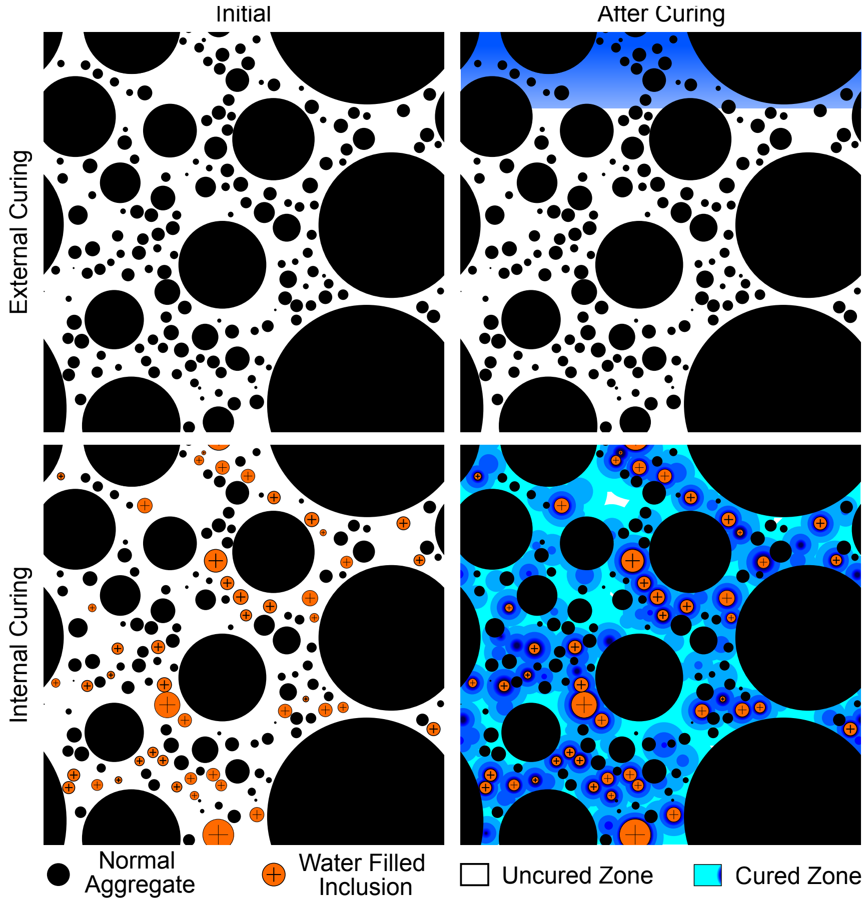
Enhancing Concrete Bridge Deck Performance with Internal Curing

by Dr. Timothy J. Barrett, Federal Highway Administration

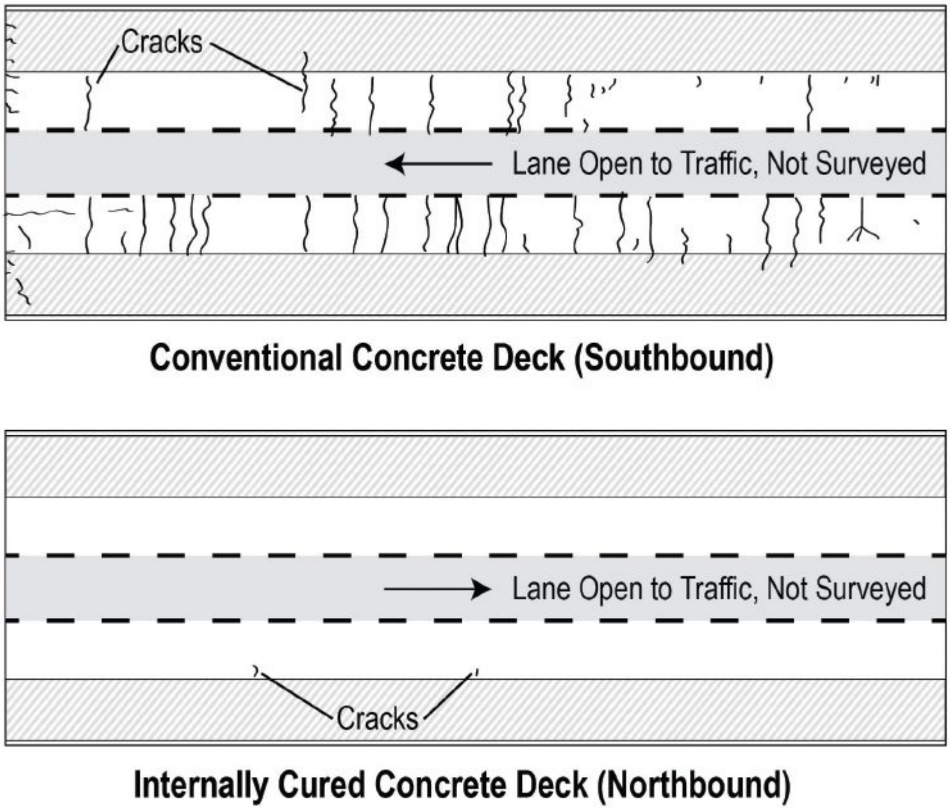
Bridge decks are frequently a limiting factor in achieving long service lives for bridges. Therefore, owners have continually innovated to find solutions to improve the performance of decks, keep them in service longer, and reduce their maintenance and preservation needs. In a recently completed U.S. Domestic Scan, *Scan 22-01: Recent Leading Innovations in Design, Construction, and Materials Used for Concrete Bridge Decks*,[1] panel members from participating state departments of transportation identified and ranked 27 innovations being leveraged to enhance the performance and extend the service of concrete bridge decks. Among these innovations is a promising technology called internal curing.

Internal curing is a concrete material–level technology that addresses the inherent shrinkage due to cement hydration (autogenous shrinkage), which is particularly challenging in concrete with a low water–cementitious material ratio (*w/cm*). While internal curing has been extensively studied in the laboratory, deployment in the field has been intermittent and the technology is more commonly known to concrete materials engineers than within the structural bridge engineering community.[2] In recognition of the technology's potential and the need for targeted deployment to accelerate its adoption, internal curing was included in the Federal Highway Administration's (FHWA's) Every Day Counts (EDC) program, under the Enhancing Performance with Internally Cured Concrete (EPIC[2]) initiative.[3] EDC, now in its seventh round, is a state-based model that identifies and deploys proven yet underused innovations.

All cement and supplementary cementitious materials that use hydration to gain strength inherently demand curing water. If the curing water is not supplied or readily available at the time it is needed, particularly during early ages when strength is rapidly developing, pores in the concrete begin to empty and concrete shrinkage results. This self-generated shrinkage due to internal water loss acts in the same manner as drying shrinkage due to external water loss. Internal curing effectively addresses this issue. The key difference between conventional methods of curing and internal curing in low *w/cm* concrete is that external curing results in well-cured concrete near the surface but self-drying elsewhere, whereas internal curing uniformly cures the concrete throughout its entire volume. Internal curing is achieved by hiding the required curing water in a suitable vessel within the concrete at the time of production. In practice, a portion of the normalweight fine aggregates is typically replaced with prewetted lightweight fine aggregates to take advantage of



Schematic comparison of conventional curing methods that result in well-cured concrete on the surface (top) versus an internal curing method (bottom) where the prewetted lightweight aggregates enable cured zones throughout the entire concrete volume. Figure: Federal Highway Administration.



The results of a crack survey of a bridge deck (plan view) after one year in service illustrates the enhanced performance from internal curing compared with conventionally cured concrete. Figure: Federal Highway Administration, created using data from the Ohio Department of Transportation.[8]

the high-absorption capacity of the latter type of aggregates. Alternative methods of supplying internal curing water continue to emerge in the market and include the use of superabsorbent polymers, cellulose and other polysaccharides, and some natural pozzolans such as rice husk ash. Use of internal curing technology is a design-time decision that mitigates a substantial source of concrete shrinkage, reducing the potential for cracking and providing a path to longer service life for bridge infrastructure elements, particularly bridge decks.

When the New York State Department of Transportation (NYSDOT) piloted internal curing technology in 17 multispan bridge decks from 2008 to 2013, the agency found that cracking in the internally cured high-performance class of concrete was reduced by two-thirds compared with the standard high-performance class of concrete.[4] Service-life estimations on two of the pilot installations gave the estimated time to corrosion initiation as 71.5 years on average.[5] NYSDOT has since fully institutionalized internal curing, which the agency now requires for all multispan bridge decks. (See the Summer 2019 issue of *ASPIRE®* for details of the NYSDOT internal curing requirement.) The impact of the enhanced performance is now being realized in service, with 60% of bridge decks installed in New York State in the past decade having a condition rating of 9 (excellent), the highest condition rating available.[6] A more recent example of internal curing in Ohio[7] was featured in the August 31, 2023, issue of the FHWA's biweekly newsletter, *EDC News*.[8]

With current industry guidance, the material cost increase for internal curing is anticipated to be on the order of 20%, which typically increases total project costs by less than 5%. In return, the enhanced performance from internal curing employed in higher-performance classes of concrete has been estimated to result in reducing life-cycle costs by 29% to 70%.[7,9,10]

The EPIC[2] initiative is making resources available for engineers and owners to design, specify, and construct with internally cured concrete and recommends the primary application of the technology in bridge decks.[3] Forthcoming resources include a case study summary report of selected pilot installations, a reference document for construction specification and design guidance, and an updated tool for internally cured concrete mixture design.

References

1. Scan 22-01 Team. 2023. *Recent Leading Innovations in the Design, Construction, and Materials Used for Concrete Bridge Decks*. NCHRP Project 20-68, Scan 22-01. https://onlinepubs.trb.org/onlinepubs/nchrp/docs/SCAN22-01.pdf.
2. National Institute of Standards and Technology. 2019. "Internal Curing of Concrete Bibliography." https://www.nist.gov/el/concrete-bibliographic-databases/internal-curing-concrete.
3. Federal Highway Administration (FHWA) Center for Accelerating Innovation. 2023. "Enhancing Performance with Internally Cured Concrete (EPIC[2])." https://www.fhwa.dot.gov/innovation/everydaycounts/edc_7/enhancing_epic.cfm.
4. Carpenter, D. 2015. "Report on Internal Curing Concrete Experimental Specification." https://www.academia.edu/36428448/Report_on_Internal_Curing_Concrete_Experimental_Specification.
5. Weiss, J., Y. Bu, C. Di Bella, and C. Villani. 2014. "Estimated Performance of As-Built Internally Cured Concrete Bridge Decks." In *RILEM International Workshop on Performance-Based Specification and Control of Concrete Durability*, edited by D. Bjegović, H. Beushausen, M. Serdar. Champs-sur-Marne, France: RILEM. https://www.rilem.net/publication/publication/433?id_papier=9737.
6. FHWA. n.d. "LTBP InfoBridge." Accessed April 22, 2024. https://infobridge.fhwa.dot.gov.
7. Wang, X., P. Taylor, K. Freeseman, and P. Vosoughi. 2019. *Extended Life Concrete Bridge Decks Utilizing Improved Internal Curing to Reduce Cracking*. FHWA/OH-2019/7. Washington, DC: FHWA. https://rosap.ntl.bts.gov/view/dot/62339.
8. FHWA. 2021. "Innovation of the Month: Enhancing Performance with Internally Cured Concrete (EPIC[2])." *EDC News*. https://www.fhwa.dot.gov/innovation/everydaycounts/edcnews/20230831.cfm.
9. Cusson, D., and T. Hoogeveen. 2008. "Internal Curing of High-Performance Concrete with Pre-soaked Fine Lightweight Aggregate for Prevention of Autogenous Shrinkage Cracking." *Cement and Concrete Research*. 38 (6): 757–765. https://doi.org/10.1016/j.cemconres.2008.02.001.
10. Guo, Y., S. Peeta, H. Zheng, T. Barrett, A.E. Miller, and W.J. Weiss. 2014. *Internal Curing as a New Tool for Infrastructural Renewal: Reducing Repair Congestion, Increasing Service Life, and Improving Sustainability*. West Lafayette, IN: NEXTRANS Center, Purdue University. https://rosap.ntl.bts.gov/view/dot/28126.