NEW ENGLAND TRANSPORTATION CONSORTIUM
RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Ground Penetrating Radar for Roadway Structural Evaluation During Spring Thaw and Flood Events

II. RESEARCH PROBLEM STATEMENT

There are many miles of roads in New England that are highly susceptible to damage during the spring thaw period. As freezing occurs from the surface downward, moisture is drawn toward the freezing front, ice lenses are formed, and the roadways become stronger. When the ice lenses (above still frozen underlying layers) melt, the structure is left in a saturated, undrained and unconsolidated condition, which is highly susceptible to damage during trafficking. A similar process occurs when roadway base layers become flooded; either from a rising groundwater table, or from inundation by surface water. In both cases, there is a time window (after thawing begins, or after a pavement base layer becomes flooded/saturated) when the overall roadway structure is weak, and then a period of days or weeks necessary to regain the strength/stiffness and return to normal operating conditions.

To reduce damage during the spring thaw, many road management agencies apply Spring Load Restrictions (SLRs), which restrict the allowable load on the road during the critical time interval when the pavement is most vulnerable to damage. Flooded roadways may also be closed during extreme events when water rises to levels that would make automobile traffic impossible, however no similar restrictions for roadways weakened by rising groundwater tables currently exist. While transportation agencies have several relatively reliable methods for deciding when to apply SLRs or to close roads due to floods, a major short-coming exists with regard to accurate timing for lifting those restrictions.

Monitoring changes in pavement load bearing capacity as indicated by deflections measured in falling weight deflectometer (FWD) tests can provide the necessary insight, however State DOTs typically own only one (or no) FWD, and can test only a small sample of roadway segments statewide. Most other road management agencies or municipalities, such as cities and counties, do not own FWDs. While it is known that the weakening and stiffness recovery process is intimately related to moisture increase and dissipation, respectively, monitoring those moisture trends by installing sensors beneath roadways poses many problems in terms of installation and expense. Furthermore, while moisture sensors tend to produce very good results when embedded in silty/clayey soils (typical of some subgrades), those moisture sensors generally don't produce good data in coarser-grained base layers and still only provide a single point measurement. Therefore, a more reliable and cost-effective means of evaluating changes in roadway weakening and stiffness recovery during spring thaw and flooding events is urgently needed. Recent advances in ground penetrating radar (GPR) equipment provide the ability to cost-effectively discern such changes in moisture content, and thus show much potential in this application (Maser and Weigand, 2005). GPR detects the reflection between the asphalt and base material, the amplitude of which is a function of the dielectric contrast between these materials. Since the dielectric permittivity of granular base can vary from as low as 5 for a dry or frozen base to as high as 25 for a saturated base, the amplitude of this reflection, and the associated dielectric calculation, can serve as a measure of moisture content variation. (Maser and Scullion, 1992). GPR data can be collected at normal driving speed, and thus can provide more extensive coverage than traditional methods without traffic interference.

III. RESEARCH OBJECTIVES

The primary objective of this research is to conduct baseline testing of currently available GPR equipment during episodes of roadway weakening and strength recovery events. The work plan will include multiple surveys of selected test sites to establish reference conditions against which changes in in moisture content can be evaluated. It is anticipated that researchers will utilize existing in situ sensor networks (and possibly newly installed sensors), as well as FWD and/or other appropriate testing/monitoring and/or analysis methods, to provide ground truth for comparison with GPR data. A secondary objective is to provide agencies with estimated cost and personnel requirements necessary to implement GPR testing for routine use during roadway weakening and strength recovery events.

IV. ESTIMATE OF FUNDING NEEDED

$175,000

V. RESEARCH PERIOD

24 months

VI. URGENCY AND PAYOFF POTENTIAL

The lack of reliable and cost-effective tools to assist transportation agencies with decisions regarding placing and lifting roadway load restrictions poses an economic hardship to the trucking and other industries responsible for the movement of goods and services. Restrictions on movement may cause trucks to take detours and/or to haul with lighter loads resulting in more trips, additional fuel consumption and increasing driving time. The premature lifting of restrictions can cause accelerated damage to the pavement, requiring more frequent maintenance and/or rehabilitation. Clearly, SLRs pose sustainability as well as financial concerns, and the challenge is to create a rational balance between infrastructure protection and roadway usage during high stress periods such as freeze-thaw cycles and flood events. There is need to evaluate innovative tools such as GPR as a means of rationally timing roadway load restrictions. Furthermore, as agencies yield opportunities to implement such tools in upcoming years, there is need to plan for appropriate equipment and testing protocols. The proposed study will provide the necessary evaluation and implementation recommendations.

VII. PRELIMINARY LITERATURE SEARCH

Source of preliminary literature search *(check as appropriate):*
__TRIS
__RIP
Other (*describe*):__X__TRID Database (has replaced TRIS)____________________

A preliminary literature search using the TRID Database (http://trid.trb.org/) was conducted. There are a number of existing papers on the use of GPR for site investigations (Scullion and Saarenketo, 2002), determining pavement layer structure information and load carrying capacity (Maser et al., 2013, et al.), and for identifying variations in moisture content of granular pavement base (Arnold et al., 2017; Chen and Zhang 2009; Maser and Scullion, 1992; Maser and Weigand, 2005; Muller, 2017). There was no information found on use of GPR for monitoring thaw weakening and recovery in seasonal frost areas or during/after flood events.

Arnold, G; Sing, P F; Saarenketo, T; Saarenpaa, T. Pavement moisture measurement to indicate risk to pavement life. New Zealand Transport Agency, Issue 611, 2017, 160p https://trid.trb.org/view/1467914

Chen, Can; Zhang, Jie. A Review on GPR Applications in Moisture Content Determination and Pavement Condition Assessment. GeoHunan International Conference: Challenges and Recent Advances in Pavement Technologies and Transportation Geotechnics, American Society of Civil Engineers, 2009, pp 138-143 https://trid.trb.org/view/899649

Maser, K; Carmichael, A; Weiss, W. Use of GPR for subsurface pavement investigations of 23 airports in South Carolina. Ninth International Conference on the Bearing Capacity of Roads, Railways and Airfields, Akademika Publishing, 2013, pp 191-197 https://trid.trb.org/view/1404591

Maser, K.R., and Scullion, T., "Automated Pavement Subsurface Profiling Using Radar: Case Studies of Four Experimental Field Sites," Transportation Research Record No. 1344, TRB National Research Council, pp. 148-154, 1992.

Maser, K.R.; Weigand, R.S., "Ground-Penetrating Radar Investigation of Clogged Underdrain on Interstate I-71," Paper No. 06-0901, TRB 85th Annual Meeting Compendium of Papers CD-ROM 2005.

Muller, W. Characterising moisture within unbound granular pavements using multi-offset ground penetrating radar. 2017, 1 file https://trid.trb.org/view/1467908

Scullion, T; Saarenketo, T. Use of Ground Penetrating Radar for Site Investigation of Low-Volume Roadways and Design Recommendations. Texas Transportation Institute; Texas Department of Transportation, 2002, 58 p. https://trid.trb.org/view/730720

VIII. KEY WORDS TO BE USED FOR ADDITIONAL LITERATURE SEARCH

Ground penetrating radar, base moisture content, monitoring spring thaw

IX. ENDORSEMENT BY THE SPONSORING DOT

(To be signed by the DOT representative to the NETC Advisory Committee through whom the Problem Statement is submitted.)

By signing the endorsement, the DOT representative is certifying that:

1. *The Problem Statement follows the required format.*
2. *The required literature search has been conducted.*
3. *The Problem Statement addresses a transportation issue of relevance to NETC and does not duplicate another Problem Statement being submitted at this time.*

Name: Dale Peabody

DOT: Maine

Signature: Dale Peabody

Date: 1/25/19

X. ENDORSEMENT BY A SECOND EMPLOYEE OF THE SPONSORING DOT who agrees to chair the project's technical advisory committee (TAC) if the Problem Statement is selected for funding. (To be signed by a DOT staff person who has technical knowledge of the project topic and is committed to the research outcome.)

DOT Technical Endorsement: *I agree to chair the project's Technical Advisory Committee if this Problem Statement is selected for funding by NETC.*

Name: CHRISTOPHER L. HELSTROM

DOT: MAINE DOT

Signature: [signature]

Date: 1/25/2019