

NHDOT SPR2 PROGRAM RESEARCH PROGRESS REPORT

Project # 42372L	Report Period Year 2024 <input checked="" type="checkbox"/> Q1 (Jan-Mar) <input type="checkbox"/> Q2 (Apr-Jun) <input type="checkbox"/> Q3 (Jul-Sep) <input type="checkbox"/> Q4 (Oct-Dec)	
Project Title: Reduce Concrete Cracking through Mix Design		
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Project Start Date: 4/12/2023	Project End Date: 12/31/2025	Project schedule status: <input type="checkbox"/> On schedule <input type="checkbox"/> Ahead of schedule <input checked="" type="checkbox"/> 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 gathering, reviewing and summarizing the literature relevant to the study. Primary focus of the most recent review has been on use of internally cured concrete (ICC) as a means to lower the early age cracking potential in concrete. A summary of the findings from the literature review on ICC is presented here.

Several sources discussed internally cured concrete (ICC), which incorporates pre-wetted fine or coarse aggregate into the mix design. The moisture held within these aggregates acts to serve as a source for hydration as the concrete is curing. This accomplishes two objectives, first it provides that much needed water for cementitious materials in concrete to hydrate and second, it reduced the early age shrinkage of concrete which is typically caused due to water loss. The use of ICC approach ensures that "surplus" moisture that is available for continued hydration of cementitious materials in concrete is evenly distributed, this is unlike common curing approaches for bridge deck slabs and curbs where only surface is periodically wetted to promote curing. A paper by Hamid et al. (2022) found that adding the pre-wetted lightweight aggregate (LWA) reduced autogenous and drying shrinkage. Additionally, they found that the LWA did not adversely affect the tensile or compressive resistance of the concrete. A second paper by Hamid et al. (2023) focused on internally curing concrete with LWA, super absorbent polymers (SAP) and additional fibers. The goal of this study was to evaluate and reduce the volumetric change of the mix as it cured. The ICC sample responded well with a w/cm ratio of 0.36 with reducing returns as the ratio increased and had the largest impact on autogenous shrinkage. These approaches of using either LWA (by themselves or together with SAP) should be further explored. Both additional review of literature as well as inclusion of this approach in the experimental plan for this study is being considered.

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A second method regarding the reduction of early life cracking was the addition of different expansive agents (EA) or shrinkage reducing admixtures (SRAs). In the first case Jeon et al. (2022) added ultra fine fly ash (UFFA), finely ground granulated blast furnace slag (FGGBS) and silica fume (SF) to three different types of concrete. The types of cement were ordinary Portland cement concrete (OPC), latex-modified concrete (LMC), and silica fume concrete (SFC). This study found that when the concrete had an EA concentration over or equal to 8%, it exhibited faster self-healing performance. The mixture's ability to seal these cracks went down over time as significant differences were noted between cracks induced at 3 and 7 days after placement. Additionally, tests were performed in lab rather than in situ which allowed researchers to control moisture content closely. In the second paper by Tanner and Buenfil (2022) granitic aggregate was mixed with SRAs and polypropylene fibers to test for early age cracking in dual and single ring tests. The SRAs were incorporated by replacing the cementitious material 2% by weight with the additives. When used with the fibers, this increased the time to crack by five times while maintaining the same mechanical properties. The results for the implementation of just one of the two remediation methods were also significant. When using solely the SRA, however, the compressive strength did reduce by an average of 17%. These studies warrant further exploration, both in an expanded literature review as well as in laboratory experimentation of this study.

List of References Gathered on Internal Curing of Concrete:

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

Deck Reinforcement Detailing and Concrete Mix Additives to Reduce Bridge Deck Cracking. [Ongoing Project]. Minnesota Department of Transportation, Local Road Research Board. Start date: 31 Jul. 2023

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.

Jeon, S., Hossain, M. S., Han, S., Choi, P., & Yun, K.-K (2022). Self-Healing Characteristics of Cement Concrete containing Expansive Agent. *Case Studies in Construction Materials*, Volume 17, Issue 0, 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, 04021037

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.

Tanner, J. E. & Buenfil, S. P. (2022). and Mountain-Plains Consortium. Evaluation of Concrete Bridge Deck Mixtures Using Shrinkage-Ring Tests [Summary]. No. MPC 22-483 (project 652). Mountain-Plains Consortium, University of Wyoming.

TRC2203 - Low-Shrinkage Concrete Mixtures for Arkansas. [Ongoing Project]. Federal Highway Administration, Arkansas Department of Transportation. Start date: 28 Mar. 2022.

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.

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

During project kick-off meeting, the research team has requested following information from the project TAG:

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- List of potential bridge maintenance construction projects for Summer, Fall and Winter for 2024 as well as Spring 2025.
- List of bridge curb and deck replacement projects undertaken by bureau of bridge maintenance from last three years.
- Laboratory testing data (QC as well as mix design approval data) for NHDOT class A and AA concrete used on recent bridge maintenance curb and decks.
- Mix batching slips from bridge curb and deck replacement projects from last three years (when available).

The above information is essential; for research team to initiate the Task 2 activities of developing an experimental plan.

Anticipated research next three (3) months:

During the first part of the upcoming quarter, the research team will synthesize the review of literature into a brief report. Further, a presentation will also be prepared to summarize the key findings from the literature review. The literature review will aid in development of a laboratory testing plan for use in Task-2 of the study. 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. The majority of it is associated with delay in arrival of the graduate student that was recruited to work on this effort. The graduate student was unable to arrive until the time of writing of this report. The project PI has now recruiting a different student (already present at UNH) for working on this research study. The new student has initiated the literature review and is making progress on the Task 1 deliverable. Further there is also delay due to receipt of information and data from NHDOT.

Tasks (from Work Plan)	Planned % Complete	Actual % Complete
Task 1 Literature and Current Practice Review	100	80
Task 2 Mix Design and Lab Evaluation	35	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.