich. Data from both Universities were combined and analyzed.

H. PROBLEMS ENCOUNTERED (If any): Some data were of suspect. Those tests are being repeated be repeated.

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 93%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: Freeze-Thaw testing at UVM and Norwich will continue. Some new specimens are being made, cured and tested.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER:
About $2,000

Progress report prepared by: Mandar Dewoolkar

Date Prepared: October 14, 2014

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.
Associate Professor
School of Engineering - University of Vermont
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: 2014 Q4: July 2014 to September 2014

G. ACCOMPLISHMENTS THIS PERIOD:

a. 1st Month (July 2014): HEC-RAS modelling on Irene damaged bridges was conducted, and compared to laboratory flume scale models. Initial results show a relationship between erodibility of the embankment, and the scour depth.
b. 2nd Month (August 2014): Expanded the comprehensive bridge database, and linked it to pre-Irene National Bridge Inventory. These data have been included in the analysis of scour damage.
c. 3rd Month (September 2014): Preparing manuscript based on the data collected from the NBI and post flood records for damaged bridges.

H. PROBLEMS ENCOUNTERED (If any):

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 60%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: The literature review will continue. A review of bridge records and scour design procedures will continue. Countermeasure and design alternatives will be investigated with HEC-RAS and scale model testing. GIS updates to the bridge files, and Rapid Geomorphic Assessment data will be included in the comprehensive bridge database, and will be used for further analysis on a watershed scale.

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

Progress report prepared by: Mandar Dewoolkar
Date Prepared: October 14, 2014

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: 7-1-14 to 9-30-14

G. ACCOMPLISHMENTS THIS PERIOD:

- All liquid markings associated with this project were applied along I-89 SB in conjunction with Brookfield-Montpelier IM 089-1(61) paving project including: 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. Retroreflectivity readings were measured on Day 1, Week 1, Week 2, Week 3, and Week 4 following installation. All readings and associated comments and observations concerning the application will be summarized in the initial update.
- Finalized draft sole source justification documents to purchase the adhesion tester and purchase the equipment.

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: 20%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Collect Month 2, 3, 4 dry retroreflectivity and durability readings will be collected.
- Collect 1st round of wet retroreflectivity readings.
- Meet with District 4 and 5 to discuss possible data collection for winter maintenance practices.
- Meet with manufacturers to discuss the application and results to date.
- Initial update/report will be drafted and published.

Progress report prepared by: Wendy Ellis
Date Prepared: 10-16-14

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, 2015

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: July 1st through September 30th , 2014

G. ACCOMPLISHMENTS THIS PERIOD:

- None. Project was on hold until October 1, 2014.

H. PROBLEMS ENCOUNTERED (if any):

- 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. A new end date of 3/31/2015 for the project has been established at no additional cost. No effort will be incurred from April 1, 2014 to October 1, 2014. The remaining budget will be used between October 1, 2014 and March 31, 2015 to accomplish the originally defined scope.

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 60%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Develop a long-term, seasonal performance measure for RSIC activities using a “time-to-normal” approach that incorporates speed/flow data from weigh-in-motion (WIM) sensors across the state

Progress report prepared by: Jim Sullivan **Date Prepared:** October 15, 2014

Development of GIS Tools to Optimize Identification of Road Segments Prone to Flood Damage

QUARTERLY REPORT

A. PROJECT NUMBER AND TITLE: RSCH016
SPR: 734

B. PRINCIPLE INVESTIGATOR(s): Jim Sullivan

C. START AND END DATE (per grant assignment): April 1, 2013 – September 30, 2014

D. ANTICIPATED COMPLETION DATE: December 31, 2014

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

- Identify road segments in Vermont with highest probability of flood damage
- Validate methodology against damage from Tropical Storm Irene and re-calibrate if necessary
- Develop an exportable ArcGIS model

F. REPORT PERIOD: July 1st through September 30th , 2014

G. ACCOMPLISHMENTS THIS PERIOD:

- Completed spatial identification of bridge and culvert capacities, and/or height differences between road surface
- Began validating the model and develop an exportable ArcGIS model
- Began writing the draft-final project report

H. PROBLEMS ENCOUNTERED (if any):

- The project team has become aware of other VTrans and ANR efforts to better understand the relationship between expected peak flows and culvert sizing statewide. It makes sense for the team to delay their completion of this project, and the exportable ArcGIS tool to coincide with these other efforts. A new end date of 12/31/2014 for the project has been established at no additional cost.

I. TECHNOLOGY TRANSFER ACTIVITIES:

J. PERCENT COMPLETION OF TOTAL PROJECT: 95%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Finish developing an exportable ArcGIS model
- Finish writing the draft-final project report

Progress report prepared by: Jim Sullivan **Date Prepared:** October 15, 2014

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 Sep 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 July through 30 Sep 2014

G. ACCOMPLISHMENTS THIS PERIOD:

- Refined process of combining horizontal and vertical data into one dataset to improve accuracy and better eliminate errors
- Completed horizontal curvature values to crash points
- Completed vertical curvature values to crash points
- Completed guardrail values to crash points
- Completed sign values to horizontal curves
- Completed traffic volume data to horizontal curves
- Completed QA/QC on roadway feature data assignment methods and results
- Revised integration of horizontal curvature and vertical curvature into one dataset containing both horizontal and vertical curvature
- Finalized development of spatial statistical models for analysis on crash data
- Conducted spatial statistical modeling
- Performed QA/QC of spatial statistical modelling
- Completed draft report

H. PROBLEMS ENCOUNTERED (If any):

- Encountered some data issues in the horizontal and vertical data from Fugro
- The version of data we could use from Fugro had missing data issues (discussed with Jennifer Royer and others at VTrans on Fri 16 May 2014).

I. TECHNOLOGY TRANSFER ACTIVITIES:

N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 80%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Submit draft report to TAC for review
- Give final project presentation to VTrans

Progress report prepared by: Sean Neely **Date Prepared:** 10 October 2014

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: 2014 Q4

G. ACCOMPLISHMENTS THIS PERIOD:

a. 1st Month (July 2014) – Searched the Pacific Earthquake Engineering and Research (PEER) database for suitable ground motion time-history records, developed a catalog of 94 seismic ground motions, and downloaded the records for subsequent bridge analyses. Computed structural seismic capacity

requirements and performed a seismic capacity/demand analysis for a typical multi-span steel girder bridge using SAP2000 software.

b. 2nd Month (August 2014) –Completed the first round of the SAP2000 analysis and compiled results for sample multi-span steel girder bridge. Performed a literature review of the background for the specified thresholds for seismic structural analyses and site liquefaction evaluation requirements in the AASHTO LRFD, AASHTO Seismic Guide Specifications (SGS), and the FHWA Seismic Retrofitting Manual (2006).

c. 3rd Month (September 2014) – Evaluated the Vermont NBI catalog for categories of bridge types on which to perform detailed analyses. Worked on the narratives for a summary report and training materials. Finalized a memo on post-earthquake response inspection plan examples from other states and recommendations for post-earthquake response prioritization.

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

I. TECHNOLOGY TRANSFER ACTIVITIES: None in this quarter.

J. PERCENT COMPLETION OF TOTAL PROJECT: 43%

K. ACTIVITIES PLANNED FOR NEXT QUARTER: Select bridges for detailed seismic analysis and begin seismic response analyses of these bridges. Continue with report narratives. Prepare for and attend a project TAC meeting, preferably to be held in the upcoming quarter.

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

Progress report prepared by: Mandar Dewoolkar
Date Prepared: October 14, 2014

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

Quarterly Report
10/12/2014

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.

Phase 1 (Year 1):

- **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: 07/16/2014 – 10/15/2014

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

Accomplishment 1: Air Coupled GPR System Development and Integration (07/16/14-10/15/14)

In this quarter, we spent three months developing and debugging our air coupled GPR system circuit hardware. As illustrated in Figure 1, UVM high-speed UWB air-coupled impulse GPR system consists of five major functional units: (1) a radio frequency (RF) transmitter; (2) Ultra-wideband (UWB) antennas; (3) a data acquisition unit comprised of a high-speed real-time digitizer and a high-speed data transmission and storage unit; (4) a multi-core computer; and (5) a Field-Programmable Gate Array (FPGA) based digital controller along with an optical wheel encoder for location registration.

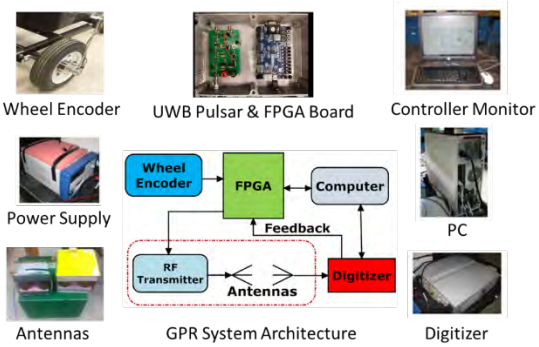

Figure 1. UVM GPR System diagram and functional units

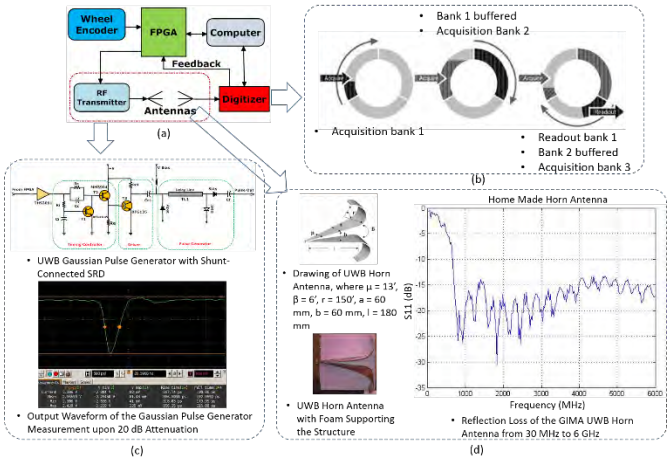

Figure 2. GPR system diagram: (a) High Speed UWB GPR System; (b) Digitizer Configured in SAR (simultaneous multi-buffer acquisition and readout) Mode; (c) UWB Pulse Generator; (d) UWB Antenna and measurement

Each individual functional unit has been developed and tested. Part of the test results are shown in Figure 2. A system integration prototype has also been completed for test validation and performance improvement. Figure 3 is the photo illustrating the integrated system packaging and mounting on a trailer. Note the current mounting structure is only for on-campus slow speed road segment test. To make it usable for normal traffic speed test, there are still a lot of work and improvements that should be done. Particularly from packaging perspective, we need to consider many factors, such as mechanical vibration, circuit board heating effect, circuit board wire connections, etc. These packaging issues will be resolved in the next quarter.

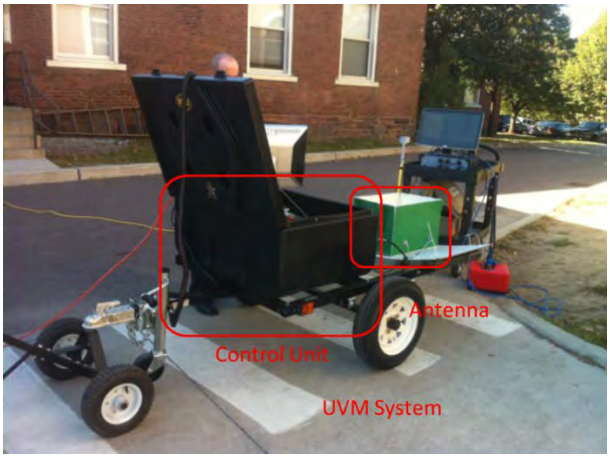

Figure 3. UVM GPR system packaging and mounting on a trailer.

2). Accomplishment 2: Purchasing a commercial GPR system (09/2014)

In order to test evaluate our UVM air-coupled GPR and its subsurface inspection results, we purchased a commercial system, GSSI SIR-30 GPR as the reference in September 2014. As of now, we have two commercial GPR systems in the UVM Lab. Besides this new purchased, the other one is Mala CX GPR. These two commercial systems have different operating frequencies and inspection capabilities. GSSI SIR-30's frequency is 400 MHz and is good at penetrating deeply buried objects but with marginal resolution; while MALA CX's frequency is 2.3 GHz and is more suitable to test shallow subsurface object but with higher resolution. Our UVM system operating frequency is 1 GHz. It can achieve a reasonable good balance between inspection depth and inspection resolution.

As illustrated as Figure 3, the left one is Mala CX GPR system, and the right one is GSSI SIR-30 GPR system. The B-Scan images collected by these two commercial GPR systems are used as reference during the test to compare with our UVM system's inspection results.

The working center frequency of above GPR systems are listed in Table 1.

Table 1. Comparison among three GPR systems

GPR System Name	Center Frequency
UVM System	1 GHz
MALA CX	2.3 GHz
GSSI SIR-30	400 MHz

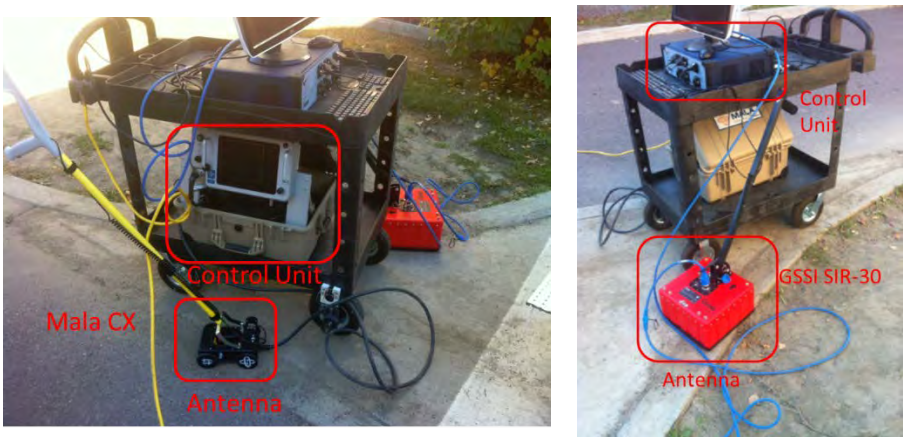

Figure 4. Two commercial GPR systems a). Mala CX GPR b). GSSI SIR-30 GPR

Accomplishment 3: On Campus Road Tests (09/2014- 10/2014)

Figure 4. GPR tests on UVM campus

All three GPR systems are tested as a selected test site on UVM campus. The test photo is shown in Figure 4. For each system, both the concrete walkway inspection and the asphalt pavement inspection are conducted. During the test, the UVM system and MALA CX system operated utilizing wheel encoder trigger mode, while the GSSI SIR-30 system worked under time based trigger mode. The reason is that GSSI SIR-30 was purchased without a wheel encoder. We plan to install one to it in the next quarter.

Accomplishment 4: GPR Data Processing Algorithm Development (07/2014- 10/2014)

GPR data processing algorithms are developed. These algorithms are utilized to process and enhance the quality of GPR inspection data collected on campus. The enhancement procedure consists of the following steps:

(1) UVM GPR data

Step 1: A cross-correlation based anti-vibration processing is applied to align all the A-Scan traces.

Step 2: Since our UVM GPR system is an air-coupled system, in the raw B-Scan image, the ground surface reflection is detected first, which is used as the data starting point in image display.

Step 3: Stack every 50 A-scan traces to calculate the average so as to increase the signal-to-noise ratio (SNR).

Step 4: Remove the background signals using average subtraction method.

(2) MALA-CX GPR Data

MALA CX is a ground-coupled system. The image enhancement procedure consists of the following steps:

Step 1: Stack every 2 A-scan traces to calculate the average so as to increase the signal-to-noise ratio (SNR).

Step 2: Remove the background signals using average subtraction method.

(3) GSSI SIR-30 GPR Data

GSSI SIR-30 is configured as a ground-coupled system during our test. Its data is processed using the commercial GSSI RADAN7 software under the default processing setting:

Step 1: Zero-offset;

Step 2: Band pass filter;

Step 3: Clutter Removal;

Step 4: Migration.

1. Test Results of Concrete Walkway

(1) UVM Data

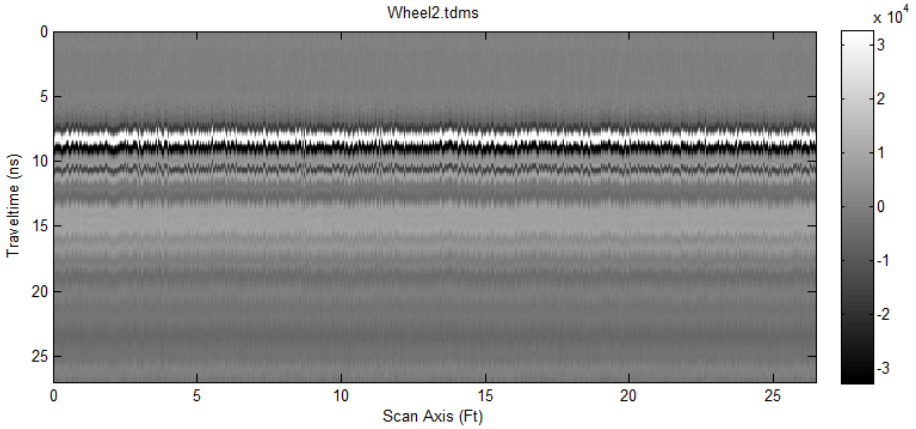

Figure 5. UVM Concrete Walkway Raw Data

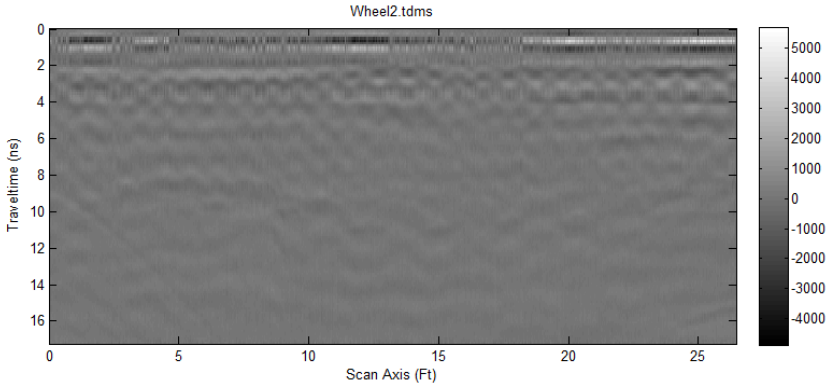

Figure 6 UVM Concrete Walkway Processed Data

In the UVM B-Scan image, the ground surface reflection appears at 0.5 ns, while the rebar hyperbola feature appears at 2 ns. Besides, some other subsurface features are also detected between 6 ns and 14 ns.

(2) MALA CX Data

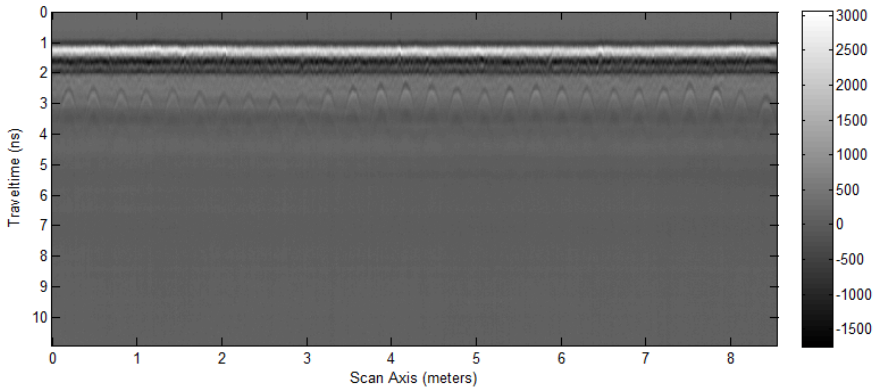

Figure 7 MALA CX GPR Concrete Walkway Raw Data

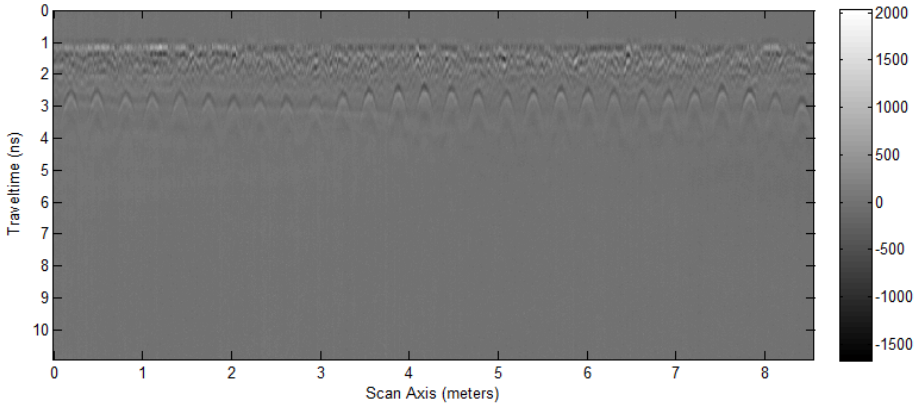

Figure 8 MALA Concrete Walkway Processed Data

In the MALA B-Scan image, the ground surface reflection appears at 1 ns, while the rebar hyperbola feature appears at 2.5 ns. Since the signal frequency of MALA system is higher than UVM system, it has higher range resolution. Also, MALA system is a ground-coupled system, so the quality of the hyperbola feature is better than that of UVM system. However, no subsurface feature can be detected beyond 6 ns for its signal's lower penetrating capability.

(3) GSSI SIR-30 Data

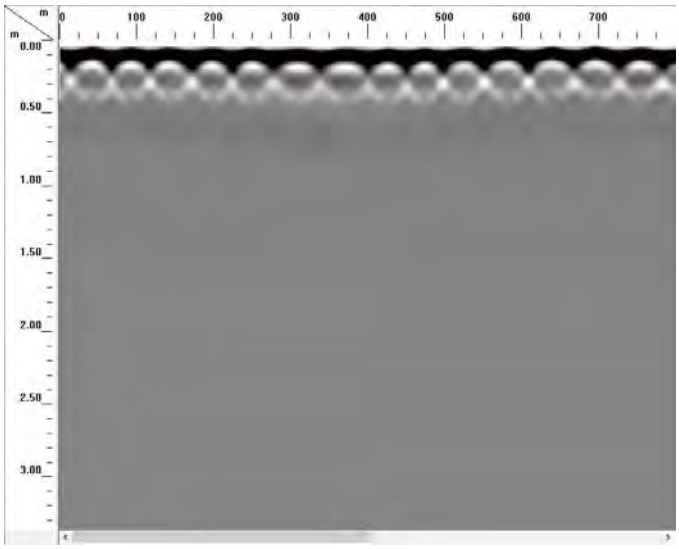

Figure 9 GSSI Concrete Walkway Raw Data

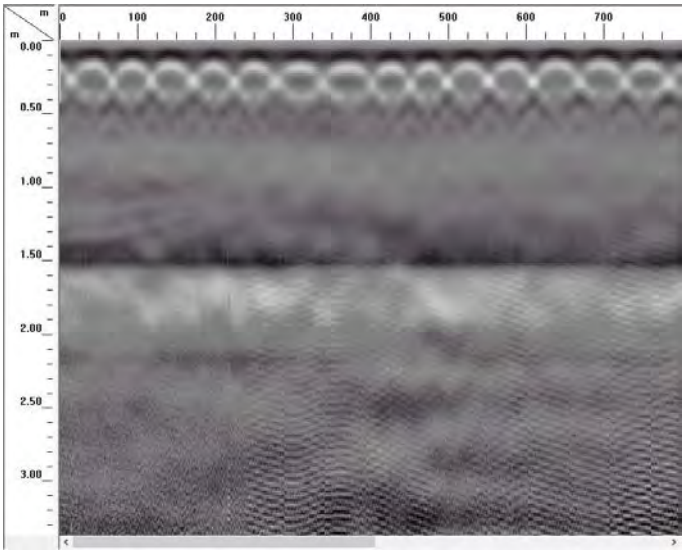

Figure 10 GSSI Concrete Walkway Processed Data

In the GSSI B-Scan image, the ground surface reflection appears at 0 meter, while the rebar hyperbola feature appears at 0.2 meter. Since the signal frequency of GSSI system is lower than UVM system, the quality of the hyperbola feature is not as good as our UVM system. However, since GSSI system is a ground-coupled system, its signal loss is relatively lower which accomplishes part of performance compensation.

2. Test Results of Asphalt Pavement

(1) UVM Data

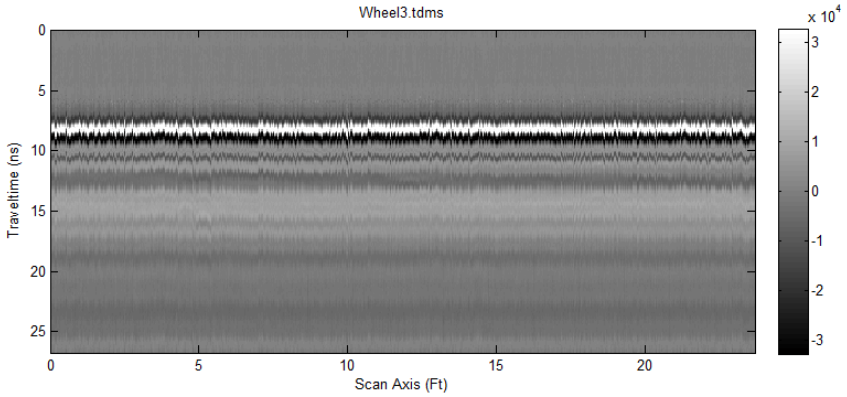

Figure 11 UVM Asphalt Pavement Raw Data

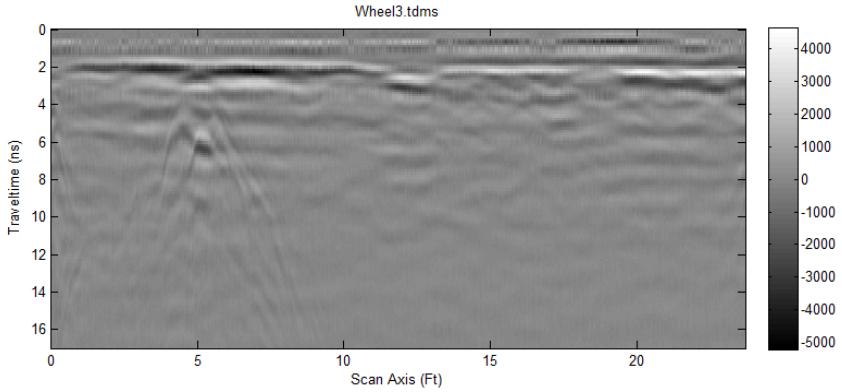

Figure 12. UVM Asphalt Pavement Processed Data

In the UVM B-Scan image, the ground surface reflection appears at 0.5 ns, and the asphalt bottom surface appears at 2 ns. Besides, some other subsurface features are detected between 4 ns and 12 ns. Especially, a strong scatter is detected at 6ns in y-axis and 5ft in x-axis.

(2) MALA CX Data

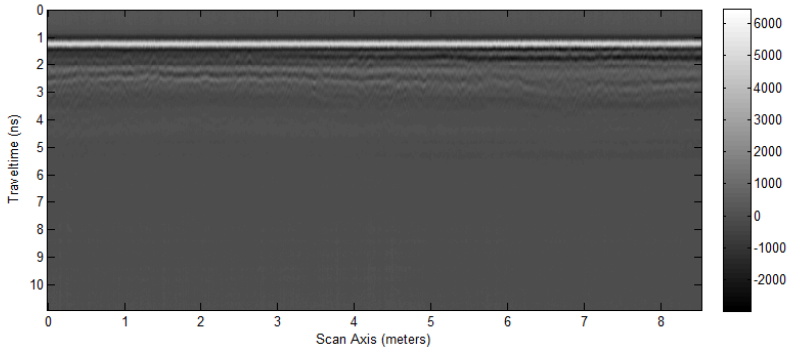

Figure 12 MALA Asphalt Pavement Raw Data

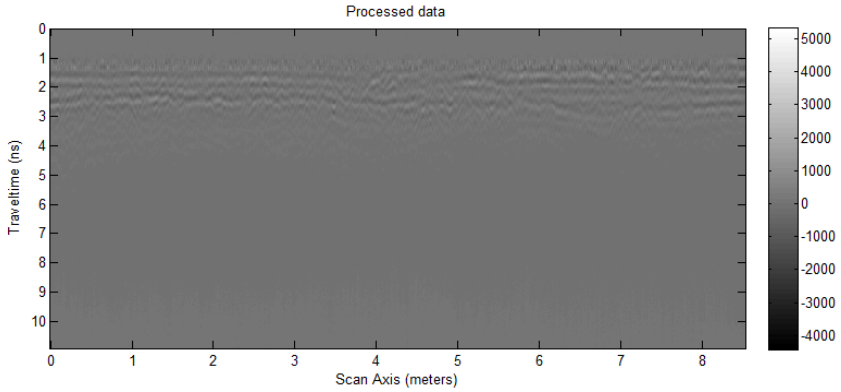

Figure 14 MALA Asphalt Pavement Processed Data

In the MALA B-Scan image, the ground surface reflection appears at 1 ns, and the bottom surface appears at 2.5 ns. Since the signal frequency of MALA system is higher than UVM system, it has higher range resolution. Also, MALA system is a ground-coupled system, the asphalt bottom surface is better detected than is done with UVM system. However, due to the weaker penetrating capability of MALA system, no subsurface feature under 4 ns is detected.

(3) GSSI SIR-30 Data

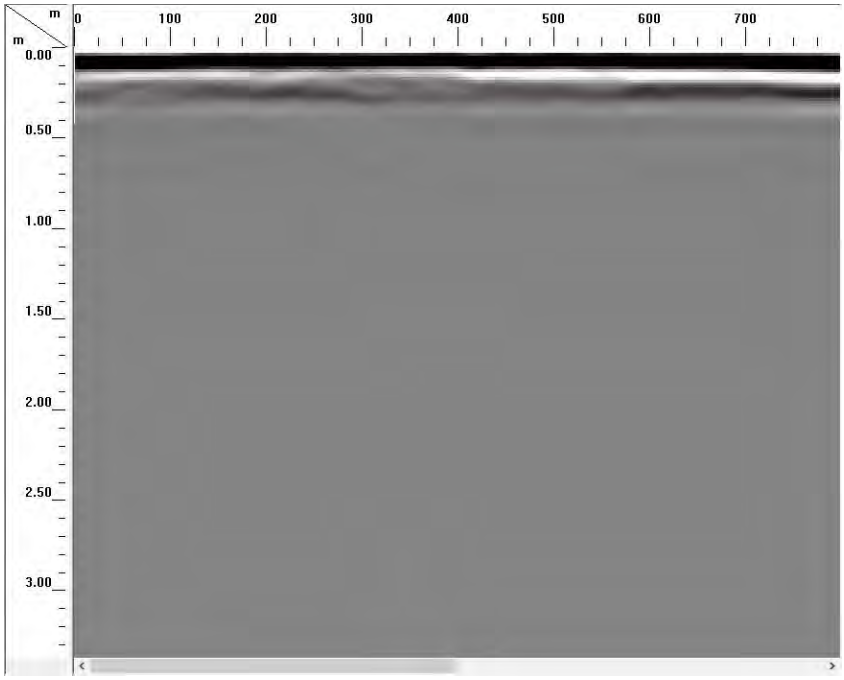

Figure 15 GSSI Asphalt Pavement Raw Data

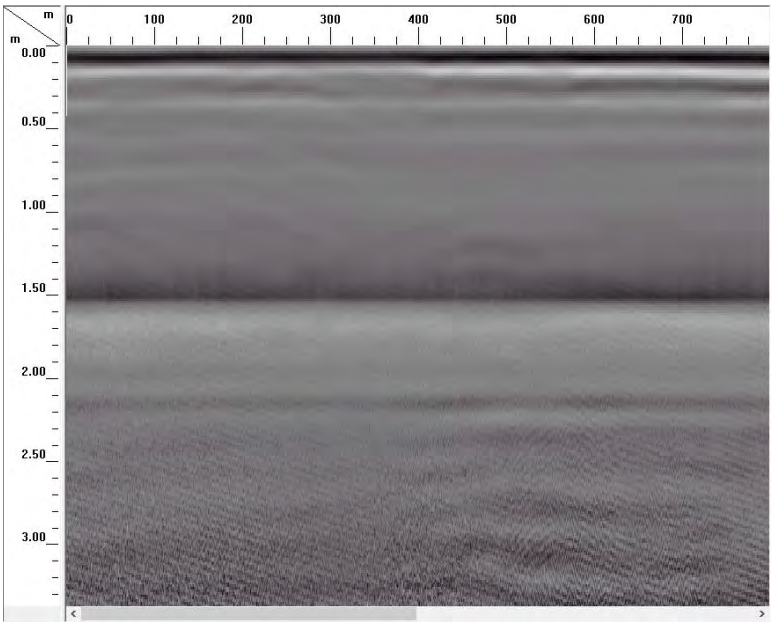

Figure 16 GSSI Asphalt Pavement Processed Data

In the GSSI B-Scan image, the ground surface reflection appears at 0 meter. It is hard to produce a clear asphalt bottom surface. Since the signal frequency of GSSI system is lower than UVM system, the range resolution of GSSI system is lower. As the thickness of the asphalt layer is small, the GSSI system cannot clearly distinguish the asphalt top surface and bottom surface clearly.

In conclusion, all three GPR systems have their own strength and limitations due to their signal frequency characteristics.

(1) MALA CX system is good for near surface small scatters detection. It has very high range resolution, and is capable of detecting very small subsurface features, such as cracks and small rebar in shallow layers.

(2) GSSI SIR-30 system is good for deep and large scatters detection. It has very good penetrating capability, which makes it capable of detecting deeply buried large objects.

(3) Our UVM system accomplishes a balance between the MALA CX and GSSI SIR-30 systems.

H. PROBLEMS ENCOUNTERED (If any):

As GPR systems will be utilized to perform roadway and bridge inspections, they need to be mounted on a test vehicle. Due to the budget and resource constraint, we have problems to find a suitable vehicle. Also to prepare the roadway and bridge field tests, significant work and supplies need are needed to improve system packaging and mounting. However we are running out of budget for them.

I. TECHNOLOGY TRANSFER ACTIVITIES:

N/A.

J. PERCENT COMPLETION OF TOTAL PROJECT:

Percent completion of total project is estimated to be around 30%. We expect much more accomplishments in the following quarters.

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- UVM GPR system packaging and mounting structure will be improved. Factors will be considered include vibration reduction, wires connections, system heat reduction, etc.
- 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.

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER (October 2014 – Jan. 2015, beak down into monthly estimates):

- 10/2014: $2,000 will be used for purchasing supplies.

Progress report prepared by: **Tian Xia**

Date Prepared: **10/11/2014**

Cost-Effective and Rapid Concrete Repair Techniques

Quarterly Report FFY2014 Q4

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

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.

Phase 1:
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:
07/16/2014 – 10/15/2014

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

a. 1st Month (July 15 – August 14, 2014)
The primary activity this month was to visit and examine a bridge repair. The repair was to the piers of an I-89 overpass in Swanton, VT. The repairs included concrete removal and replacement, followed by strengthening with fiber-reinforced polymer (FRP) strips. As part of Objectives 2 and 3, the repaired bridge was photographed using low-cost 3-D cameras. Photogrammetry software converted the 3-D stereo images into 3-D surface point clouds, which were then imported into a Building Information Modeling (BIM) database and then converted into a 3-D printed solid model.

b. 2nd Month (August 15 – September 15, 2014)
The primary activity during this month was to work on the development of the decision-making flowchart. This included examining information in the ACI Concrete Repair manual, ACI 546R-14: Guide to Concrete Repair, and ACI 562 Concrete Repair Code. While much of this literature focuses on the repair of concrete buildings, there is sufficient information on bridges and other transportation structures.

Contact was also established with the New York State Department of Transportation, Structures Maintenance Division, which agreed to provide information on their concrete repair practices.

c. 3rd Month (July 2014)
Activity continued this month on decision-making flowchart development. The progress included putting together a pictorial representation of a draft flowchart, and a preliminary examination of presentation methods, along with the methodology for including life-cycle cost analysis.

Scheduling for future bridge site visits was initiated.

H. PROBLEMS ENCOUNTERED (If any):
The principal Vtrans point of contact on this project changed during this quarter. It is now JB McCarthy. This transition delayed somewhat the scheduling of bridge site visits and interactions with Vtrans personnel. At the moment, the plan is to complete the project as scheduled

I. TECHNOLOGY TRANSFER ACTIVITIES:

As mentioned above in G.b. 2nd Month (August 15 – September 15, 2014) contact was established with the New York State Department of Transportation, Structures Maintenance Division, which agreed to provide information on their concrete repair practices.

D. Huston presented some of the results on bridge photogrammetry and integration in BIM databases at the 6th World Conference on Structural Control and Monitoring (6WCSCM).

J. PERCENT COMPLETION OF TOTAL PROJECT:

Percent completion of total project is estimated to be around 35%. It is anticipated that the pace will pick up in the next months.

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Visit damaged bridge sites with Vtrans maintenance personnel
- Continue with decision-making flow chart development
- Conduct technology transfer activities related to concrete repair with the State of New York and possibly Maine and New Hampshire Departments of transportation

L. ESTIMATED BUDGET AMOUNT SPENT NEXT QUARTER (October 15, 2014 – January 14, 2015):

- $2,225 combined salary and fringe benefits for Post Doc D. Burns
- $2,500 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: **10/15/2014**

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 July 2014 to 30 September 2014

G. ACCOMPLISHMENTS THIS PERIOD:

- Held first TAC meeting (14 July)
- Received approval for Human Subjects Research Protocols by UVM IRB 28 July 2014
- Conducted literature review
- Worked on report focused on people with disabilities
- Worked on report focused on veterans
- Completed informational interviews with transit providers and organizations serving the populations of interest
- Developed set of protocols for conducting focus groups and collection of focus group participants
- Conducted focus for Disabilities and Transportation:
    - Vermont Association of the Blind and Visually Impaired (6 August)
    - National Multiple Sclerosis Society – Greater New England Chapter (25 August)
    - AARP (3 September)
    - Cathedral Square (22 September)
    - Vermont Council of Independent Living (19 September)
- Conducted focus for Veterans and Transportation:
    - National Guard – Vermont Veterans Outreach Program (8 August)
    - Canal Street House, Winooski (22 September)
    - Veterans Inc., Bradford (29 September)

H. PROBLEMS ENCOUNTERED (If any): N/A

I. TECHNOLOGY TRANSFER ACTIVITIES: N/A

J. PERCENT COMPLETION OF TOTAL PROJECT: 30%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- Complete focus groups
- Develop survey instruments
- Disseminate survey instruments
- Complete literature reviews
- Continue report focused on people with disabilities
- Continue report focused on veterans

Progress report prepared by: Sean Neely **Date Prepared:** 10 Oct 2014

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):

Troy Lawson
Asphalt & Hot Mix Unit
Materials and Research

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

D. ANTICIPATED COMPLETION DATE: September 30, 2014

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: 2014 Q3

G. ACCOMPLISHMENTS 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: Troy Lawson
Date Prepared: October 15, 2014

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: 7-1-14 to 9-30-14

G. ACCOMPLISHMENTS THIS PERIOD:

- All remaining annual site visits were completed except for Guilford-Brattleboro.
- All cracking and rutting data has been counted and entered into the overall spreadsheets.

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:

- Complete Guilford-Brattleboro

Progress report prepared by: Wendy Ellis
Date Prepared: 10-16-14

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: 7-1-14 to 9-30-14

G. ACCOMPLISHMENTS THIS PERIOD:

- Initial report draft is in review.

H. PROBLEMS ENCOUNTERED (If any): None

I. TECHNOLOGY TRANSFER ACTIVITIES: None

J. PERCENT COMPLETION OF TOTAL PROJECT: 90%

K. ACTIVITIES PLANNED FOR NEXT QUARTER:

- An outline to accomplish reporting requirements will be completed.
- Initial report will be published.

Progress report prepared by: Wendy Ellis
Date Prepared: 10-16-14