Research Need Statement 605

I. Need Statement Champions and Information

I.A. Need Statement Champion Information

I.A.1. First and Last Name of Research Champion: Maria Masten
I.A.2. Research Champion's Office: MnDOT Office of Materials and Road Research
I.A.3. Research Champion's Phone Number: 651-366-5572
I.A.4. Research Champion's Email: maria.masten@state.mn.us

I.B. Research Co-Champion

I.A.1. First and Last Name of Research Co-Champion: Kyle Fritz
I.A.2. Research Co-Champion's Office: MnDOT Bridge Office
I.A.3. Research Co-Champion's Phone Number: 651-366-4538
I.A.4. Research Co-Champion's Email: kyle.fritz@state.mn.us

I.C. Research Needs Title (115 Characters): Bridge Low Slump Concrete Overlay Mix Design for Mobile Mixers

I.D. Project Sponsor: MnDOT Research Program

II. Research Need Background and Description

II.A. Research Need Background

II.A.1. Describe the problem or opportunity.

Aging bridge decks pose a risk to the public. Internal reinforcement corrosion caused by water intrusion and/or chloride diffusion can cause concrete to spall and fall onto traffic below; pavement surfaces to develop potholes (driving hazards); or create weakness in the tire carrying capacity of the bridge deck through corrosion of internal reinforcement.

The low slump concrete overlay has historically been a sound strategy for extending the useful service life of Minnesota bridges. Both MnDOT Districts and Bridge Contractors are familiar with the product and understand its purpose. However, cracking has become prevalent in this technique even though the general formulation has remained the same. Cracking reduces service life, increases maintenance sealing needs, and increases costs. It is suspected that the individual materials that make up the mix have evolved over the years resulting in different behavior compared to the past mix compositions thus resulting in more cracking.

The current low slump overlay mix design, 3U17A, has not been significantly modified in the Standard Specifications in over 30 years. This mix design has exhibited high-levels of early-age cracking for the past 10 years, which ultimately results in a decrease in service life. While low slump overlays are not

often used in new construction (due to a policy change in late 2017), this system remains a primary tool on bridge preservation projects to extend the useful service life of existing bridges.

By developing a new mix design outside of a construction contract, MnDOT can better manage risks to schedule and cost associated with having a mix design approved after contract award.

II.A.2. If applicable, describe how this project will build on previous research.

MnDOT Research Project 2018-24, A Rational Method of Surface Treatment Selections for Concrete Decks, developed a program to model chloride ingress. This tool using NT Build 492 for measurement at 28 days is currently being used to predict the service life of bridge decks and timing of repairs and overlays to prolong service life. While the model does modify the diffusion coefficient of the concrete to account for some cracking, an overlay with map cracking cannot accurately be modeled in this program. By reducing the amount of cracking in the overlay, the service life predictions by the program developed in this previous research project will improve.

II.A.3. If applicable, include the title/s or previous research.

An internal MnDOT literature review identified minimal research has been completed on improvements to the original low slump concrete bridge deck overlay concept developed in Iowa and used by several other state agencies including Minnesota.

The following resources may provide information regarding other State Agency practices:

- Travis Hopper et al. Bridge Deck Cracking: Effects on In-Service Performance, Prevention, and Remediation. (Harrisburg, PA : Pennsylvania Department of Transportation, 2015.)
- NCC State Reports Spring 2017 – Bridge Deck Overlays/Approaches/Mix Designs, etc. Survey [PDF file]. Retrieved from https://intrans.iastate.edu/app/uploads/2018/07/5-Spring-2017-NCC-State-Report_final_5-9-17.pdf
- Longer lasting bridge deck overlays / University of Kentucky Transportation Center. (Lexington, Kentucky: Kentucky Transportation Center, 2018.)

II.A.4. What is the objective of the proposed research?

This research seeks to develop an updated low slump mix design (MnDOT 3U17A) that dramatically reduces the incidence of cracking. MnDOT acknowledges other overlay mixes (latex modified, silica fume, etc.) provide additional solutions but desires to focus this research on improvements to the current MnDOT 3U17A concrete mix design.

Curing, which is often a focus for reducing cracking, has been investigated and is determined to not be an area of focus after several trials with superior curing and ideal conditions still resulted in cracking within a year. If the researcher determines a specific curing regime should be used with the updated mix design which is different than MnDOT's current requirements the researcher should include those recommendations.

Additional information regarding MnDOT specifications and construction requirements for low slump concrete overlays include the following:

- MnDOT Specification 2404, Concrete Wearing Courses for Bridges
- MnDOT Weekly Report of Low Slump Concrete spreadsheet at the following location: http://www.dot.state.mn.us/materials/concretedocs/Weekly_Report_of_Low_Slump_Concrete_4-2017.xls
- MnDOT Concrete Manual 5-694.450, Low Slump Concrete Overlays
- MnDOT Bridge Construction Manual 5-393.363, Bridge Deck Low Slump and Latex Wearing Courses
- MnDOT Low Slump Wearing Course Video at the following location: https://youtu.be/z50TuVQkdPM

Tasks may include, but not be limited to:

- Review low slump concrete overlay mobile mix designs and construction requirements used by other North Central States, National Concrete Consortium States or owners with similar seasonal climate variation. Solicit state feedback through the use of a survey on the most effective specification changes in the last 20 years. MnDOT can provide other State Agency contacts for completion of the researcher developed survey.

- Identify attributes of the current low slump mix and construction specifications that should be modified to improve cracking performance while maintaining durability for concrete batched in a mobile mixer. The current low slump overlay mix design (3U17A) is shown below:

Low Slump Concrete Mix Design 3U17A

Strength	- 5600 psi concrete at 28 days	06002 Ortonville Stone	(Sp.G 2.64) - 1369 pounds
Water	- 270 pounds	17001 Sioux Quartzite	(Sp.G 2.65) - 1374 pounds
Air	- 6.5 percent	52003 New Ulm Quartzite	(Sp.G 2.63) - 1364 pounds
Cement (C	- 836 pounds (Sp.G 3.15)	73006 Marietta Granite	(Sp.G 2.72) - 1411 pounds
FA *	- 1415 pounds, Concrete Sand (Spec 3126)	87002 Granite Falls Granite	(Sp.G 2.67) - 1385 pounds
CA **	- CA, Class A (Spec 3137):>>>>>>>>>>>>>>>>>>>>>>>>>>	94009 Dresser Trap Rock	(Sp.G 2.97) - 1540 pounds
Slump	- 3/4 in. ± 1/4 in.	94035 RME-Athens	(Sp.G 2.95) - 1530 pounds
Water Red	- Must be a MnDOT Approved Water Reducer - Use Manufacturer's Recommendations for Dosage Rate		

* Includes assumed 3% moisture
** If a coarse aggregate other than listed is to be used, the concrete mix shall be obtained from the Concrete Engineering Unit.

- Review current materials (cements, aggregates, additives, etc.) used by local contractors in their mobile mixers and local suppliers. Develop list of alternative products (blended cements, additives, etc.) from the same suppliers that may be considered in low slump mix changes batched in a mobile mixer.

- Review plastic and hardened concrete testing requirements that MnDOT currently specifies for evaluation of the MnDOT 3U17A low slump concrete overlay mix.

- Using trial batching with a mobile concrete mixer, develop a prescriptive updated low slump concrete overlay mix design that: (a) exhibits reduced shrinkage, (b) has low permeability, (c) reduces the cementitious content (d) modifies the required compressive strength from 5600 psi to 4000 psi minimum at 28 days (e) utilizing MnDOT specified type and size of coarse aggregate, and (f) will be batched with a mobile concrete mixer.

- Batch the current MnDOT specified 3U17A mix design as a control mix for all testing.

- Evaluate proposed mix designs using standard concrete tests and additional tests identified in AASHTO PP84, Performance Engineered Mixtures (ie. Bucket test, Super Air Meter, Shrinkage, etc.) MnDOT is open to discussing current and emerging test methods that may better represent the desired information which could lead to a reduction in the incidence of cracking if applicable.
- Develop strength-maturity relationships and calorimetry curves to observe the hydration of the control mix and proposed low slump overlay mix design.
- Measure chloride diffusion coefficient of new mix designs through NT Build 492 at 28 days. MnDOT will provide chloride diffusion coefficient data for the current low slump overlay mix design.

- Participate in a field trial by a local contractor with the proposed mix design and provide a summary of the observations and findings from the field placement. MnDOT may request the field trial placement to include thermal sensors and moisture sensors which collect the data for a period of 12 months. Report on crack inspection results performed by MnDOT personnel from prior to opening to traffic and 1 year after opening to traffic.

III. Strategic Priorities, Benefits, and Expected Outcomes

Section III. is for MnDOT sponsored and co-sponsored projects only; all LRRB projects proceed to section IV.

III.A. MnDOT Strategic Priorities

Instructions: Briefly describe how the project aligns with the following MnDOT Research Strategic Priorities. Complete all that apply.

III.A.1. Innovation & Future Needs:

This project will adapt currently available materials into a refined field-mixed design that exhibits low cracking. An overlay mix less prone to cracking will result in longer bridge deck lives, less ongoing investments in crack sealing, and lower bridge preservation budget needs.

IIIA.2. Advancing Equity:

III.A.3. Asset Management:

A robust mix that enables bridge deck preservation with familiar means and methods would allow MnDOT to better manage aging bridge decks and extend service lives. A standardized mix and understanding of the chloride the diffusion coefficient will help directly manage bridge assets with better service life predictions.

III.A.4. Safety:

Aging bridge decks pose a risk to the public through corrosion of internal reinforcement. Internal reinforcement corrosion caused by water intrusion and/or chloride diffusion can result in concrete spalling/falling onto traffic below; development of potholes (driving hazards), or reduced carrying capacity of the bridge deck. Improved concrete overlay performance is expected to result in less service interruption, improved safety, and reduced maintenance costs as the bridge deck ages.

III.A.5 Climate Change & Environment:

Concrete construction and associated cement production generate significant amounts of carbon dioxide, a major contributor to climate change. An overlay mix that enables longer bridge deck life with decreased cracking can provide environment benefits on many fronts: reduced cement needs by way of extending deck service life; reduced vehicle traffic interruptions; and reduced construction impacts.

III.B. Expected Outcomes

Instructions: Check all expected direct outcomes of this research.

- ☒ New or improved technical standard, plan, or specification
- ☐ New or improved manual, handbook, guidelines, or training
- ☐ New or improved policy, rules, or regulations
- ☐ New or improved business practices, procedure, or process
- ☐ New or improved tool or equipment
- ☐ New or improved decision support tool, simulation, or model/algorithm (software)
- ☐ Evaluation of a new commercial product
- ☒ New or improved technical standard, plan, or specification
- ☐ Other. Please specify below:

III.C. Expected Benefits

Instructions: Select all expected benefits that may be realized if the findings and recommendations from this research is adopted or implemented

III.C.1. Construction Savings Improved quality of construction

III.C.2.Decrease Engineering/Administrative Costs Reduced planning/design costs

The alternative to a reduced cracking concrete wearing course is a full deck replacement rather than overlay. These projects are much more demanding of engineering, project development time and plan development time.

III.C.3. Environmental Aspects Hazardous Waste Reduction

As with III.C.2, the alternative of replacing a bridge deck involves substantially more materials and waste generation.

III.C.4. MnDOT Policy Changed or inform a policy

A reduced-cracking concrete overlay option would be incorporated into the expected service life used for asset life prediction and investment interval planning

III.C.5. Lifecycle Products with longer lifespan

III.C.6. Operations and Maintenance Savings Reduced time

III.C.7. Reduce Risk Other

Public risk of deteriorating bridge decks due to service interruption, hazards associated with traffic during construction.

III.C.8. Reduce Road User Cost Other

With reduced deck cracking, there will be less need for lane closures to seal cracks and patch concrete damage.

III.C.9. Safety Improve worker safety (i.e. workzone safety)

Reduced cracking overlays reduce the need for maintenance and enable projects with shorter construction times (overlays) versus projects that would have higher demands (redeck).

III.C.10. Technology Other technology related benefit. Please describe below.

A mix with a predefined chloride diffusion coefficient enables better asset life prediction. Additionally, a mix design with less cracking decreases the variability of service life predictions, because cracking directly impacts service life.

III.C.11. Other, please describe below:

IV. Technical Advisory Panel

Instructions: Please list the name and affiliation of individuals to consider for the Technical Advisory Panel.

MnDOT Bridge Office: Nick Haltvick, Kyle Fritz, Paul Pilarski, Paul Rowekamp, Karl Gronvall

MnDOT OCIC: Troy Strassburg

Materials Office: Maria Masten, Gordy Bruhn

District Construction: Tom Villar (Metro), Tom Lund (D1)

Industry partners: Lunda Construction, PCI Roads Inc, Lafarge/Holcim (Joe Clendenen)

Your assigned Project Advisor is available to answer questions and provide guidance (assigned by the Office of Research & Innovation).
Your Project Advisor is: Beth Klemann Email: beth.klemann@state.mn.us