NHDOT SPR2 PROGRAM
RESEARCH PROGRESS REPORT

Project # 42372M	Report Period Year 2024 ☐ Q1 (Jan-Mar) ☒ Q2 (Apr-Jun) ☐Q3 (Jul-Sep) ☐ Q4 (Oct-Dec)	
Project Title: Reduce Concrete Cracking through Mix Design		
Project Investigator: Eshan Dave, University of New Hampshire **Phone:** 603-862-5268 **E-mail:** eshan.dave@unh.edu		
Project Start Date: 4/12/2023	**Project End Date:** 12/31/2025	**Project schedule status:** ☐ On schedule ☐ Ahead of schedule ☒ Behind schedule

Brief Project Description:

Concrete cracking affects the long-term condition and performance of both bridge and culvert structures. Shrinkage cracking is perceived to be a deterrent to placing exposed decks/slabs during bridge and culvert rehabilitation and replacement projects. Concrete cracking during bridge construction allows oxygen, moisture and salts into the structure accelerating corrosion and deterioration. Understanding methods to avoid cracking at the mix design level will allow exposed decks to be more often considered as a viable option. This is especially critical as more rapid bridge projects are proposed.

Different construction and specification methods have been previously explored to reduce concrete cracking at bridge curb locations. This research will explore alternates to current mix design practice including lightweight concrete, changes to PCC and pozzolan content, etc., to reduce concrete cracking. Stand alone, off structure concrete placement like sidewalks, concrete slabs, etc., could be used as test areas for observation. The Bureau of Bridge Maintenance will work with researchers at those locations and consider placement in bureau projects.

Progress this Quarter (include meetings, installations, equipment purchases, significant progress, etc.):

During the reporting quarter, the research team focused their efforts on finalizing the literature review and developing the experimental plan for task 2. The final review consisted of seventeen sources representing over twenty years of research on bridge deck and curb cracking in PCC. The specific focus of each source fell into the three main categories of: concrete placement, concrete mix specifications, and structural aspects of the bridge. Of these categories the mix design was the most popular with the placement of concrete being the next and structural aspects being the least popular. This was due to the difficulty of creating multiple trials which would involve the recreation of the bridge sub structure. The specific mechanisms that cause early age cracking were also described in the literature and were shrinkage (autogenous and drying), rebar corrosion, and the exposure to weather conditions. The shrinkage of the concrete curbs and decks induces tensile stresses that the hydrating cement paste is not strong enough to resist and thus microcracks form. These cracks can also be exacerbated by the corrosion of rebar that expands as excess moisture and chloride infiltrate through the cracks. Weather conditions such as direct sunlight or rain events also induce tensile stress. Differences in heat and humidity between the top and bottom surface cause additional tensile forces to develop which can cause further cracking. The most popular remediation for early age cracking found within the literature was the use of Internally Cured Concrete (ICC). ICC is concrete that includes pre-saturated additives such as Light Weight Fine Aggregate (LWFA) and Super Absorbent Polymers (SAP). As the cement hydrates, the stored water allows for consistent strength to develop in the curb and deck and controls the heat of hydration. ICC also reduces both forms of shrinkage through the reduction of capillary action and uneven drying. Although ICC reduces the cracking potential of a deck it also can reduce the strength of the mix design. Generally, the amount the strength loss is within 10% of its original strength.

The potential of ICC will be further tested by the research team throughout the experimental program of task two. The experimental program will also include testing information gathered regarding both placement and structural considerations. The curing room present in the laboratory will aid in testing the former and some trial curbs sections (6-ft long) that are cast using a mold provided by the NHDOT. Control mixes selected for this study were chosen based on mix designs and acceptance testing information shared by the NHDOT from recent bridge maintenance projects. The differences in the amount of cementitious material, percent Portland cement replacement with slag, and coarse and fine aggregate proportions were used as variables in selecting baseline designs. The two most dissimilar mixes (from Alton 076/277 and Troy 101/088 projects) were then selected to understand how PCC mix variations help lower the early age cracking potential. The experimental program proposes the planned variations be the use of ICC using both additives (LWFA and SAP), and the reduction and replacement of Portland cement with slag. Information gathered in this process will be the fresh properties (air content and workability), mechanical properties (elastic modulus, compressive strength evolution and split-cylinder tensile strength), durability to chloride penetration (surface resistivity) and the shrinkage potential (unrestrained and restrained) of the concrete. A meeting was held during the reporting quarter with NHDOT project TAG on 20th June 2024. At the meeting the research team presented a summary of the literature review as well as the experimental plan for Task 2 of the study. Feedback of TAG was gathered during the meeting and is being incorporated into the experimental plan.

List of literature sources included in the task-1 reivew:

Chen, Huating; Li, Dewang; Zhu, Xiufu; Zhang, Wenxue. Short-term shrinkage stress in deck concrete of rail-cum-road truss bridge. Case Studies in Construction Materials, Volume 19, Issue 0, 2023, e02252

Hamid, W. K., Khoury, I., Mandadapu, M., Al Rikabi, F. T., & Ali, H. (2023). Evaluating the Effect of Incorporating Slag Cement with Pre-wetted Lightweight Aggregate on Reducing Cracking of Concrete Bridge Decks. Advances in Civil Engineering Materials, 12(1), 24-40.

Hamid, W. K., Steinberg, E. P., Khoury, I., Walsh, K. K., Semendary, A., & Ahmed, S. (2022). Determination of Concrete Shrinkage Initiation in Internally Cured and Conventional Concrete Decks. Journal of Testing and Evaluation, 50(3), 1673-1682.

Hamid, W. K., Steinberg, E. P., Semendary, A. A., Khoury, I., & Walsh, K. (2020). Early-age behavior of internally cured concrete bridge deck under environmental loading. Journal of Performance of Constructed Facilities, 34(4), 04020066.

Jeon, Sungil; Hossain, Mohammad Shakhawat; Han, Seungyeon; Choi, Pangil; Yun, Kyong-Ku. (2022) Self-Healing Characteristics of Cement Concrete containing Expansive Agent. Case Studies in Construction Materials, Volume 17, Issue 0, 2022, e01609

Khajehdehi, R.; Darwin, D.; Feng, M. (2021) Dominant Role of Cement Paste Content on Bridge Deck Cracking. Journal of Bridge Engineering, Volume 26, Issue 7, 2021, 04021037

Khajehdehi, R. (2018). Controlling cracks in bridge decks. In KU Scholarworks. University of Kansas. https://kuscholarworks.ku.edu/handle/1808/27765

Lafikes, J., Darwin, D., O'Reilly, M., Feng, M., Bahadori, A., & Khajehdehi, R. (2020). Construction of low-cracking high performance bridge decks incorporating new technology. University of Kansas Center for Research, Inc..

Nelson, T., Pham, L., Krauss, P. D., Wagner, E., Rahmani, E., & Dai, J. (2021). Bridge Deck Cracking Evaluation (No. FHWA-MT-21-005/9696-700). Montana. Department of Transportation.

Pacheco, J., Vaddey, P., Amini, K., & Vosahlik, J. (2021). Internal Curing of Bridge Decks and Concrete Pavement to Reduce Cracking (No. WHRP 0092-19-02). Wisconsin. Dept. of Transportation. Research and Library Unit.

Phares, B. M., Liu, Z., & Alomari, A. (2022). Investigation of the Causes of Transverse Bridge Deck Cracking (No. InTrans Project 14-503). Iowa State University. Bridge Engineering Center.

Ramey, G. E., Wolff, A. R., & Wright, R. L. (1997). Structural design actions to mitigate bridge deck cracking. Practice Periodical on Structural Design and Construction, 2(3), 118-124.

Schindler, A., Byard, B., & Tankasala, A. (2019). Mitigation of early-age cracking in concrete structures. In MATEC Web of Conferences (Vol. 284, p. 07005). EDP Sciences.

Shi, W., Shafei, B., Liu, Z., & Phares, B. M. (2019). Early-age performance of longitudinal bridge joints made with shrinkage-compensating cement concrete. Engineering Structures, 197, 109391

Tanner, J.; Buenfil, S. P. Evaluation of Concrete Bridge Deck Mixtures Using Shrinkage-Ring Tests. NHDOT SPR2 Quarterly Reporting

University of Wyoming, Laramie; University of Wyoming, Laramie; Mountain-Plains Consortium; Office of the Assistant Secretary for Research and Technology, 2022, 34p

Zerin, A. I., Hosoda, A., Komatsu, S., & Ishii, H. (2020). Full scale thermal stress simulation of multiple span steel box girder bridge evaluating early age transverse cracking risk of durable RC deck slab. Journal of Advanced Concrete Technology, 18(7), 420-436.

Zhu, J., Wang, C., Yang, Y., & Wang, Y. (2023). Hygro-thermal–mechanical coupling analysis for early shrinkage of cast insitu concrete slabs of composite beams: theory and experiment. Construction and Building Materials, 372, 130774.

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Items needed from NHDOT (i.e., Concurrence, Sub-contract, Assignments, Samples, Testing, etc...):

Following information has been requested from the project TAG:

- List of potential bridge maintenance construction projects for Winter for 2024 as well as Spring 2025.

Anticipated research next three (3) months:

During the first part of the upcoming quarter, the research team will finalize the experimental program and begin collecting material to produce samples. Further, ring shrinkage test hardware will be acquired to begin testing the effect of restrained shrinkage. The research team is also expecting various data and information from NHDOT, this will be documented in the Task-1 deliverable, and it will aid in finalizing experimental plan for Task-2.

Circumstances affecting project:

There is a delay in the Task 1 of the project and a minor delay in Task 2. Most of the delay is associated with the delay in recruitment of the graduate student for this study. While tasks 1 and 2 are delayed, we do not expect an overall delay in project end date or timeline for other tasks.

Tasks (from Work Plan)	Planned % Complete	Actual % Complete
Task 1 Literature and Current Practice Review	100	90
Task 2 Mix Design and Lab Evaluation	15	0
Task 3 Survey of Study Sites for Cracking Performance	0	0
Task 4 Analysis of Results and Recommendation Development	0	0
Task-5 Final Report and Poster	0	0

Barriers or constraints to implementing research results

Nothing to report.