



Victoria F. Sheehan  
Commissioner

THE STATE OF NEW HAMPSHIRE  
DEPARTMENT OF TRANSPORTATION



William Cass, P.E.  
Assistant Commissioner

Bureau of Materials & Research  
October 11, 2016

Her Excellency, Governor Margaret Wood Hassan  
and the Honorable Council  
State House  
Concord, New Hampshire 03301

**REQUESTED ACTION**

- 1.) Authorize the Department of Transportation to enter into three (3) individual **SOLE SOURCE** Cooperative Project Agreements with the UNH Sponsored Programs Administration (vondor 177867), Durham, New Hampshire, for a combined fee not to exceed \$415,000.00 for various cooperative investigations, effective upon Governor and Council through March 31, 2019. 100% Federal Funds.
- 2.) Further, authorize the Department of Transportation to enter into a **SOLE SOURCE** Cooperative Project Agreement with the UNH Sponsored Programs Administration (vondor 177867), Durham, New Hampshire, for a fee not to exceed \$56,080.00 for observing early age cracking in new concrete curbs on bridges, effective upon Governor and Council through March 31, 2020. 100% Federal Funds.

Funding is available as follows for FY 2017 and is contingent upon the availability and continued appropriation of funds in Fiscal Year 2018, as follows:

|  | <u>FY 2017</u> | <u>FY 2018</u> |
|--|----------------|----------------|
| 04-96-96-962015-3036                       |                |                |
| SPR Research Funds                         |                |                |
| 046-500464 General Consultants Non-Benefit | \$263,580.00   | \$207,500.00   |

**EXPLANATION**

The following four (4) research studies will each address an immediate Department need; are unique to New Hampshire's environment and conditions, thereby requiring substantial local experience; and are directly aligned with a particular area of University expertise. In addition, the Principal Investigators are nationally recognized experts in their respective fields. As such, the proposed work does not lend itself to a selection process that includes private industry or out-of-state organizations, and it is in the Department's and the State's best interest to work directly with the University of New Hampshire.

This work is part of the Department's Statewide Planning and Research (SPR) program. The Department of Transportation and the University of New Hampshire (UNH) is a long-standing cooperative relationship of transportation research. This relationship has been mutually beneficial, culminating in savings to the State while enhancing work force development and maintaining New Hampshire's position on the leading edge of new technology. Research studies conducted by UNH for the Department have led to numerous innovations in the highway and bridge industry, including such successes as high performance concrete, improved pavements, alternative reinforcing for bridge decks, increased use of recycled materials, stormwater management evaluation, and rapid construction techniques.

Statewide-SPR 26962M, Gusset-less Truss Connection Physical and Structural Model to Aid Bridge Inspection and Condition Assessment

The UNH Structures Group has performed extensive developmental research for the Department's bridge projects including a structural health study of the Memorial Bridge between Portsmouth, NH and Kittery, ME. This research will integrate field-collected performance data, laboratory experimental testing, and physics-based structural modeling to develop a protocol to assess the condition and predict the remaining life of the gusset-less truss connections used at the Memorial Bridge. This project is expected to provide information to develop a framework to extend this protocol for application to future innovative structural elements for a total fee not to exceed \$110,000, effective upon Governor and Council approval through March 31, 2019.

Statewide-SPR 26962N, Layer Coefficients for NHDOT Pavement Design

UNH has performed extensive research on asphalt pavement for the Department including evaluation of the use of recycled asphalt pavement. The Department employs the AASHTO Empirical Pavement Design procedure structural design of highway pavements (new construction, reconstruction and major rehabilitations). The current design parameters (commonly called layer coefficients) used by the Department are a combination of the original values proposed by AASHTO in the 1960s with updated research from 1994. The asphalt mixtures in use today and vehicle loadings are substantially different from the ones characterized by AASHTO during the development of the design guide in 1960s. This research will provide the Department with updated layer coefficients that reflect the asphalt mixtures in use today for a total fee not to exceed \$150,000, effective upon Governor and Council approval through March 31, 2019.

Statewide-SPR 26962O, Incorporating Impact of Binder Aging on Cracking Performance of Asphalt Mixtures During Design

UNH has performed extensive research on asphalt pavement for the Department including the characterization of asphalt mixes. Cracking is a primary concern for asphalt pavements in New Hampshire because it affects ride quality and allows water to penetrate from the surface to underlying soil layers, decreasing the life of the pavement, and requiring more frequent maintenance or rehabilitation. Not all mixtures age at the same rate or to the same extent, and therefore, different mixtures could have very similar cracking properties soon after construction but may have drastically different properties after some level of aging. It is important to have an understanding of how the cracking resistance of a mixture will change over time at the time materials are selected and mix designs are performed.

The results of this project will help the Department improve the selection of asphalt mixtures to resist cracking, thus resulting in long term cost savings and better ride quality. The experimental study will provide the Department and industry with information on cracking characteristics of mixtures including different percentages of recycled asphalt pavement (RAP), different binder grades, and different aging conditions for a total fee not to exceed \$155,000, effective upon Governor and Council approval through March 31, 2019.

Statewide-SPR 26962P, Reducing Cracking in New Bridge Curbs

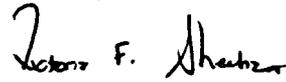
UNH has performed extensive research for the Department including the evaluation of improved materials in bridge construction. The Department has observed early-age cracking in new concrete curbs on a number of New Hampshire bridges. Early age cracking severely reduces the service life of curbs by allowing the introduction of water and deicing salts into contact with the reinforcing steel within the concrete. It also increases propensity for cracks to propagate into bridge decks.

This study is designed to review current practice of bridge curb construction in order to identify potential causes for early-age cracking. Construction and observation of bridge curbs with a trial of different modifications to current practice will lead to the development of recommended changes to current practice to reduce/alleviate the early-age cracking problem for a total fee not to exceed \$56,080, effective upon Governor and Council approval through March 31, 2020.

These four (4) **sole source** Agreements have been approved by the Attorney General as to form and execution. Copies of the fully-executed Agreements are on file at the Secretary of State's Office and the Department of Administrative Services, and subsequent to Governor and Council approval will be on file at the Department of Transportation.

Your approval of this resolution is respectfully requested.

Sincerely,

A handwritten signature in black ink that reads "Victoria F. Sheehan". The signature is written in a cursive style with a large initial "V".

Victoria F. Sheehan  
Commissioner

Attachments

**COOPERATIVE PROJECT AGREEMENT**

between the

STATE OF NEW HAMPSHIRE, **Department of Transportation**

and the

**University of New Hampshire** of the UNIVERSITY SYSTEM OF NEW HAMPSHIRE

- A. This Cooperative Project Agreement (hereinafter "Project Agreement") is entered into by the State of New Hampshire, **Department of Transportation**, (hereinafter "State"), and the University System of New Hampshire, acting through **University of New Hampshire**, (hereinafter "Campus"), for the purpose of undertaking a project of mutual interest. This Cooperative Project shall be carried out under the terms and conditions of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, except as may be modified herein.
- B. This Project Agreement and all obligations of the parties hereunder shall become effective on the date the Governor and Executive Council of the State of New Hampshire approve this Project Agreement ("Effective date") and shall end on **3/31/19**. If the provision of services by Campus precedes the Effective date, all services performed by Campus shall be performed at the sole risk of Campus and in the event that this Project Agreement does not become effective, State shall be under no obligation to pay Campus for costs incurred or services performed; however, if this Project Agreement becomes effective, all costs incurred prior to the Effective date that would otherwise be allowable shall be paid under the terms of this Project Agreement.
- C. The work to be performed under the terms of this Project Agreement is described in the proposal identified below and attached to this document as Exhibit A, the content of which is incorporated herein as a part of this Project Agreement.

Project Title: **Gusset-less Truss Connection Physical and Structural Model to Aid Bridge Inspection and Condition Assessment (SPR Project # 29662M)**

- D. The Following Individuals are designated as Project Administrators. These Project Administrators shall be responsible for the business aspects of this Project Agreement and all invoices, payments, project amendments and related correspondence shall be directed to the individuals so designated.

**State Project Administrator**

Name: Elizabeth S. Klemann  
 Address: NHDOT  
 Bureau of Materials & Research  
 5 Hazen Drive, P.O. Box 483  
 Concord, NH 03302-0483  
 Phone: 603-271-8995

**Campus Project Administrator**

Name: Dianne Hall  
 Address: University of New Hampshire  
 Sponsored Programs Administration  
 51 College Rd. Rm 116  
 Durham, NH 03824  
 Phone: 603-862-1942

- E. The Following Individuals are designated as Project Directors. These Project Directors shall be responsible for the technical leadership and conduct of the project. All progress reports, completion reports and related correspondence shall be directed to the individuals so designated.

**State Project Director**

Name: Robert Landry  
 Address: NHDOT  
 Bureau of Bridge Design  
 7 Hazen Drive, P.O. Box 483  
 Concord, NH 03302-0483  
 Phone: 603-271-3921

**Campus Project Director**

Name: Erin Santini Bell  
 Address: University of New Hampshire  
 Civil Engineering  
 Kingsbury Hall, Room W141  
 Durham, NH 03824  
 Phone: 603-862-3850

F. Total State funds in the amount of \$110,000.00 have been allotted and are available for payment of allowable costs incurred under this Project Agreement. State will not reimburse Campus for costs exceeding the amount specified in this paragraph.

Check if applicable

Campus will cost-share \_\_\_\_\_ % of total costs during the term of this Project Agreement.

Federal funds paid to Campus under this Project Agreement are from Grant/Contract/Cooperative Agreement No. \_\_\_\_\_ from **the Federal Highway Administration** under CFDA# **20.205**. Federal regulations required to be passed through to Campus as part of this Project Agreement, and in accordance with the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, are attached to this document as Exhibit B, the content of which is incorporated herein as a part of this Project Agreement.

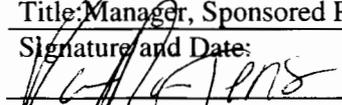
G. Check if applicable

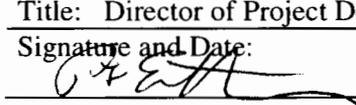
Article(s) \_\_\_\_\_ of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002 is/are hereby amended to read:

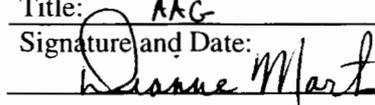
H.  State has chosen **not to take** possession of equipment purchased under this Project Agreement.  
 State has chosen **to take** possession of equipment purchased under this Project Agreement and will issue instructions for the disposition of such equipment within 90 days of the Project Agreement's end-date. Any expenses incurred by Campus in carrying out State's requested disposition will be fully reimbursed by State.

This Project Agreement and the Master Agreement constitute the entire agreement between State and Campus regarding this Cooperative Project, and supersede and replace any previously existing arrangements, oral or written; all changes herein must be made by written amendment and executed for the parties by their authorized officials.

IN WITNESS WHEREOF, the University System of New Hampshire, acting through the **University of New Hampshire** and the State of New Hampshire, **Department of Transportation** have executed this Project Agreement.

**By An Authorized Official of:**  
**University of New Hampshire**  
Name: Karen M. Jensen  
Title: Manager, Sponsored Programs Administration  
Signature and Date:  9/30/16

**By An Authorized Official of:**  
**Department of Transportation**  
Name: Peter E. Stamnas  
Title: Director of Project Development  
Signature and Date:  9/14/2016

**By An Authorized Official of:** the New Hampshire Office of the Attorney General  
Name: Dianne Martin  
Title: AKG  
Signature and Date:  10/10/16

**By An Authorized Official of:** the New Hampshire Governor & Executive Council  
Name: \_\_\_\_\_  
Title: \_\_\_\_\_  
Signature and Date: \_\_\_\_\_

## EXHIBIT A

**A. Project Title:** Gusset-less Truss Connection Physical and Structural Model to Aid Bridge Inspection and Condition Assessment (SPR Project # 26962M)

**B. Project Period:** Governor and Council Approval - December 31, 2018

**C. Objectives:** The Memorial Bridge connecting Portsmouth, NH and Kittery, ME was re-opened to traffic in 2013. One of the major innovations of the reconstructed bridge is the first ever gusset-less truss connection in a vehicular bridge in the United States. Traditional gusset plates are the most vulnerable element in a truss-bridge structure and a source of significant cost, effort, and concern for bridge managers and owners. One of the major advantages of gusset-less connections is the reduction in the number of bolts required at the bridge, which potentially decreases the vulnerability of the connection. However, the condition of these innovative gusset-less connections cannot be accurately and confidently assessed using the available tools for load rating of gusset-plate connections for steel truss bridges (FHWA Publication FHWA-HRT-14-063). Therefore, there is a need to develop methods to reliably evaluate the condition of gusset-less truss connections that incorporate the identification of areas of concern over the service life of the bridge.

The Memorial Bridge is also the focus of two federally-funded (National Science Foundation and Federal Highway Administration) research initiatives to create smart, sustainable transportation by installing a structural health monitoring system and tidal energy conversion system at the bridge. One of the focus areas of the structural monitoring is the innovative gusset-less truss connection. The instrumentation plan for the Memorial Bridge includes an array of strain rosettes installed across two sets of gusset-less connections to measure strains experienced across the connection during normal bridge traffic and lift operation. This data will be available to perform the various tasks proposed in this State project.

The goal of the proposed research is to integrate field-collected performance data, laboratory experimental testing, and physics-based structural modeling to develop a protocol to assess the condition and predict the remaining life of the gusset-less truss connections used at the Memorial Bridge. It is anticipated that the aforementioned approach will be modified to develop a framework to extend this protocol for application to future innovative structural elements.

The objectives of this project are to:

- Create two specimen pairs (A and B) of a scale model of a gusset-less connection from the Memorial Bridge. Specimen pair A will be tested to failure in a quasi-static testing protocol and Specimen pair B will be tested for fatigue performance.
- Conduct quasi-static set of tests on each member of Specimen pair A to determine stress distribution in the connection and failure mode.
- Evaluate these results in conjunction with field collected data and analytical models that are the work product of a complimentary FHWA-AID DEMO project to: (i) further understand and quantify the structural performance of the gusset-less connection, and (ii) validate analytical models.
- Conduct fatigue testing on Specimen pair B and collect performance data to determine the stress pattern and predict fatigue failure mode.
- Compare the findings of this project with the FHWA guideline for connection assessment to facilitate the development of an evaluation protocol for inspection and structural condition assessment.

**D. Scope of Work:** A research study is proposed herein to examine the behavior of the gusset-less truss connection used at the Memorial Bridge for long-term structural condition assessment and potential use in future bridge designs in New Hampshire and throughout the United States. The proposed study is to be conducted through nine major research tasks. Brief descriptions of these tasks are provided below.

**Task 1: Literature Review and Finalize Testing Plan**

A comprehensive literature review on connection load rating and fatigue assessment will be performed to inform the development of the final testing plan. The research team will work with State to finalize the testing plan and the specimen sizes to be evaluated in this project.

**Task-2: Design and Construction of Small-scale Physical Models**

Small-scale physical models of a gusset-less truss connection (four specimens or two pairs: A and B) will be designed, detailed, and constructed for laboratory testing under quasi-static and fatigue (cyclic) loading at the Campus structural laboratory. The connection type will be modeled after an instrumented gusset-less truss connection of the Memorial Bridge. Half of the specimens will be used for quasi-static testing and the other half for fatigue testing. Specimens will be designed to cover two bend ratios (i.e., one bend ratio per specimen pair) in order to have both quasi-static and a fatigue testing for each bend ratio. One bend ratio will correspond to the bend ratio of the Memorial Bridge connection. Specimen sizes will be consistent with the largest possible scale model to be accommodated at the Campus structural laboratory.

**Task-3: Analytical Models of Small-scale Physical Specimens**

Modify the physics-based analytical models of the gusset-less truss connection developed as part of the NSF-funded Living Bridge Project to reflect the small-scale physical models constructed in Task 2. These analytical models will be used to design the laboratory experiments to quantify the structural behavior and performance of the connection. This design process will incorporate the estimation of the distribution of loading demands on the connection as well as the characterization of appropriate boundary conditions for testing.

**Task-4: Quasi-Static Testing to Failure**

Use digital image correlation via GoPro cameras, potentially photoelastic coatings, and strain gauges to measure and visualize the stress distribution across the connection, specifically in the heat-affected zone of the welds during laboratory experiments at Campus using quasi-static loading. Each connection will be loaded to failure. A testing jig will be designed to mimic the loading conditions appropriate for this connection. Bridge inspectors will be invited to view and examine the connection before, during, and after testing. Before the first test is conducted, a dummy specimen will be fabricated to verify the test setup and check the functionality of the data acquisition system.

**Task 5: Validation of Structural Connection Analytical Model**

Validate the structural connection model with available field data and laboratory data obtained in Task 4. Special attention will be placed on the implementation of appropriate structural similitude and scaling laws to effectively utilize both field and laboratory data. Use the validated structural model to design the set of fatigue tests by estimating appropriate traffic-induced stress/load levels and number of cycles to represent representative demands experienced by the Memorial Bridge connection. Provide an interim report and presentation to the State on project results.

**Task-6: Fatigue Testing**

Use digital image correlation, photoelastic coatings, and strain gauges to measure and visualize the stress distribution across the connection, specifically in the heat-affected zone of the welds during the fatigue experiments. The loads used during the fatigue experiment will be appropriate for the test setup and correlated with a structural model of the connection. Bridge inspectors will be invited to view and examine the connection before and at a maximum of three different stages during the fatigue tests.

**Task-7: Data Analysis and Interpretation of Laboratory Testing**

Experimental data will be analyzed to identify structural parameters and visual indicators of reduced structural performance. Then, statistical analysis of the data collected from field data together with quasi-static and fatigue testing will be used to identify, with a higher degree of confidence, the significant factors that impact structural performance and prediction of remaining service life.

**Task-8: Evaluation Protocol for Inspection and Condition Assessment**

The research team will develop an evaluation protocol for inspection and structural condition assessment for gusset-less connections. Once the evaluation protocol is designed for the Memorial Bridge connection, a general procedure will be implemented to develop similar protocols for other future innovative structural elements using the results from Tasks 2 through 7. In addition, the team will also develop foundational information for load rating of the gusset-less connection of the Memorial Bridge.

**Task-9: Final Report and Presentation**

A final report and a presentation will be prepared to the State. Videos and images from each test useful for bridge inspection and condition assessment will be available to the State as part of the final project report.

- E. Deliverables Schedule:** Quarterly scheduled progress reports (brief one-two page memos) will be submitted to the State to memorialize purchase of equipment, design of experiments, fabrication of specimens, major decisions made, evaluation of progress, and any additional relevant information for the State.

The interim report and presentation will be delivered to the State after the completion of Task 5. The final report shall be stand-alone (i.e. a student thesis is not sufficient) and shall have undergone complete grammatical and editorial prior to submittal to the State, in order that State reviewers can focus only on the technical aspects of the report. The report shall include an abstract, executive summary, project objectives, data collected, analyses performed, conclusions, and recommendations. The final report shall be provided in electronic format ready for publication within 30 days of the completed review by the State.

- F. Budget and Invoicing Instructions:** Campus will submit invoices to State on regular Campus invoice forms no more frequently than monthly and no less frequently than quarterly. Invoices will be based on actual project expenses incurred during the invoicing period, and shall show current and cumulative expenses. State will pay Campus within 30 days of receipt of each invoice. Campus will submit its final invoice not later than 60 days after the Project Period end date. State may withhold 10% of funds until receipt of final report from Campus. State will provide final payment within 30 days of receipt of the accepted final report.

| Budget Items                | State Funding | Cost Sharing | Total   |
|-----------------------------|---------------|--------------|---------|
| 1. Salaries & Wages         | 50,073        | 0            | 50,073  |
| 2. Employee Fringe Benefits | 2,758         | 0            | 2,758   |
| 3. Travel                   | 2,000         | 0            | 2,000   |
| 4. Supplies and Services    | 27,436        | 0            | 27,436  |
| 5. Equipment                | 5,000         | 0            | 5,000   |
| 6. Facilities & Admin Costs | 22,733        | 0            | 22,733  |
| Subtotals                   | 110,000       | 0            | 110,000 |
| Total Project Costs:        |               |              | 110,000 |

## EXHIBIT B

This Project Agreement is funded under a Grant/Contract/Cooperative Agreement to State from the Federal sponsor specified in Project Agreement article F. All applicable requirements, regulations, provisions, terms and conditions of this Federal Grant/Contract/Cooperative Agreement are hereby adopted in full force and effect to the relationship between State and Campus, except that wherever such requirements, regulations, provisions and terms and conditions differ for INSTITUTIONS OF HIGHER EDUCATION, the appropriate requirements should be substituted (e.g., OMB Circulars A-21 and A-110, rather than OMB Circulars A-87 and A-102). References to Contractor or Recipient in the Federal language will be taken to mean Campus; references to the Government or Federal Awarding Agency will be taken to mean Government/Federal Awarding Agency or State or both, as appropriate.

Special Federal provisions are listed here:  None or **Uniform Guidance issued by the Office of Management and Budget (OMB) in lieu of Circulars listed in paragraph above. .**

**COOPERATIVE PROJECT AGREEMENT**

between the

STATE OF NEW HAMPSHIRE, **Department of Transportation**

and the

**University of New Hampshire** of the UNIVERSITY SYSTEM OF NEW HAMPSHIRE

- A. This Cooperative Project Agreement (hereinafter "Project Agreement") is entered into by the State of New Hampshire, **Department of Transportation**, (hereinafter "State"), and the University System of New Hampshire, acting through **University of New Hampshire**, (hereinafter "Campus"), for the purpose of undertaking a project of mutual interest. This Cooperative Project shall be carried out under the terms and conditions of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, except as may be modified herein.
- B. This Project Agreement and all obligations of the parties hereunder shall become effective on the date the Governor and Executive Council of the State of New Hampshire approve this Project Agreement ("Effective date") and shall end on **3/31/19**. If the provision of services by Campus precedes the Effective date, all services performed by Campus shall be performed at the sole risk of Campus and in the event that this Project Agreement does not become effective, State shall be under no obligation to pay Campus for costs incurred or services performed; however, if this Project Agreement becomes effective, all costs incurred prior to the Effective date that would otherwise be allowable shall be paid under the terms of this Project Agreement.
- C. The work to be performed under the terms of this Project Agreement is described in the proposal identified below and attached to this document as Exhibit A, the content of which is incorporated herein as a part of this Project Agreement.

Project Title: **Layer Coefficients for NHDOT Pavement Design (SPR Project # 26962N)**

- D. The Following Individuals are designated as Project Administrators. These Project Administrators shall be responsible for the business aspects of this Project Agreement and all invoices, payments, project amendments and related correspondence shall be directed to the individuals so designated.

**State Project Administrator**

Name: Ann Scholz, PE  
Address: NHDOT  
Bureau of Materials & Research  
5 Hazen Drive, P.O. Box 483  
Concord, NH 03302-0483  
Phone: 603-271-1659

**Campus Project Administrator**

Name: Dianne Hall  
Address: University of New Hampshire  
Sponsored Programs Administration  
51 College Rd. Rm 116  
Durham, NH 03824  
Phone: 603-862-1942

- E. The Following Individuals are designated as Project Directors. These Project Directors shall be responsible for the technical leadership and conduct of the project. All progress reports, completion reports and related correspondence shall be directed to the individuals so designated.

**State Project Director**

Name: Eric Thibodeau, PE  
Address: NHDOT  
Bureau of Materials & Research  
5 Hazen Drive, P.O. Box 483  
Concord, NH 03302-0483  
Phone: 603-271-1545

**Campus Project Director**

Name: Eshan Dave, PhD  
Address: University of New Hampshire  
Civil Engineering  
Kingsbury Hall, Room W173  
Durham, NH 03824  
Phone: 603-862-3277

F. Total State funds in the amount of \$150,000.00 have been allotted and are available for payment of allowable costs incurred under this Project Agreement. State will not reimburse Campus for costs exceeding the amount specified in this paragraph.

Check if applicable

Campus will cost-share \_\_\_\_\_ % of total costs during the term of this Project Agreement.

Federal funds paid to Campus under this Project Agreement are from Grant/Contract/Cooperative Agreement No. \_\_\_\_\_ from **Federal Highway Administration** under CFDA# **20.205**. Federal regulations required to be passed through to Campus as part of this Project Agreement, and in accordance with the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, are attached to this document as Exhibit B, the content of which is incorporated herein as a part of this Project Agreement.

G. Check if applicable

Article(s) \_\_\_\_\_ of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002 is/are hereby amended to read:

H.  State has chosen **not to take** possession of equipment purchased under this Project Agreement.  
 State has chosen **to take** possession of equipment purchased under this Project Agreement and will issue instructions for the disposition of such equipment within 90 days of the Project Agreement's end-date. Any expenses incurred by Campus in carrying out State's requested disposition will be fully reimbursed by State.

This Project Agreement and the Master Agreement constitute the entire agreement between State and Campus regarding this Cooperative Project, and supersede and replace any previously existing arrangements, oral or written; all changes herein must be made by written amendment and executed for the parties by their authorized officials.

IN WITNESS WHEREOF, the University System of New Hampshire, acting through the **University of New Hampshire** and the State of New Hampshire, **Department of Transportation** have executed this Project Agreement.

**By An Authorized Official of:  
University of New Hampshire**

Name: Karen M. Jensen  
Title: Manager, Sponsored Programs Administration  
Signature and Date: \_\_\_\_\_

**By An Authorized Official of: the New  
Hampshire Office of the Attorney General**

Name: Dianne Martin  
Title: AAG  
Signature and Date: Dianne Martin 10/6/16

**By An Authorized Official of:  
Department of Transportation**

Name: Peter E. Stamnas  
Title: Director of Project Development  
Signature and Date: \_\_\_\_\_

**By An Authorized Official of: the New  
Hampshire Governor & Executive Council**

Name: \_\_\_\_\_  
Title: \_\_\_\_\_  
Signature and Date: \_\_\_\_\_

## EXHIBIT A

- A. Project Title:** Layer Coefficients for Currently Used Asphalt Materials (SPR Project # 26962N)
- B. Project Period:** Governor and Council Approval - December 31, 2018
- C. Objectives:** At present, New Hampshire Department of Transportation (NHDOT) employs AASHTO Empirical Pavement Design procedure for structural design of highways (new construction, reconstruction and major rehabilitations). The AASHTO procedures uses material specific coefficients (commonly called layer coefficients) to account for the structural capacity provide by each pavement layer. The current layer coefficients used by NHDOT are a combination of the original values proposed by AASHTO in 1960s and research conducted by Janoo in 1994 (CRREL Special Report 94-30). The research by Janoo was primarily focused on layer coefficient characterization of subgrade soils and aggregate courses. The asphalt mixtures in use today and vehicle loadings are substantially different from the ones characterized by AASHTO during the development of the design guide in 1960s. With current use of newer asphalt binder modification technologies, allowance for recycled materials (RAP, ground tire rubber), and newer manufacturing and construction techniques (such as, cold in-place recycling) there is an urgent need to reevaluate the layer coefficients for materials that are currently being used in construction of State pavements. Due to lack of reliable layer coefficient values, there is high potential for over-design of pavements that translate in substantially higher spending.
- D. Scope of Work:** In order to promote sustainability and to maintain integrity through reliable pavement designs, this research study will characterize asphalt mixtures currently used by State for determination of the actual layer coefficient values for those materials. As described in the problem statement, there is an urgent need to determine actual structural contributions of asphalt materials currently used by State.

In order to address the problem discussed here, this study will undertake four major research tasks.

**Task-1 Literature Review and Testing Plan:** State will identify the projects in the 2016 and 2017 paving program to be sampled. A thorough review of the literature on the topic of asphalt layer coefficients for AASHTO Empirical design procedures will be conducted. Concurrent with this task, the researchers will work closely with State engineers to identify materials for laboratory characterization to develop layer coefficients. The focus of the laboratory characterization is to establish layer coefficients for current New Hampshire asphalt mixtures. Information from literature review will be used to develop the experimental plan; preliminary review suggests use of resilient modulus (AASHTO TP31) and dynamic modulus (AASHTO T342) characterization for layer coefficient determination. If appropriate, available test data from previous State research projects will be included. During this task the researchers will also work with the project technical advisory group (TAG) to establish parameters for the extent of pavement performance data that would be obtained for analysis in task-3 of the study.

**Task-2: Laboratory Characterization.** State will collect the designated number of mix samples in 5-gallon buckets for this study. Campus will be responsible for retrieving samples from State. For the rubber mixes only, State will prepare gyratory specimens to avoid the need to reheat the mix and also provide the identified amount of rubber mix sample buckets. State will not be responsible for preparing any other gyratory specimens of mixes. During this task the testing plan developed in

Task-1 will be executed. The task will begin with sampling of materials. The primary focus will be given to plant produced materials to ensure that the measured properties are representative of the material used in pavement construction. If needed, select number of lab produced mixes will be used to supplement the plant mixtures. In order to encompass different asphalt binders, mix sizes, design traffic level and recycled asphalt amounts for different asphalt courses, a minimum 16 mixtures will be considered for laboratory evaluation. Literature review showed that resilient modulus and dynamic modulus of asphalt mixtures have been successfully correlated to layer coefficients. These tests will be employed in this study for determining asphalt layer coefficients.

**Task-3: Development of Layer Coefficients**

This task will develop the layer coefficients for asphalt mixtures that can be used in future pavement designs by State. The development of the layer coefficients will be conducted by analyzing the lab measured resilient and dynamic modulus values for typical State asphalt mixtures. A preliminary correlation of the coefficients with the currently realized pavement performances will also be undertaken in this task. The pavement management distress data (available from 2009 onwards) will be used for this correlation. Previously established relationships in the published literature between material properties and layer coefficients will also be utilized in this analysis. The researchers will also conduct comparative analysis of pavement designs using current and proposed layer coefficients. These designs will be simulating in AASHTO PavementME software to predict their anticipated performances. If needed, these comparisons will be used to adjust the layer coefficients prior to final recommendations.

**Task-4: Reporting**

At end of each task researchers will deliver an interim report to State. At end of each calendar year quarter, a brief quarterly report summarizing the progress of the project will also be delivered. Researchers will also visit NHDOT offices in Concord at the start of the project as well 1 year (after 12 months) into the project and at conclusion of Task-3 to make presentations and give project updates. A comprehensive final report will be prepared at the end of the study and delivered to State with the recommendations for asphalt layer coefficients. The report will be prepared in a stand-alone format.

**E. Deliverables Schedule: See Statement of Work**

| TASK  | Month |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |
|---|-------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|--|--|--|--|--|--|--|--|
|   | 1     | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |  |  |  |  |  |  |  |  |  |
| Task-1 Literature Review and Testing Plan Development | █     |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |
| Task-2 Laboratory Characterization                    |       |   |   | █ |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |
| Task-3 Development of Layer Coefficients              |       |   |   |   |   |   |   |   |   |    |    | █  |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |
| Task-4 Reporting                                      |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    | █  |  |  |  |  |  |  |  |  |  |
| 4.1 Quarterly Status Report                           |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |
| 4.2 Technical Committee Meetings                      |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |
| 4.3 Progress Reports                                  |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |
| 4.4 Final Report and Recommendations                  |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |

**F. Budget and Invoicing Instructions:** Campus will submit invoices to State on regular Campus invoice forms no more frequently than monthly and no less frequently than quarterly. Invoices will be based on actual project expenses incurred during the invoicing period, and shall show current and cumulative expenses. State will pay Campus within 30 days of receipt of each invoice. Campus will submit its final invoice not later than 60 days after the Project Period end date. State may withhold 10% of funds until receipt of final report from Campus. State will provide final payment within 30 days of receipt of the accepted final report.

| Budget Items                | State Funding | Cost Sharing (if required) | Total   |
|-----------------------------|---------------|----------------------------|---------|
| 1. Salaries & Wages         | 81,514        | 0                          | 81,514  |
| 2. Employee Fringe Benefits | 4,287         | 0                          | 4,287   |
| 3. Travel                   | 1,000         | 0                          | 1,000   |
| 4. Supplies and Services    | 31,094        | 0                          | 31,094  |
| 5. Equipment                | 0             | 0                          | 0       |
| 6. Facilities & Admin Costs | 32,105        | 0                          | 32,105  |
| Subtotals                   | 150,000       | 0                          | 150,000 |
| Total Project Costs:        |               |                            | 150,000 |

## EXHIBIT B

This Project Agreement is funded under a Grant/Contract/Cooperative Agreement to State from the Federal sponsor specified in Project Agreement article F. All applicable requirements, regulations, provisions, terms and conditions of this Federal Grant/Contract/Cooperative Agreement are hereby adopted in full force and effect to the relationship between State and Campus, except that wherever such requirements, regulations, provisions and terms and conditions differ for INSTITUTIONS OF HIGHER EDUCATION, the appropriate requirements should be substituted (e.g., OMB Circulars A-21 and A-110, rather than OMB Circulars A-87 and A-102). References to Contractor or Recipient in the Federal language will be taken to mean Campus; references to the Government or Federal Awarding Agency will be taken to mean Government/Federal Awarding Agency or State or both, as appropriate.

Special Federal provisions are listed here:  None or **Uniform Guidance issued by the Office of Management and Budget (OMB) in lieu of Circulars listed in paragraph above. .**

**COOPERATIVE PROJECT AGREEMENT**

between the

STATE OF NEW HAMPSHIRE, **Department of Transportation**

and the

**University of New Hampshire** of the UNIVERSITY SYSTEM OF NEW HAMPSHIRE

- A. This Cooperative Project Agreement (hereinafter "Project Agreement") is entered into by the State of New Hampshire, **Department of Transportation**, (hereinafter "State"), and the University System of New Hampshire, acting through **University of New Hampshire**, (hereinafter "Campus"), for the purpose of undertaking a project of mutual interest. This Cooperative Project shall be carried out under the terms and conditions of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, except as may be modified herein.
- B. This Project Agreement and all obligations of the parties hereunder shall become effective on the date the Governor and Executive Council of the State of New Hampshire approve this Project Agreement ("Effective date") and shall end on **3/31/19**. If the provision of services by Campus precedes the Effective date, all services performed by Campus shall be performed at the sole risk of Campus and in the event that this Project Agreement does not become effective, State shall be under no obligation to pay Campus for costs incurred or services performed; however, if this Project Agreement becomes effective, all costs incurred prior to the Effective date that would otherwise be allowable shall be paid under the terms of this Project Agreement.
- C. The work to be performed under the terms of this Project Agreement is described in the proposal identified below and attached to this document as Exhibit A, the content of which is incorporated herein as a part of this Project Agreement.

**Project Title: Incorporating Impact of Binder Aging on Cracking Performance of Asphalt Mixtures During Design (269620)**

- D. The Following Individuals are designated as Project Administrators. These Project Administrators shall be responsible for the business aspects of this Project Agreement and all invoices, payments, project amendments and related correspondence shall be directed to the individuals so designated.

**State Project Administrator**

Name: Ann Scholz, PE  
 Address: NH DOT  
 5 Hazen Dr. PO Box 483  
 Concord, NH 03302-0483  
 Phone: 603-271-1659

**Campus Project Administrator**

Name: Dianne Hall  
 Address: University of New Hampshire  
 Sponsored Programs Administration  
 51 College Rd. Rm 116  
 Durham, NH 03824  
 Phone: 603-862-1942

- E. The Following Individuals are designated as Project Directors. These Project Directors shall be responsible for the technical leadership and conduct of the project. All progress reports, completion reports and related correspondence shall be directed to the individuals so designated.

**State Project Director**

Name: Denis Boisvert, PE  
 Address: NH DOT  
 5 Hazen Dr. PO Box 483  
 Concord, NH 03302-0483  
 Phone: 603-271-1545

**Campus Project Director**

Name: Jo Sias Daniel, PhD, PE  
 Address: University of New Hampshire  
 Civil Engineering  
 Kingsbury Hall  
 Durham, NH 03824  
 Phone: 603-862-3277

Campus Authorized Official KJ  
 Date 8/30/16

F. Total State funds in the amount of **\$155,000** have been allotted and are available for payment of allowable costs incurred under this Project Agreement. State will not reimburse Campus for costs exceeding the amount specified in this paragraph.

Check if applicable

Campus will cost-share \_\_\_\_\_ % of total costs during the term of this Project Agreement.

Federal funds paid to Campus under this Project Agreement are from Grant/Contract/Cooperative Agreement No. **N/A** from **Federal Highway Administration** under CFDA# **20.205**. Federal regulations required to be passed through to Campus as part of this Project Agreement, and in accordance with the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, are attached to this document as Exhibit B, the content of which is incorporated herein as a part of this Project Agreement.

G. Check if applicable

Article(s) \_\_\_\_\_ of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002 is/are hereby amended to read:

H.  State has chosen **not to take** possession of equipment purchased under this Project Agreement.  
 State has chosen **to take** possession of equipment purchased under this Project Agreement and will issue instructions for the disposition of such equipment within 90 days of the Project Agreement's end-date. Any expenses incurred by Campus in carrying out State's requested disposition will be fully reimbursed by State.

This Project Agreement and the Master Agreement constitute the entire agreement between State and Campus regarding this Cooperative Project, and supersede and replace any previously existing arrangements, oral or written; all changes herein must be made by written amendment and executed for the parties by their authorized officials.

IN WITNESS WHEREOF, the University System of New Hampshire, acting through the **University of New Hampshire** and the State of New Hampshire, **Department of Transportation** have executed this Project Agreement.

**By An Authorized Official of:**  
**University of New Hampshire**  
Name: Karen M. Jensen  
Title: Manager, Sponsored Programs Administration  
Signature and Date: [Signature] 9/30/16

**By An Authorized Official of:** the New Hampshire Office of the Attorney General  
Name: Dianne Martin  
Title: AAG  
Signature and Date: [Signature] 10/6/16

**By An Authorized Official of:**  
**Department of Transportation**  
Name: Peter E. Stamnal  
Title: Director of Project Development  
Signature and Date: [Signature] 9/14/2016

**By An Authorized Official of:** the New Hampshire Governor & Executive Council  
Name: \_\_\_\_\_  
Title: \_\_\_\_\_  
Signature and Date: \_\_\_\_\_

## EXHIBIT A

- A. Project Title:** Incorporating Impact of Binder Aging on Cracking Performance of Asphalt Mixtures During Design (269620)
- B. Project Period:** Governor and Council Approval - December 31, 2018
- C. Objectives:** Cracking – both environmental and load related - is a primary concern for asphalt pavements in New Hampshire. Cracking affects ride quality and allows water to penetrate from the surface to underlying soil layers, decreasing the life of the pavement and requiring more frequent maintenance or rehabilitation. It has been well recognized in the literature and through field observations that a mixture's resistance to cracking decreases with time as the mixture ages in the field. The inclusion of already aged material in the form of RAP would also be expected to decrease the cracking resistance. Not all mixtures age at the same rate or to the same extent, and therefore, different mixtures could have very similar cracking properties soon after construction but may have drastically different properties after some level of aging. Therefore, it is important to have an understanding of how the cracking resistance of a mixture will change over time at the time materials are selected and mix designs are performed.

Presently, the NHDOT relies upon the performance grading of the binder to ensure the appropriate selection of materials to resist cracking in the field. However, recent research presented at various conferences and the FHWA Expert Task Group meetings has shown that the current PAV aging for binders may only represent the condition of in service pavements after 2-3 years. In some cases, this is not adequate to differentiate or screen materials that may age quickly and lead to increased cracking. Also, research has shown the importance of evaluating the mixture properties, to include the effect of aggregate structure and mineralogy, on cracking performance; this is currently not part of the NHDOT specification.

The results of this project will help NHDOT to improve the selection of asphalt mixtures to resist cracking, resulting in long term cost savings and better ride quality. The experimental study will provide the NHDOT and industry with information on cracking characteristics of mixtures including different percentages of RAP, different binder grades, and different aging conditions.

This project builds upon the work conducted under Project No. 15680R, which evaluated the differences between binder and mixture testing, and materials produced in the lab and in the plant for high recycled content materials. This project will also take advantage of the mixture characterization that has already been completed and the field sections that are in place. Available data includes mixtures with different binder PG grades (PG 58-28, PG 52-34, and PG 64-28), binder sources, nominal maximum size of aggregate (9.5, 12.5, and 19 mm), and amount of RAP.

The objectives of this project are to:

- Develop a method (including aging protocol) to identify crack susceptible binders/mixtures as a screening tool during material selection and mix design
- Determine if binder testing is adequate or if mixture testing is required
- Evaluate how the cracking potential of typical NHDOT mixtures change with different aging levels for future maintenance and rehabilitation planning

- Develop guidance on how to quantitatively evaluate cracking susceptibility of NH mixtures considering aging

**D. Scope of Work:** In order to address the problem discussed here, this study will undertake the following major research tasks.

**Task 1: Literature Review and Finalize Testing Plan**

A comprehensive literature review on aging of asphalt binders and mixtures will be performed to inform the development of the final testing plan. The research team will work with NHDOT to finalize the testing plan and the materials to be evaluated in this project. This project will take advantage of testing results, materials, and mixtures already evaluated during the project No. 15680R, "Correlation between Laboratory and Plant produced High RAP/RAS Mixtures" to the extent possible based on the remaining materials. The 10 different mixtures shown in Table 1 are available for inclusion in this study. Test results on short term aged material (plant and lab) available for these mixtures include: complex modulus, SVECD fatigue and low temperature cracking evaluated using disc-shaped compact tension (DCT) testing. There are 10 buckets of loose plant mix available for each of the Lebanon mixtures that can be used to fabricate specimens for long term aging. The Lebanon mixtures were placed in test sections in Westmoreland and performance is being monitored by NHDOT.

The research team will also investigate using the results of NHDOT project 15680B "Performance of High RAP Pavement Sections in NH", which evaluated six mixtures with varying RAP content and virgin binder grade:

- Virgin PG 58-28
- 15% RAP with PG 58-28 binder
- 25% RAP with PG 58-28 binder
- 25% RAP with PG 52-34 binder
- 30% RAP with PG 52-34 binder
- 40% RAP with PG 52-34 binder

Extensive binder and mixture characterization was performed on short-term aged materials in this project; this included full performance grading, complex modulus, and SVECD fatigue testing. The six mixtures have been in place on I93 for 5 years and the performance over time has been monitored.

During this first task, the research team will investigate the potential of obtaining field cores from both the Westmoreland and I93 sections to evaluate how the mixtures have aged in the field over time and compare to the laboratory aging results.

The research team will work with NHDOT to identify additional mixtures for evaluation to incorporate the most commonly used materials in the state. To the extent possible, coordination on material testing with the Layer Coefficients for NHDOT Pavement Design project will be done.

**Task 2: Laboratory Aging of Mixtures**

The primary purpose of this research is to evaluate how the properties of mixtures change with aging, not necessarily to correlate a laboratory aging level with a period of time in the field, although this will be investigated with available field cores, if possible. Therefore, the focus of this task is to produce test specimens at different aging levels. The current aging protocol, AASHTO R30-02, states that a compacted mixture of aggregate and binder should be conditioned in a forced-draft oven for 5 days ( $120 \pm 0.5$  hr) at  $85 \pm 3^\circ\text{C}$  for long term mixture conditioning. Research has shown that this simulates approximately 2-3 years of service in field, and is therefore not sufficient to simulate the field long-term aging behavior. Recent research conducted by FHWA shows that a significant difference in mix

characteristics can be observed with 10-days of oven aging. There is also NCHRP project 9-54: Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction, currently underway with the objective develop a procedure to simulate long-term aging of asphalt mixtures for performance testing and prediction. The current recommendation from the NCHRP 9-54 project is to oven age loose mixtures in the laboratory prior to compaction. During Task 1, the research team will evaluate available literature and current recommendations from ongoing NCHRP projects and the FHWA Expert Task Groups to determine the aging protocol(s) to be used in this project.

It is anticipated that three different aging levels will be evaluated in this study:

1. Short term aged following the current NHDOT method for lab produced mixtures or plant produced mixtures compacted without reheating
2. Intermediate aging level following existing recommendations
3. Long term aging level following existing recommendations

Loose mix sampled at the plant and stored in sealed metal 5-gallon buckets will be reheated at 10°C below compaction temperature, divided into the appropriate weights and specimens will be fabricated following the appropriate aging procedures. Specimens 150 mm in diameter and approximately 180 mm tall will be compacted to a target air void content of  $7 \pm 0.5\%$  in the UNH laboratory using a Superpave gyratory compactor. The specimens will then be cut and cored to the final test specimen dimensions. All tested specimens will have an air void content of  $6 \pm 0.5\%$  to simulate typical in-place field densities.

The number of specimens needed for each type of testing is:

- Complex modulus: 3 specimens
- S-VECD fatigue: 4 specimens
- Disc shaped compact tension (DCT), 3 specimens (2 Gyratory specimens are required)

Therefore, about 10 specimens are needed for full characterization of the material properties for both fatigue and low temperature cracking.

### Task 3: Characterization of Extracted and Recovered Binders

Virgin binders and binders extracted and recovered from aged mixtures and field cores will be tested in this task. Virgin binders will be aged according to the protocols determined in the literature review conducted during Task 1. Currently, research groups are recommending that 40 hrs of PAV aging be used for extended aging time. There are also recommendations for extended low temperature conditioning times that will be investigated as part of the literature review conducted in Task 1. Materials extracted and recovered from mixtures and cores will not be further aged. Testing binders will include:

- Low temperature PG grading using the BBR device. Testing will be conducted at multiple temperatures to bracket the continuous grade (performed at NHDOT)
- G\* master curves using the 4mm DSR testing to allow for complete characterization across a range of temperatures (performed at UNH)

Analysis will include continuous grading, critical cracking temperature, and rheological evaluation using the Christensen-Anderson-Marasteanu (CAM) parameters and the Glover-Rowe black space parameters. Binder test results conducted through project Nos. 15680R and 15680B will also be included in the analysis.

### Task 4. Mixture Material Characterization Testing and Analysis

Material characterization testing will be performed at UNH on the asphalt mixtures. Testing will be done using the AMPT and MTS equipment and will include:

1. Complex modulus testing at a range of temperatures (-10 C to 37.8 C) and frequencies to develop dynamic modulus and phase angle master curves (Figure 1a)
2. Fatigue testing following the SVECD protocols to develop the characteristic damage curve for the mixtures (Figure 1b)
3. Disk-shaped compact tension (DCT) testing to evaluate the low temperature cracking potential of mixtures (Figure 1c)

Analysis will be performed using the SVECD approach that will include evaluation of fatigue behavior of the mixtures. In addition, the measured dynamic modulus and fatigue properties will be input to the Linear Viscoelastic for Critical Distress (LVECD) pavement evaluation software to assess relative performance of the mixtures in an actual pavement structure over time. The fracture testing results from DCT test will be used to make comparisons between the mixtures in terms of their thermal cracking performances. The comparisons will be made using existing database of fracture energy results that are available to the researchers from previous studies as well as through use of the IlliTC thermal cracking prediction system that was developed through the Pooled Fund Study on Low Temperature Cracking (TPF-5(132)). Using the fracture test results and the dynamic modulus master-curves the IlliTC predicts the pavement thermal cracking performance over its service life.

**Task 5. Development of Screening Tool and Guidelines**

Based on the results of the testing and analysis under Tasks 3 and 4, the research team will develop the screening tool to be used to evaluate both binders and mixtures, if appropriate. This will include the appropriate aging protocol. Guidance on how to evaluate cracking potential of NH mixtures considering how the properties of the materials change with aging will also be developed in this task.

**Task 6. Reporting**

Quarterly reports will be submitted through the duration of the project using the form provided by NHDOT, interim progress reports will be submitted at regular intervals during the project and a final report summarizing and fully documenting the experimental work will be prepared. The research team will also visit NHDOT at the start of the project and at key stages during Tasks 3 and 4 to discuss results and receive direct feedback.

**E. Deliverables Schedule:**

|  | Month |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
|--|-------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|
|  | 1     | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |  |
| Task 1: Literature Review and Finalize Testing Plan                      |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Task 2: Laboratory Aging of Mixtures                                     |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Task 3: Characterization of Extracted and Recovered Binders and Analysis |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Task 4: Mixture Material Characterization Testing and Analysis           |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Task 5: Development of Screening Tool and Guidelines                     |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Task 6: Reporting  |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Progress Reports   |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Quarterly Reports  |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| Final Report   |       |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |

**Anticipated delivery dates**

- Task 1: Literature Review - end month 3
- Task 2: Laboratory Aging - batch 1 end month 5; batch 2 end month 14
- Task 3: Characterization of Extracted and Recovered Binders and Analysis - end month 21
- Task 4: Mixture Material Characterization Testing and Analysis - end month 22
- Task 5: Development of Screening Tool Guidelines - end of month 22

Task 6: Final Report (accepted by NHDOT) - end month 24

**F. Budget and Invoicing Instructions:** Campus will submit invoices to State on regular Campus invoice forms no more frequently than monthly and no less frequently than quarterly. Invoices will be based on actual project expenses incurred during the invoicing period, and shall show current and cumulative expenses. State will pay Campus within 30 days of receipt of each invoice. Campus will submit its final invoice not later than 60 days after the Project Period end date. Total payments will not exceed 90% until receipt of final report acceptable to State. State will provide final payment within 30 days of receipt of the accepted final report.

| Budget Items                | State Funding | Cost Sharing | Total   |
|-----------------------------|---------------|--------------|---------|
| 1. Salaries & Wages         | 81,336        | 0            | 81,336  |
| 2. Employee Fringe Benefits | 4,035         | 0            | 4,035   |
| 3. Travel                   | 2,000         | 0            | 2,000   |
| 4. Supplies and Services    | 34,249        | 0            | 34,249  |
| 5. Equipment                | 0             | 0            | 0       |
| 6. Facilities & Admin Costs | 33,380        | 0            | 33,380  |
| Subtotals                   | 155,000       | 0            | 155,000 |
| Total Project Costs:        |               |              | 155,000 |

## EXHIBIT B

This Project Agreement is funded under a Grant/Contract/Cooperative Agreement to State from the Federal sponsor specified in Project Agreement article F. All applicable requirements, regulations, provisions, terms and conditions of this Federal Grant/Contract/Cooperative Agreement are hereby adopted in full force and effect to the relationship between State and Campus, except that wherever such requirements, regulations, provisions and terms and conditions differ for INSTITUTIONS OF HIGHER EDUCATION, the appropriate requirements should be substituted (e.g., OMB Circulars A-21 and A-110, rather than OMB Circulars A-87 and A-102). References to Contractor or Recipient in the Federal language will be taken to mean Campus; references to the Government or Federal Awarding Agency will be taken to mean Government/Federal Awarding Agency or State or both, as appropriate.

Special Federal provisions are listed here:  None or **Uniform Guidance issued by the Office of Management and Budget (OMB) in lieu of Circulars listed in paragraph above. .**

**COOPERATIVE PROJECT AGREEMENT**

between the

STATE OF NEW HAMPSHIRE, **Department of Transportation**

and the

**University of New Hampshire** of the UNIVERSITY SYSTEM OF NEW HAMPSHIRE

- A. This Cooperative Project Agreement (hereinafter "Project Agreement") is entered into by the State of New Hampshire, **Department of Transportation**, (hereinafter "State"), and the University System of New Hampshire, acting through **University of New Hampshire**, (hereinafter "Campus"), for the purpose of undertaking a project of mutual interest. This Cooperative Project shall be carried out under the terms and conditions of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, except as may be modified herein.
- B. This Project Agreement and all obligations of the parties hereunder shall become effective on the date the Governor and Executive Council of the State of New Hampshire approve this Project Agreement ("Effective date") and shall end on **3/31/20**. If the provision of services by Campus precedes the Effective date, all services performed by Campus shall be performed at the sole risk of Campus and in the event that this Project Agreement does not become effective, State shall be under no obligation to pay Campus for costs incurred or services performed; however, if this Project Agreement becomes effective, all costs incurred prior to the Effective date that would otherwise be allowable shall be paid under the terms of this Project Agreement.
- C. The work to be performed under the terms of this Project Agreement is described in the proposal identified below and attached to this document as Exhibit A, the content of which is incorporated herein as a part of this Project Agreement.

Project Title: **Reducing Cracking in New Bridge Curbs (SPR Project # 26962P)**

- D. The Following Individuals are designated as Project Administrators. These Project Administrators shall be responsible for the business aspects of this Project Agreement and all invoices, payments, project amendments and related correspondence shall be directed to the individuals so designated.

**State Project Administrator**

Name: Elizabeth S. Klemann, PE  
 Address: NHDOT Bureau of Materials & Research  
 5 Hazen Drive, P.O. Box 483  
 Concord, NH 03302-0483  
 Phone: 603-271-8995

**Campus Project Administrator**

Name: Dianne Hall  
 Address: University of New Hampshire  
 Sponsored Programs Administration  
 51 College Rd. Rm 116  
 Durham, NH 03824  
 Phone: 603-862-1942

- E. The Following Individuals are designated as Project Directors. These Project Directors shall be responsible for the technical leadership and conduct of the project. All progress reports, completion reports and related correspondence shall be directed to the individuals so designated.

**State Project Director**

Name: Douglas Gosling  
 Address: NHDOT Bureau of Bridge Maintenance  
 7 Hazen Drive, P.O. Box 483  
 Concord, NH 03302-0483  
 Phone: 603-271-1552

**Campus Project Director**

Name: Eshan Dave, PhD  
 Address: University of New Hampshire  
 Civil Engineering  
 Kingsbury Hall, Room W173  
 Durham, NH 03824  
 Phone: 603-862-5268

Campus Authorized Official *KJ*  
 Date *07/2/16*

F. Total State funds in the amount of \$56,080.00 have been allotted and are available for payment of allowable costs incurred under this Project Agreement. State will not reimburse Campus for costs exceeding the amount specified in this paragraph.

Check if applicable

Campus will cost-share \_\_\_\_\_ % of total costs during the term of this Project Agreement.

Federal funds paid to Campus under this Project Agreement are from Grant/Contract/Cooperative Agreement No. \_\_\_\_\_ from **Federal Highway Administration** under CFDA# **20.205**. Federal regulations required to be passed through to Campus as part of this Project Agreement, and in accordance with the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, are attached to this document as Exhibit B, the content of which is incorporated herein as a part of this Project Agreement.

G. Check if applicable

Article(s) \_\_\_\_\_ of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002 is/are hereby amended to read:

H.  State has chosen **not to take** possession of equipment purchased under this Project Agreement.  
 State has chosen **to take** possession of equipment purchased under this Project Agreement and will issue instructions for the disposition of such equipment within 90 days of the Project Agreement's end-date. Any expenses incurred by Campus in carrying out State's requested disposition will be fully reimbursed by State.

This Project Agreement and the Master Agreement constitute the entire agreement between State and Campus regarding this Cooperative Project, and supersede and replace any previously existing arrangements, oral or written; all changes herein must be made by written amendment and executed for the parties by their authorized officials.

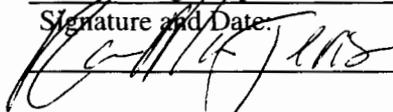
IN WITNESS WHEREOF, the University System of New Hampshire, acting through the **University of New Hampshire** and the State of New Hampshire, **Department of Transportation** have executed this Project Agreement.

**By An Authorized Official of:  
University of New Hampshire**

Name: Karen M. Jensen

Title: Manager, Sponsored Programs Administration

Signature and Date:

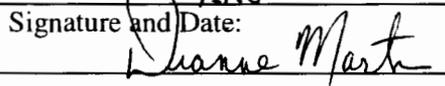
 8/30/16

**By An Authorized Official of: the New  
Hampshire Office of the Attorney General**

Name: Dianne Martin

Title: AAG

Signature and Date:

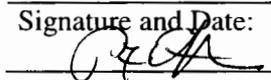
 10/6/16

**By An Authorized Official of:  
Department of Transportation**

Name: Peter E. Stamnas

Title: Director of Project Development

Signature and Date:

 9/14/2016

**By An Authorized Official of: the New  
Hampshire Governor & Executive Council**

Name:

Title:

Signature and Date:

\_\_\_\_\_

## EXHIBIT A

- A. **Project Title:** Reducing Cracking in New Bridge Curbs (SPR Project # 26962P)
- B. **Project Period:** Governor and Council Approval - December 31, 2019
- C. **Objectives:** In recent years, a number of new concrete curbs on New Hampshire bridges have undergone early age cracking, in many instances within few weeks after casting. These cracks have been observed by State Bridge Maintenance office on short single-span bridges (typically 25-45 ft. span). Hairline cracks at regular interval have been observed. Concrete curbs are typically replaced at the same time when bridge deck is replaced. Standard practice is to used State Class AA Portland cement concrete (Section 520). Picture below shows early age cracking in curb on Bridge 175/076 near Thornton NH.

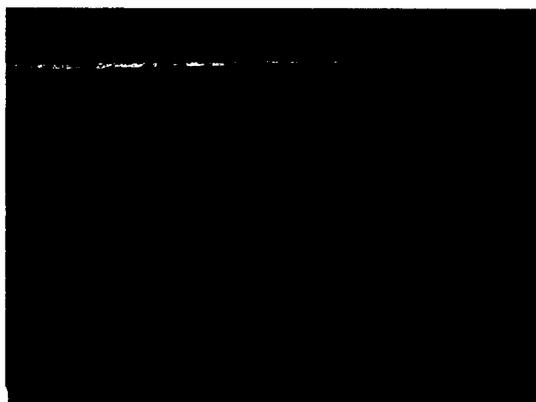


Figure 1: Early age cracking in concrete bridge curb (Thornton 175/076).

Early age cracking severely reduces service life of curbs and increases propensity for cracks to propagate into bridge decks. Premature failure leads to substantial costs associated with curb (and deck) replacement as well as closure of bridges that lead to traffic related challenges. There is need for review of current practices as well as to develop recommendations for future practices to prolong life of curbs and lower potential for early age cracking.

This study is designed with following objectives:

- Review of current practice for State bridge curb construction and concrete mixes to identify cause(s) of early age cracking;
- Construction and observation of bridge curbs with trial of different concrete and construction practice modifications; and,
- Development of practice change recommendations to alleviate early age cracking problem.

Preliminary literature review has shown that changes to curing practices as well as amount of cementitious materials in concrete, specifically silica fume, can have significant effect on early age crack formation. This study will include these as possible changes to current practice as well as others that will be identified early in the study. In order to realize above objectives, four research tasks are identified. Descriptions of these tasks as well as deliverables/outcomes from each are provided in the next section.

**D. Scope of Work:** In order to address early age cracking in concrete curbs of New Hampshire bridges, this study will undertake four major research tasks.

**Task-1 Review of Current Practices: Evaluation of Existing Concrete Curbs, Mix Design and Test Results**  
During this task, researchers will visit existing bridge installations where concrete curbs have undergone early age cracking. The purpose of these visits will be to document the type of cracking and to collect necessary information for developing automated crack survey system. Development of the automated crack survey procedure will be done as a senior design project for engineering students at Campus. Researchers from this project will act as liaison for the senior design project.

Concrete mix designs as well as quality control and acceptance test results from producer and State will be reviewed and analyzed. Comparisons between the mix design data, current construction practices and review of existing literature will be used for identifying potential causes for early age cracking. The information gathered by researchers on existing practices will be used to develop trials of mix designs and construction practice changes that will be undertaken in Task 2 of this study.

**Task Deliverables:** Memo on review of current State practices for bridge curb construction; sample data from the curb cracking evaluation system; recommendations for PCC mix and construction processes trials to be undertaken in task 2.

**Task-2: Construction of Concrete Curbs with Different Mix Designs and Construction Processes**  
Bridge curb construction with of different concrete mixes and construction practices will be conducted in this task. Over the course of this study, curbs at six bridge sites are planned to be constructed. On basis of the preliminary literature review, the trials are expected to include following:

- Mixes with lower total cementitious materials
- Mixes without or with limited amounts of silica fume
- Mixes with chemical admixtures and/or fly ash
- Extended wet cure (up to 14 days)
- Use of internal curing mix, such as one with light weight aggregates

Researchers will travel to bridge sites during the concrete placement to document the placement process and to take initial pictorial measurement on the curb.

**Task Deliverable:** Memo summarizing construction of concrete curbs as part of study trials.

**Task-3: Survey of Concrete Curbs for Cracking Performance**

Cracking performance data will be collected and analyzed during this task of the study. Researchers will periodically visit each of the curb installation from Task-2 of this project and use automated crack measurement system for collection and documentation of cracking. Since early age cracking is the focus of this research, the visits for measurement are planned to be conducted as per following plan (days after casting of curb): 3; 7, 14, 21 and 28 days. Due to practical reasons it might not be possible to exactly follow the above schedule, target will be to make minimum three visits to bridge sites within first 28 days after casting of curbs. At least one visit will be conducted between 3 and 7 days, one between 14 and 21 days and one after 28 days. If needed, up to two more visits might be made to the site.

During each visit, in addition to automated crack measurements, field notes will be taken to document aspects associated with the condition of curb, weather conditions, air and curb temperature and pictures of any other features and factors that would help the research.

**Task Deliverable:** Memo with analyzed cracking data results in terms of amount, severity and spacing of cracking for each of the study location. Memo will also document other information collected during site visits.

**Task-4: Analysis of Results and Recommendation Development**

This final task of the project will utilize data and analysis results from all previous tasks to propose change of practice to lower the propensity of early age cracking in bridge curbs. A comprehensive final report will be prepared at the end of the study and delivered to State with the recommendations for specification and practice changes. The report will be fully edited for grammar and format prior to submittal and should not be a thesis. A poster (30"x40") will also be prepared for the project, poster will meet guidelines of State.

Task Deliverable: Final report and a poster for the project to be submitted and accepted by State by September 30, 2019.

Since this project involves substantial coordination between researchers from Campus and State staff, key activities of the research project along with responsible entity for those activities are shown in table below.

| Task | Major Activity  | Entity Responsible |
|------|---|--------------------|
| 1    | Traffic control for site visits   | State              |
|      | Collection of mix designs, QC results, acceptance test results for existing bridge sites          | State              |
|      | Analysis of mix designs, QC results, acceptance test results for existing bridges                 | Campus             |
|      | Memo on review of current practices   | Campus             |
|      | Use automated crack survey method to document cracking amount in existing bridge curbs            | Campus             |
| 2    | Construction of concrete bridge curbs for different concrete mix and construction practice trials | State              |
|      | Traffic control for site visits   | State              |
|      | Periodic crack surveys at study locations   | Campus             |
|      | Memo summarizing construction of study locations  | Campus             |
| 3    | Analysis of cracking performance at various study locations                                       | Campus             |
|      | Memo summarizing cracking performance at study locations  | Campus             |
| 4    | Practice change recommendations on basis of findings from previous tasks                          | Campus             |

**E. Deliverables Schedule:**



## EXHIBIT B

This Project Agreement is funded under a Grant/Contract/Cooperative Agreement to State from the Federal sponsor specified in Project Agreement article F. All applicable requirements, regulations, provisions, terms and conditions of this Federal Grant/Contract/Cooperative Agreement are hereby adopted in full force and effect to the relationship between State and Campus, except that wherever such requirements, regulations, provisions and terms and conditions differ for INSTITUTIONS OF HIGHER EDUCATION, the appropriate requirements should be substituted (e.g., OMB Circulars A-21 and A-110, rather than OMB Circulars A-87 and A-102). References to Contractor or Recipient in the Federal language will be taken to mean Campus; references to the Government or Federal Awarding Agency will be taken to mean Government/Federal Awarding Agency or State or both, as appropriate.

Special Federal provisions are listed here:  None or **Uniform Guidance issued by the Office of Management and Budget (OMB) in lieu of Circulars listed in paragraph above. .**