Accelerating Concrete Overlay Construction: A Case Study

IOWA STATE UNIVERSITY
Institute for Transportation

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National Concrete Pavement Technology Center
CP Tech Center

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16. Abstract A growing number of agencies across the United States have demonstrated interest in adopting or expanding their use of concrete overlays for pavement rehabilitation. However, some agencies face perceived obstacles or challenges to constructing concrete overlays, such as complex project staging and maintenance of traffic requirements and the potential for lengthy and disruptive roadway closures. This tech brief highlights an innovative project undertaken in the summer of 2022 to demonstrate ways to accelerate concrete overlay construction while minimizing impacts to local traffic and ensuring a safe environment for both construction crews and the traveling public. The project team paved 8.6 mi of a 6 in. thick, 36 ft wide concrete overlay and fully re-opened the roadway to traffic just 25 calendar days after the first closure. Several innovative practices were employed to shorten the duration of traffic impacts, provide a safe work zone, and complete the project on a rapid timeline. This case study offers valuable insights for agencies of all sizes around the country on effective staging, maintenance of traffic strategies, and accelerated construction for concrete overlay projects.			
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Introduction

Concrete overlays are an increasingly prominent pavement rehabilitation solution for streets and highways across the United States. A growing number of agencies have demonstrated interest in adopting or expanding their use of concrete overlays. Despite the benefits of this solution, some agencies face perceived obstacles or challenges to constructing concrete overlays, such as complex project staging and maintenance of traffic requirements and the potential for lengthy and disruptive roadway closures.

This tech brief highlights an innovative project undertaken by the Iowa Department of Transportation (DOT) and Croell, Inc. in the summer of 2022 to demonstrate ways to accelerate concrete overlay construction while minimizing impacts to local traffic and ensuring a safe environment for both construction crews and the traveling public. The project team completed a 6 in. thick, 36 ft wide concrete overlay on an 8.6 mi long section of Iowa Highway 3 in Plymouth County (Figure 1) and fully re-opened the roadway to traffic just 25 calendar days after the first closure.

The Iowa DOT and contractor employed several innovative practices to shorten the duration of traffic impacts, provide a safe work zone, and complete the project on a rapid timeline. This case study offers valuable insights for agencies of all sizes around the country on effective staging, maintenance of traffic strategies, and accelerated construction for concrete overlay projects.

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Figure 1. Concrete overlay on Iowa Highway 3 under construction

Background

The development of concrete overlays as a pavement rehabilitation treatment is one of the most significant developments in concrete pavement technology in recent decades. A concrete overlay involves extending the life of an existing concrete- or asphalt-surfaced pavement with a new concrete surface. The versatility and adaptability of concrete overlays offer a variety of benefits to agencies in maintaining their pavement networks, as overlays may be designed for a wide variety of existing pavement conditions, traffic loads, and service life expectations (Fick et al. 2021).

A number of state and local agencies began constructing concrete overlays in the years leading up to the 2000s. Building on early experimentation and successes, construction expanded rapidly across the United States beginning in the 2000s (Cackler et al. 2021). Today, there are more than 1,800 concrete overlays on US roadways in 46 states (Gross 2023), as shown in Figure 2, and they have been an important part of initiatives such as the Federal Highway Administration's (FHWA's) Targeted Overlay Pavement Solutions (TOPS) program as part of Round 6 of Every Day Counts (EDC-6) (FHWA 2023).

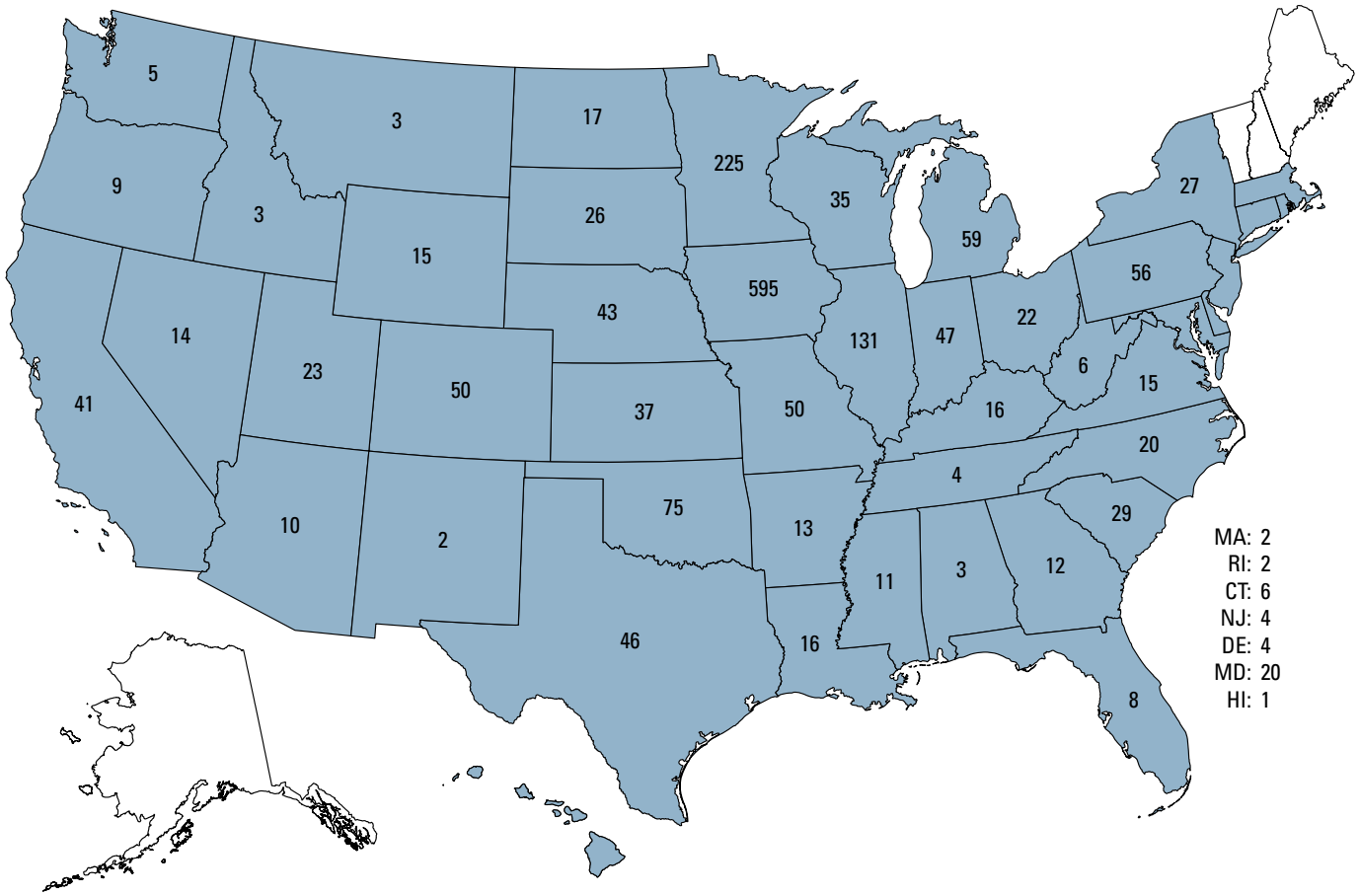

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Figure 2. Concrete overlays constructed in the United States through 2022

Concrete Overlay Construction

The construction process for a concrete overlay is generally faster than that of a conventional full-depth concrete pavement (Fick et al. 2021). Since overlays are built directly over an existing pavement surface, no time is needed for demolition, preparation of the new grade, and/or construction of new subbase layers. The existing pavement surface also provides a stable platform that is less prone to disruption by weather and moisture conditions that might otherwise slow construction.

The construction of concrete overlays uses conventional materials, mixtures, and equipment, and in many ways the paving process is streamlined compared to the process used for full-depth construction. Dump trucks or ready mix trucks can back up directly in front of the paving machine to deliver concrete, as seen in Figure 1, so haul roads are not required to deliver the concrete, and a placer/spreader is not needed as part of the paving train. Additionally, since the thickness of a concrete overlay design is usually thinner than that of a full-depth pavement, paving productivity can be greater in terms of length or area paved per day, provided a similar staging pattern is used.

A few aspects of concrete overlay construction may require more effort and attention than are needed for full-depth construction. For example, overlay designs with a short joint spacing (e.g., 6 ft by 6 ft) have an increased joint length and therefore require additional joint sawing. Thinner overlays (e.g., 6 in. or less) with a greater surface area-to-volume ratio may require more timely application or a higher application rate of curing compound. That said, these items can be managed easily with proper planning without affecting the construction schedule.

Maintenance of Traffic During Construction

Overall, concrete overlays offer many characteristics that provide contractors the ability to complete overlay projects faster and more efficiently than full-depth reconstruction projects, and even faster than comparable asphalt overlay projects. However, some agencies have less experience staging concrete overlay projects than they do these other types of projects, and they sometimes cite maintenance of traffic requirements as an obstacle to planning a concrete overlay project.

Concrete overlays can either be constructed using a full closure, as shown in Figure 3a, or paved while the roadway remains open to traffic, as shown in Figure 3b (Cable 2012). Under a full closure, the roadway is closed to through traffic and can be paved several lanes wide at a time, including shoulders. The main advantages of this process are that it creates a safer work environment and that it usually shortens the duration of the project. Traffic is kept away from construction crews, construction equipment and trucks delivering concrete have easier access to the site, and the overlay cross section can be constructed in fewer passes or even in a single pass.

GCC, used with permission (top) and CP Tech Center (bottom)

Figure 3. Construction of concrete overlays (a) with a full closure and (b) under traffic

The primary disadvantage of a full closure is that, unless the roadway is a divided highway or boulevard, a detour is required for through traffic. A full closure may also be more disruptive to local businesses and residents than a project built under traffic. These disadvantages can be managed in a number of ways, such as by staging construction to divide closures into smaller portions or by providing temporary access for local traffic and businesses. However, all portions of the roadway must be fully closed to through traffic at some point during construction to accommodate the paving train and the time needed for the concrete to reach opening strength.

When a concrete overlay is paved under traffic, one or more lanes are paved at a time while the adjacent lane(s) remain open to through traffic. When only one adjacent lane is available for travel in both directions, pilot cars can direct alternating one-way traffic. The main advantage of this process is that through traffic is able to proceed through the construction zone without a detour. Additionally, since concrete overlays are constructed in a single lift, the overall project duration may be shorter than that of a comparable asphalt overlay project, where each lane may require multiple lifts.

The main disadvantages of building a concrete overlay under traffic are increased safety risks and a longer project duration. Public vehicles mix with construction traffic and drive alongside the paving train, increasing risks to both construction crews and the traveling public. A thicker concrete overlay may also be more likely than a comparable asphalt overlay to exceed edge drop-off requirements. Finally, given the need to divide the paving work into multiple lanes, building an overlay under traffic generally increases the overall project duration compared to the use of a full closure and detour.

Project Motivation

Agencies have successfully deployed many variations of the maintenance of traffic methods described above to build concrete overlays. That said, the disadvantages or tradeoffs associated with these methods can present significant challenges during project planning. Agencies and contractors have a great interest in developing new strategies to improve the safety of concrete overlay construction while reducing the degree and duration of impacts to local residents, businesses, and the traveling public.

In the summer of 2022, the Iowa DOT and contractor Croell, Inc. collaborated to implement a number of changes to the typical staging and construction practices on a concrete overlay built on Iowa Highway 3 in Plymouth County. The goal of these changes was twofold:

1. Maximize the benefits to safety and efficiency that come with paving under a full closure with an end-to-end project detour
2. Minimize the impacts to the public by keeping as much of the roadway as possible fully accessible to traffic and targeting a project completion date of 24 calendar days

Iowa Highway 3 Project Details

The overlay on Iowa Highway 3 was constructed on an 8.6 mi section of two-lane roadway between the cities of Le Mars and Remsen in Plymouth County. Figure 4 shows the project location, with the portion of the roadway that received the overlay highlighted in green and the end-to-end detour that was established for the project highlighted in red.

The existing roadway consisted of a full-depth asphalt pavement that was originally constructed in 1995 and received a 2 in. asphalt overlay in 2009. Figure 5 shows the existing pavement conditions as of 2021 prior to the concrete overlay. The overlay was designed as a concrete on asphalt–unbonded (COA–U) overlay with 6 in. thickness and 6 ft by 6 ft joint spacing. The asphalt surface was profile milled prior to placement of the overlay. The cross section also included 9 in. thick, 6 ft wide integral shoulders added to both sides of the overlay, as well as new granular shoulders. Figure 6 shows the cross section.

Table 1 lists the full project details, including the existing pavement conditions and concrete overlay design parameters. The anticipated design life of 40 years was backcalculated using the COA–U module in PavementDesigner.org (Ferrebee et al. 2018).

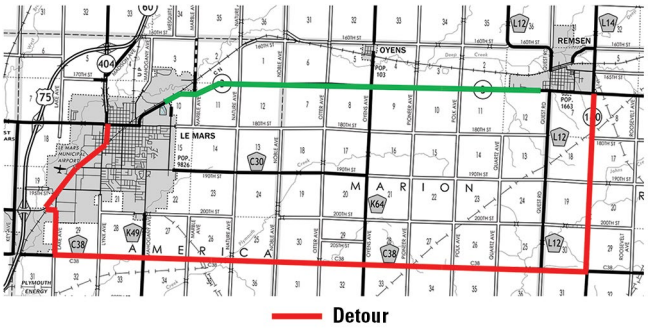

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Figure 4. Project location along Iowa Highway 3

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Figure 5. Existing pavement conditions in 2021

Table 1. Iowa Highway 3 project details

General Project Details	
Project length	8.6 mi
Annual average daily traffic (2022)	3,940 vpd
Truck traffic	9%
Existing Asphalt Pavement	
Year of original construction	1995
Original asphalt pavement thickness	11 in.
Year of asphalt overlay	2009
Asphalt overlay thickness	2 in.
Pavement condition index (2021)	55/100
International roughness index (2021)	99 in./mi
Concrete Overlay	
Year of construction	2022
Overlay type	COA–U
Overlay thickness	6 in.
Joint spacing	6 ft x 6 ft
Width of integral shoulders	6 ft
Total overlay cross section width	36 ft
Tie bars	#4 bars at 30 in. centers at centerline and shoulders
Dowel bars	N/A
Anticipated design life	40 years

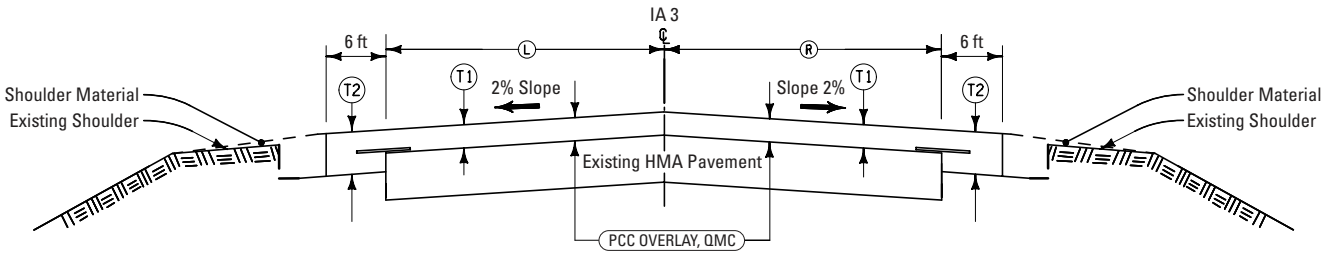

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Figure 6. Concrete overlay cross section

Concrete Materials and Mixture Design

Table 2 provides the design concrete mixture proportions for the project. The contractor designed the mixture according to standard Iowa DOT quality management concrete (QM-C) specifications. No accelerated or high early strength concrete materials or mixtures were needed to meet the accelerated construction requirements. The aggregate proportions included an optimized blend of limestone coarse aggregate, intermediate gravel, and natural sand. Class C fly ash was substituted for cement at a rate of 20% by weight.

Before the project started, the contractor expected to use Type IL portland-limestone cement. However, the cement supplier needed to make a change just before construction and supplied a Type I/II portland cement from a different source. After the project began and the contractor gained experience with the new source of cement, the contractor opted to change the mix on July 14 by adjusting the admixture dosage rates and using a hydration stabilizer in place of a traditional retarding admixture. These changes ultimately improved workability and increased strength gain, which is discussed further in later sections.

Table 2. Concrete mixture proportions

Constituents	Batch Quantities (lb/yd^3)
Cement	448
Fly ash	112
Water	224
Target w/cm	0.40
Coarse aggregate	1,413
Intermediate aggregate	378
Fine aggregate	1,339

Figure 7 shows the design combined aggregate gradations for the mixtures. QMC3 refers to the first mix, and QMC5 refers to the second mix. While the design mixture proportions were the same for both mixtures, the differences in the combined gradations between the two mixtures reflect variations in the gradations of the individual aggregate sources over the course of the project. The dotted lines in Figure 7 indicate the tarantula curve (Cook et al. 2015).

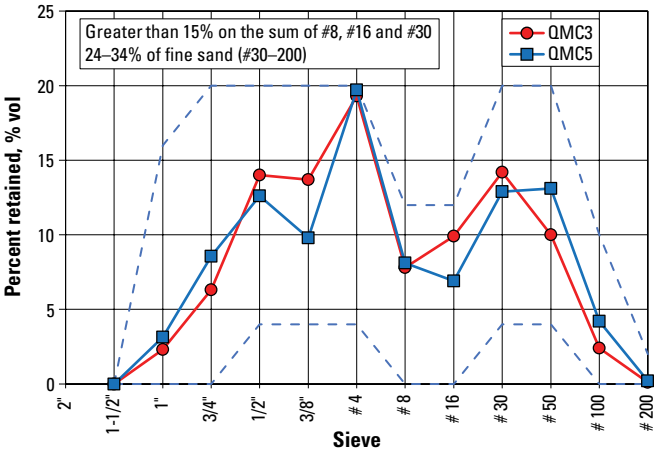

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Figure 7. Combined aggregate gradations

Typical Project Timelines

Most concrete overlay projects on two-lane roadways in Iowa are constructed with a full closure and an end-to-end detour for the duration of the project, with some access provided to local traffic where possible. The usual contract period for a project of comparable length is 40 to 60 working days and 60 to 90 calendar days, with liquidated damages for days over the project deadline.

Most asphalt overlay projects on two-lane roadways in Iowa are paved under traffic with single-lane closures and a pilot car. Depending on the number of lifts in the overlay and whether the project includes cold in-place recycling, the usual contract period for a project of comparable length is 24 to 60 working days and 36 to 90 calendar days. This staging method is also available for concrete overlay construction, but the Iowa DOT and most local agencies in Iowa usually opt to use a full closure.

Accelerated Project Timeline and Moving Closure Concept

For the Iowa Highway 3 project, the Iowa DOT provided the contractor 24 calendar days from the first roadway closure to complete all project activities and re-open the roadway to traffic. The contract included significant incentives and disincentives for completion before or after the contract period. In addition, while the project included an end-to-end detour for through traffic between Le Mars and Remsen, only 3 mi of the roadway could be fully closed to traffic at a time.

To meet these project timeline and maintenance of traffic requirements, Croell, Inc. devised a moving closure concept, which is illustrated in Figure 8. At any given point in time, about ½ mi of roadway was closed to prepare the shoulders and existing surface for paving; about 1 mi was closed for paving, finishing, and sawing operations; and about 1½ mi was closed to allow the concrete to reach opening strength and to complete joint sealing, shouldering, and cleanup.

While through traffic was routed along the end-to-end detour for the duration of the project, Croell, Inc. maintained full access to traffic ahead of and behind the 3 mi closure. As construction progressed, the contractor moved the signage and barriers that indicated the fully closed portion of the roadway and closed and re-opened intersections as needed.

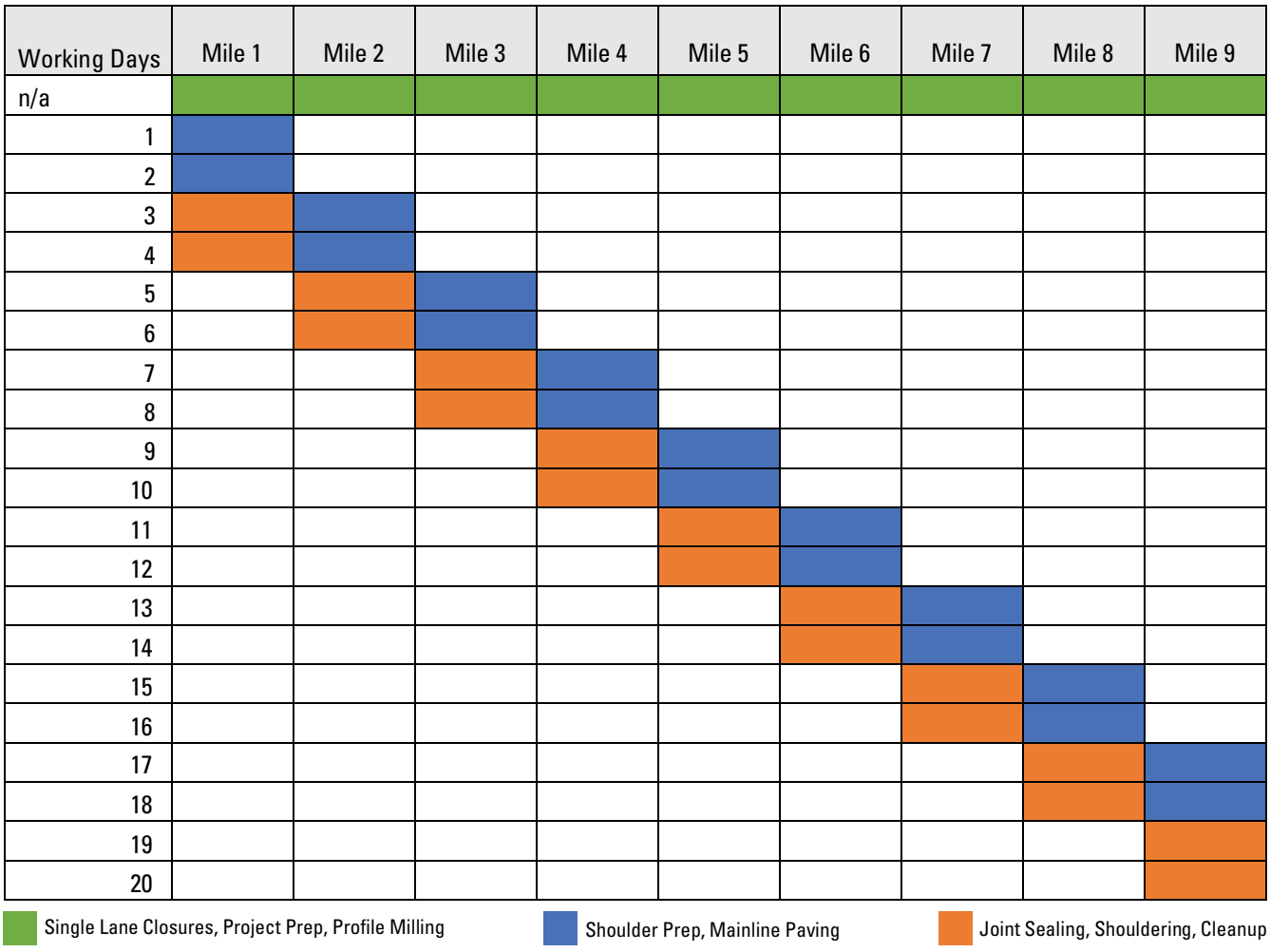

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Figure 8. Illustration of moving closure concept

Project Schedule and Progression

Just one project activity, profile milling of the existing asphalt surface, was performed outside of the 24-calendar day contract period. Milling was completed under a single-lane closure during the week of June 27. Milling prior to the official contract period and roadway closure proved helpful to complete the process as quickly as possible while keeping the roadway fully open to through traffic up to the start of the paving process.

The roadway was first closed to through traffic on the first day of mainline paving, July 7. Paving began from west to east, with the central batch plant located at approximately the midpoint of the project. After reaching the batch plant, the paving train was moved to the east end of the project, with paving continuing from east to west. Staging the plant at the midpoint and paving toward the center shortened haul times and allowed trucks to travel between the paving machine and the batch plant directly on Iowa Highway 3. Figure 9 illustrates the progression of the paving process.

Mainline paving operations occurred over 14 working days within a period of 20 calendar days between July 7 and July 26. The average paving distance during the 14 days of mainline paving was 0.54 mi per day, with a daily maximum of 0.80 mi achieved on July 19. Figure 10 plots the daily mainline paving distances. Ultimately, Iowa Highway 3 was fully re-opened to through traffic on August 1, 25 calendar days after the first closure was established and 1 day after the target of 24 days.

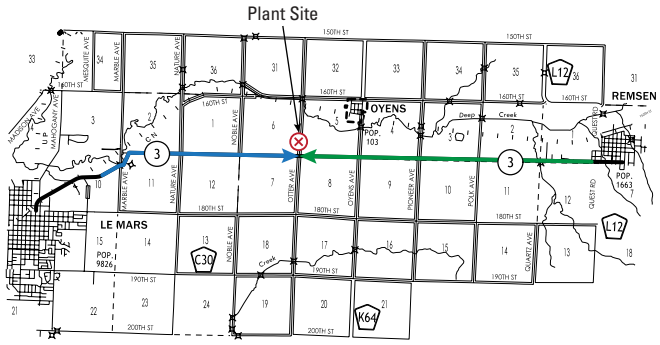

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Figure 9. Paving progression and batch plant location

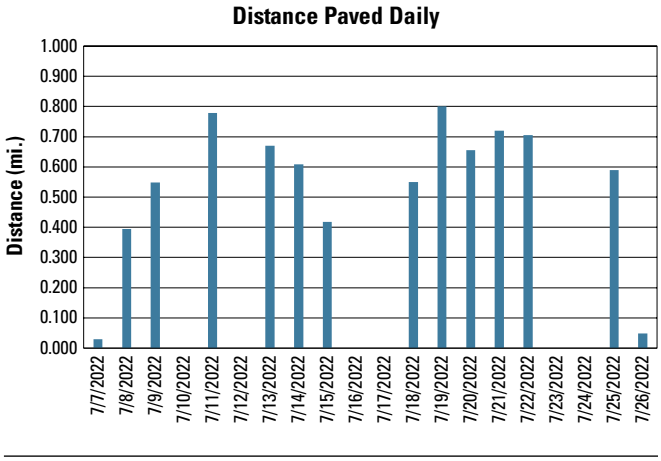

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Figure 10. Daily mainline paving distances

Maturity Method and Reduced Opening Strength Requirement

Two of the most important factors that facilitated the successful completion of the Iowa Highway 3 overlay on such an accelerated timeline were a reduction in the required opening strength and the use of the maturity method (Iowa DOT IM 383) to determine when the required strength had been reached.

To determine opening strength, concrete pavement construction specifications traditionally require either a set period of time (e.g., 7 or 14 days) after paving, strength testing of cylinders or beams that were cast during construction, or both. In contrast to these traditional approaches, the maturity method allows the opening strength to be determined in place and in real time, allowing for accelerated opening to traffic.

The maturity method for determining concrete opening strength has been widely used on concrete paving projects in Iowa since the 1990s (Ouyang 1996). First, a trial batch is prepared to establish a maturity curve correlating the product of concrete temperature and time (time-temperature factor [TTF]) with flexural strength. Then, during construction, thermocouples are embedded in the concrete slab to monitor the TTF in place. Once the pavement reaches the TTF corresponding to the specified concrete opening strength, it may be opened to traffic. Figure 11 displays the maturity curve produced for the post-July 14 mix using the Iowa DOT's standard worksheet.

MATURITY - STRENGTH DEVELOPMENT MOR-CPL

5/12/2022
v 4.2

COUNTY: 75-Plymouth
CURVE #: 2
PROJ. #: NHSN-003-1(106)--2R-75
MONITOR: JON HANSEN
REP/CONTRACTOR:
CONCRETE SUPPLIER: CROELL
PLANT LOCATION: LEMARS
BEAM SIZE: 6
INSPECTOR: JEFF MARIENAU
DATE: 7/14/2022
Expiration Date : 10/12/2022

BEAM #	LOAD AT BREAK (lbs)	TABLE VALUE (lbs)	BREAK LOCATION (in)	WIDTH (in)	DEPTH (in)	FLEXURAL COEFFICIENT	FLEXURAL STRENGTH CPL (psi)	AGE AT BREAK (hours)	TTF CH 1	TTF CH 2	AVERAGE TTF	BEAM TEMP (AVG)	Beam Size 20
	Enter	Enter		Enter	Enter			Enter	Enter	Enter		Enter	
1	1500	1660		6.25	6.00	0.120000	199	12	460	459	460	23	
2	1800	1960		6.00	6.00	0.125000	245	12	460	459	460	23	
3	1700	1860		6.13	6.00	0.122449	228	12	460	459	460	23	
4	2100	2260		6.00	6.00	0.125000	283	14	538	539	539	26	
5	2000	2160		6.25	6.00	0.120000	259	14	538	539	539	26	
6	2100	2260		6.25	6.00	0.120000	271	14	538	539	539	26	
7	3000	3150		6.25	6.00	0.120000	378	16	616	617	617	29	
8	3100	3250		6.00	6.00	0.125000	406	16	616	617	617	29	
9	2900	3050		6.25	6.00	0.120000	366	16	616	617	617	29	
10	3200	3350		6.25	6.00	0.120000	402	18	696	695	696	33	
11	3300	3440		5.88	6.00	0.127660	439	18	696	695	696	33	
12	3100	3250		5.88	6.25	0.117551	382	18	696	695	696	33	

MIX INFORMATION	Enter	
AIR:	9	
w/c:	0.416	
Max on grade W/C ratio:	0.42	DO NOT EXCEED w/c ratio MAX.
Select FlyAsh Type / MIX:	QMC C20	%
C / FLYASH SOURCE CODE:	FA011C-Nebraska City Station	20
GGBFS SOURCE CODE:		
CEMENT SOURCE CODE:	PC2902-GCC - Pueblo-I/II	
COARSE AGGREGATE A#:	A84510-HAWARDEN-NORTH	
INTERM. AGGREGATE A#:	A84510-HAWARDEN-NORTH	
FINE AGGREGATE A#:	A75502-AKRON	
WATER REDUCER BRAND:	OptiFlo 700-Premiere Admix	
Add. Rate:	2-14 OZ/100WT	
AIR ADMIXTURE BRAND:	ConAir 260-Premiere Admix.	
Add. Rate:	VARIES	
METHOD OF DEVELOPMENT:	BEAMS	
Desired Flexural Strength (MOR-CPL):	325	psi
CarbonCure:	0	%
REQUIRED TTF:	575	

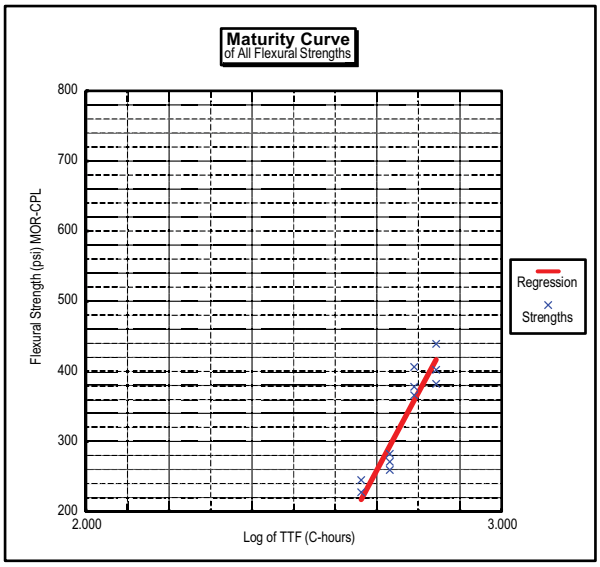

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Figure 11. Project maturity curve spreadsheet

The maturity method frequently accelerates the time to opening to traffic, especially in the summer months when warmer temperatures increase early-age in-place strength gain. That said, opening strength requirements themselves are often more conservative than they need to be, and studies have shown that concrete pavements can be opened to traffic at much lower strengths than typically required without negative impacts to long-term performance (Khazanovich et al. 2021, Delatte et al. 2023).

Recognizing that reducing the opening strength requirement could accelerate construction of the Iowa Highway 3 project without adverse long-term performance implications, the Iowa DOT lowered the required flexural strength from 500 to 325 psi. Implementation of the reduced opening strength requirement allowed the roadway to be re-opened to local traffic and construction vehicles much sooner than traditionally allowed after paving.

Figure 12 shows the time to opening the pavement to traffic as determined using the maturity method at 15 separate locations along the project. One notable trend during the project was that the time to opening decreased substantially after the contractor changed the mix on July 14. Before the change, the time to reach the opening flexural strength of 325 psi ranged from 24 to 30 hours after paving; after the change, the time to opening decreased significantly to 12 to 16 hours after paving.

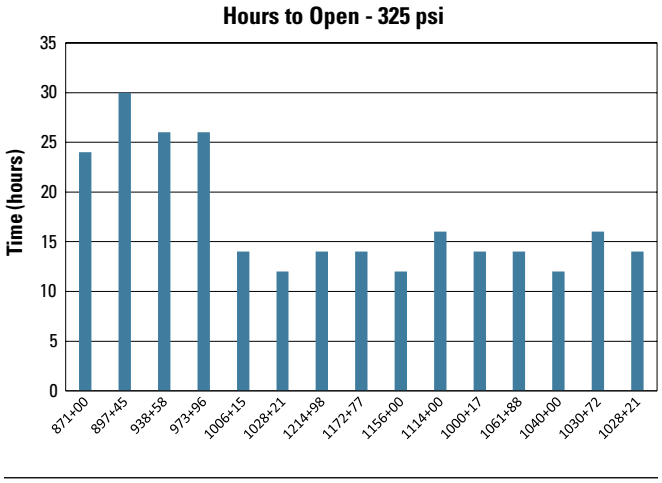

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Figure 12. Time to opening strength determined using the maturity method

The use of the maturity method and the reduction in the concrete opening strength requirement were highly influential in accelerating the completion of the Iowa Highway 3 project. These actions also demonstrate how agencies and contractors can improve construction efficiency and reduce the impacts of closures on the traveling public when building concrete overlays.

Completing Other Project Activities

The ability to re-open the concrete overlay to local traffic as soon as 12 hours after paving not only provided significant benefits to the traveling public but also facilitated more rapid completion of joint sealing, shouldering, and cleanup. The accelerated completion of these other project activities was crucial to help the contractor satisfy the maximum 3 mi closure requirement and to complete the project in 25 calendar days.

Normally, contractor personnel and subcontractors that perform activities such as joint sealing, shouldering, and pavement marking do not begin work until all mainline paving is completed. However, given the accelerated contract schedule, as well as the flexibility enabled by the reduced opening strength requirement and use of the maturity method, these other project activities were finished on a rolling basis just a few days after paving.

Joint sealing was typically completed within 24 to 48 hours after paving. Temporary rock shouldering was completed at driveways as soon as the pavement was opened to local residents, and shouldering was fully finished along the rest of the roadway approximately 48 to 72 hours after construction. Figure 13 shows joint sealing crews working at a location about 1 mi away from the paving machine approximately 24 hours after paving, with rock shoulders built up at a driveway.

Figure 14 shows a section of the completed roadway about 72 hours after paving that had been re-opened to local traffic after completion of joint sealing and rock shouldering but before final pavement markings were applied. Application of pavement markings and final project cleanup were performed after the final day of mainline paving on July 26, and the roadway was fully re-opened to through traffic on August 1.

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Figure 13. Joint sealing operations about 24 hours after paving

Eric Ferrebee, ACPA, used with permission

Figure 14. Completed concrete overlay on Iowa Highway 3

Other Project Considerations

During construction of this project in the summer of 2022, the contractor faced a number of logistical challenges unrelated to the project design or the accelerated construction requirements. Due to lingering impacts from the COVID-19 pandemic, the labor force of construction workers and truck drivers was very tight, and material supply chains were stretched thin.

These impacts combined to lower the overall production rate. The reduced availability of materials and truck drivers slowed the delivery of aggregates and cement to the batch plant and limited the amount of concrete that the contractor could produce per day without running out of materials.

As mentioned previously, the cement supplier also changed the source and type of cement that the contractor was anticipating on short notice prior to the start of the project, which required the contractor to make changes to the mixture. After these changes, workability and the rate of strength gain improved. If the contractor had been given more advance notice of the material change, these adjustments could have been made before the project started, further improving efficiency.

Aftermath

In many ways, the concrete overlay on Iowa Highway 3 was a favorable project on which to experiment with changes to staging and construction processes to accelerate completion. Traffic levels were relatively low, it was easy to establish an end-to-end detour, and there were a limited number of driveways and intersections along the project corridor.

On the other hand, logistical challenges that limited production rates prevented the contractor from finishing the pavement as quickly as theoretically possible. In spite of these limitations, the project was completed in just 25 calendar days after the initial closure, one day behind the original target. Most importantly, no accidents were experienced during construction. The success of this project demonstrates that concrete overlays can be completed on an accelerated timeline while maintaining a significant degree of access to local traffic and providing a safe environment for construction workers and the traveling public.

As of 2024, the overlay is in excellent condition, with a pavement condition index value of 87/100 and an International Roughness Index value of 69 in./mi. Ultimately, after this 8.6 mi section of roadway was closed to through traffic for less than one calendar month, the newly constructed concrete overlay should serve traffic for 40 years.

Conclusions

As the adoption of concrete overlays continues to expand across the United States, more agencies are poised to gain experience with planning and implementing various maintenance of traffic strategies. Every project has unique demands that may drive the selection of one strategy over another (e.g., full closure versus paving under traffic), and certain strategies may not be feasible in all cases.

The case study of Iowa Highway 3 shows that agencies and contractors can work together to improve and innovate on existing construction practices and maintenance of traffic strategies. Creative, cutting-edge solutions like these exist for all types of concrete overlay projects to accelerate project completion while enhancing access for local residents. No matter what types of constraints may exist for a given project, concrete overlays can be constructed to provide agencies and the traveling public with a long-lasting roadway while minimizing challenges during construction.

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