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Best practices and promising technologies that can be used now to enhance concrete paving

Concrete Overlays

WINTER 2023

PROJECT TITLE
Concrete Overlays

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Introduction

Concrete overlays serve as a viable, cost-effective preservation treatment that can improve the performance of existing roadways. Concrete overlays are an important part of the Federal Highway Administration (FHWA) Every Day Counts initiative, including the innovative Targeted Overlay Pavement Solutions (TOPS) program. Potential TOPS benefits for concrete overlays include improved safety, improved performance, retained investments, cost savings, and environmental soundness. This program provides technical support and educational materials to state highway agencies (https://www.fhwa.dot.gov/pavement/tops/concrete_resources.cfm).

This document provides a brief background, technical resources, and key benefits for concrete overlays to argue that they should be considered a long-life preservation treatment for aging roadway facilities. Concrete overlays are simple and sustainable and have shown a history of long-term performance for multiple agencies.

Concrete Overlay Types

A concrete overlay is a concrete pavement layer placed directly on an existing pavement. Concrete overlays are constructed using the same materials, equipment, and processes as a conventional concrete pavement placed on a base course. Concrete overlays are categorized into four main types:

- Concrete on asphalt–bonded (COA–B)
- Concrete on asphalt–unbonded (COA–U)
- Concrete on concrete–bonded (COC–B)
- Concrete on concrete–unbonded (COC–U)

Concrete on Asphalt (COA)

If the existing pavement is asphalt and is in fair or good condition, a COA–B overlay can restore and improve an existing pavement's structure value. In a bonded overlay, the existing pavement serves as a structural component to the new pavement system.

If the existing pavement is asphalt and is in poor or deteriorated condition, a COA–U overlay can add structural value to the roadway. Although the placement of concrete on a clean and stable pavement will inherently have some amount of bonding, this bond is not considered to aid in the design for bonded concrete overlays. The existing pavement serves as a uniform support layer.

Concrete on Concrete (COC)

If the existing pavement is concrete and is in fair or good condition, a COC–B overlay can restore or increase the pavement's original structural value. Special design and construction considerations need to be followed for this type of overlay to be successful, so this type of overlay is not common.

If the existing pavement is concrete and is in poor or deteriorated condition, a COC–U overlay can add structural value to the roadway. A required separation layer helps prevent cracks from reflecting up from the existing pavement, prevents bonding, and provides drainage. The separation layer is either a nonwoven geotextile or a thin (1 to 2 in.) layer of hot-mix asphalt (HMA).

Figure 1 illustrates the four types of concrete overlays.

Concrete on Asphalt

Concrete on asphalt (COA) overlays can be designed to address a broad range of existing pavement conditions on both composite and full-depth asphalt pavements. Both bonded (COA–B) and unbonded (COA–U) options enable designs to cost-effectively match the condition of the existing asphalt—from deteriorated to good—as well as geometric parameters.

Concrete on Concrete

Concrete on concrete (COC) overlays can be designed for applications on both existing jointed plain concrete pavement (JPCP) and continuously reinforced concrete pavement (CRCP). The majority of COC overlay designs are unbonded (COC–U) systems; however, bonded (COC–B) applications can be successful, provided the existing pavement is in good condition.

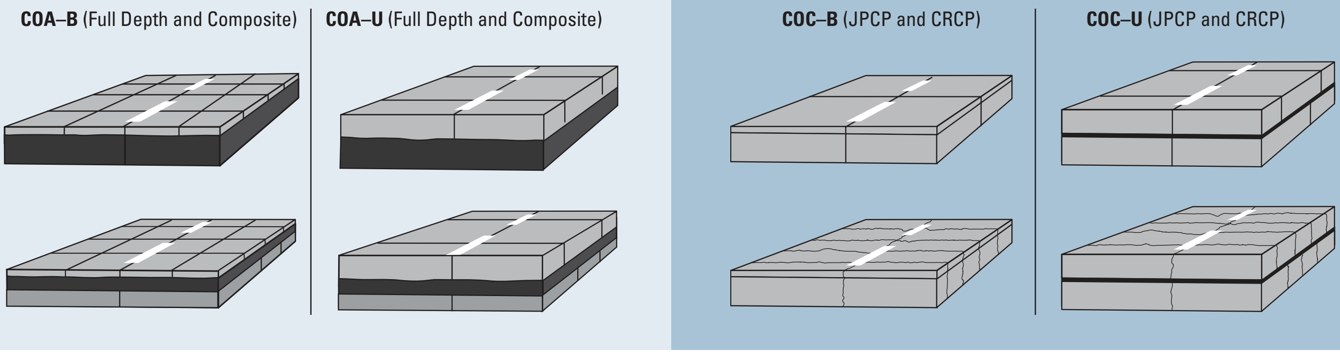

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Figure 1. Concrete overlay types

Simplicity

Simplified Construction Documents

Concrete overlays can be constructed based on a simple set of drawings using only a few sheets. Because concrete overlays are constructed on an existing pavement, a proposed elevation profile for the roadway is often not needed in the drawing set except when minor cross-section or design profile adjustments are needed in spot locations. It is only necessary to conduct a new survey of the existing pavement when a change in the profile is needed. In such cases, a detailed survey that includes cross sections at multiple lines as well as lidar scanning can help minimize concrete quantity overruns. This information may be provided electronically as supplemental information.

The drawing set, at a minimum, should include the items listed in Figure 2.

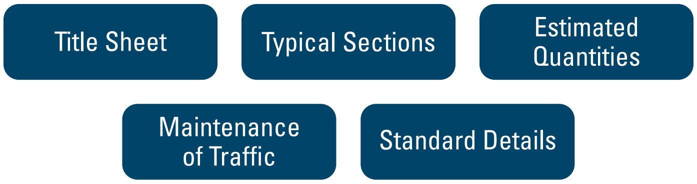

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Figure 2. Concrete overlay drawing sheets

The title sheet should include a map with the project limits, traffic data, standard drawing templates, an index of sheets, engineering certification, and a detour route if applicable.

The typical sections should illustrate the existing pavement section, a milling section (when necessary), and the proposed pavement section showing the concrete overlay and any adjustments to shoulders and appurtenant structures. Key features of the typical sections include overlay thickness, lane width, roadway cross slope, shoulder width, shoulder cross slope, and station limits for the overlay section.

The estimated quantities sheet lists the bid item quantities. It is good practice to include two bid items for the concrete overlay: one item for furnishing concrete material (measured in cubic yards) and another for concrete placement (measured in square yards). By establishing a bid item for concrete by volume, the contractor gets paid for the actual material used and bids may be more competitive for the agency. If only one bid item is established in square yards in projects that have a high overrun (less control of yield), there is risk for higher bid prices.

If a road closure is not practical due to insufficient detour routes or high traffic volumes, it is critical to define maintenance of traffic within the construction documents. The plans and specifications should provide the contractor with clear criteria for maintenance of traffic requirements, including schedule milestones. Successful concrete overlay projects have allowed a detailed staging plan to be developed by the contractor with review and approval by the contracting agency.

Design details should include transition sections at the beginning and ending of the project or at bridge decks, shoulder or side road sections, and curb and utility access details if the project is in an urban area.

In Oklahoma, there have been many concrete overlay projects with simplified construction documents consisting of letter-sized (8.5 by 11 in.) pages. A comprehensive inventory of available construction drawing elements for all types of concrete overlays is available in *Guide for the Development of Concrete Overlay Construction Documents* (Gross and Harrington 2018). This document also includes guidance specifications with commentary, cost information, and lessons learned to improve the long-term performance of concrete overlays with respect to pavement widening, synthetic structural fibers, and separation layers.

Sustainability

For a paving project to be sustainable it should have a low environmental impact, be economical, and be socially acceptable. Concrete overlays are beneficial within each of the three aspects of sustainability, as shown in Figure 3.

Environmental Benefits

Recently, there has been an increased emphasis in the United States on reducing CO_2 emissions. According to the Portland Cement Association (PCA), cement manufacturers in the United States have committed to the goal of reaching carbon neutrality by 2050.

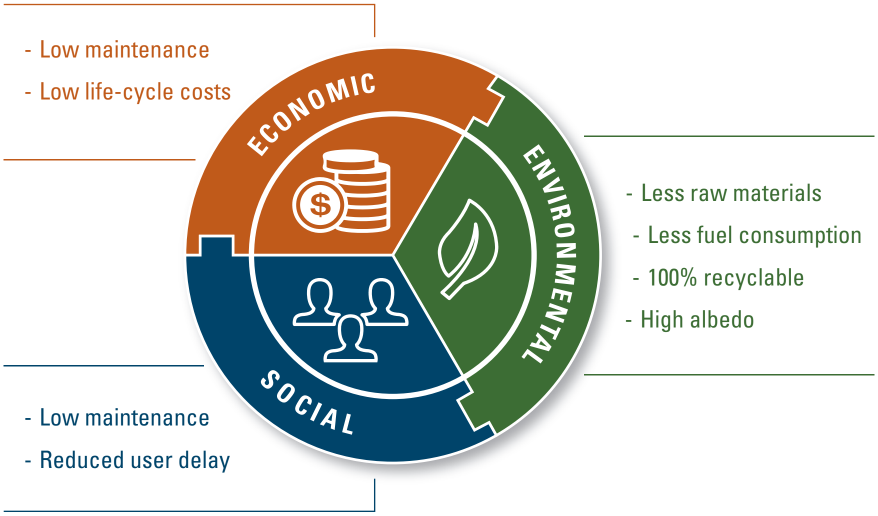
How can concrete overlays help our environment?

Concrete overlays have proven to be a long-lasting preservation treatment that can give aging pavements new life. Instead of planning for reconstruction of a pavement in the next 10 years, a concrete overlay can last at least 30 years with routine maintenance, the proper candidate roadway, and proper design and construction. Concrete overlays maximize the use of the existing pavement system. Operations such as demolition and earthwork are eliminated when using concrete overlays instead of reconstruction, thus reducing fuel consumption and ultimately carbon emissions.

According to the Environmental Protection Agency (EPA), transportation generates approximately 27% of CO_2 emissions in the United States. While the road-building phase of transportation is a small fraction compared to the on-road vehicle use phase, key opportunities have been identified to reduce CO_2 emissions during the road-building phase. These opportunities include consuming less concrete, consuming less cement in concrete mixtures, and consuming less clinker when manufacturing cements.

Consuming Less Concrete

Concrete overlays inherently use less concrete because of their reduced thickness compared to a new full-depth pavement. Further, software allows the designer to optimize various parameters to achieve the proper thickness for the desired design life. By optimizing design parameters, the designer can establish more efficient thickness designs. Table 1 lists recommended concrete overlay design software.



Recreated from US Department of Energy 2023

Figure 3. Three aspects of sustainability

Table 1. Concrete overlay design software

Name	Link	Design Procedure	Overlay Type
AASHTOWare PavementME Design	https://me-design.com/MEDesign	Mechanistic-empirical	All types
PavementDesigner.org	https://www.pavementdesigner.org/	PCA/StreetPave method	COC–B, COC–U, and COA–U
BCOA-ME	https://www.engineering.pitt.edu/Vandenbossche/BCOA-ME/	Mechanistic-empirical	COA–B
UBOL Design v1.0	https://uboldesign3.azurewebsites.net/	Mechanistic-empirical	COC–U

Consuming Less Cement in Concrete Mixtures

As with conventional concrete paving, concrete overlays can be designed using less cement by allowing optimized aggregate gradations and maximizing the use of supplementary cementitious materials such as fly ash and slag.

Consuming Less Clinker

Less clinker production during the cement manufacturing process leads to reduced CO_2 emissions. The use of portland limestone cement (PLC) or Type IL cement allows for the substitution of up to 15% fine limestone to replace cement. This translates to approximately 10% lower greenhouse gas emissions. As an example, 203 tons of CO_2 are saved when using a Type IL cement compared to a Type I/II cement based on a 6 in. thick, 24 ft wide, 4 mi long concrete overlay using 570 lb/yd^3 of cement (based on PCA's CO_2 calculator https://www.greenercement.com/advanced-co2-calculator). Based on PCA, 45 state agencies have specifications that accept PLC, with another three states planning to accept PLC and one state considering acceptance.

Additionally, alternative low-carbon cements should be considered. The replacement of cement with alternative pozzolans can significantly reduce CO_2 emissions. Test sections were completed in 2022 at the MnROAD facility as part of an ongoing research project, Use of Alternative Pozzolanic Materials Towards Reducing Cement Content in Concrete Pavements (https://www.dot.state.mn.us/mnroad/nrra/structure-teams/rigid/reduced-cement-content.html). The goal of the study is to investigate the factors impacting production and placement of concrete pavement using alternative pozzolanic materials as well as determine field performance when exposed to heavy traffic loading and extreme climate conditions.

Use Phase Benefits

The EPA estimates that 84% of the CO_2 emissions from transportation are related to the on-road vehicle use phase. Key benefits of concrete overlays that can lead to reduced CO_2 emissions include the following:

- High albedo: Concrete reflects solar energy back into the atmosphere, leading to a reduced urban heat island effect and lower pavement temperatures.
- Pavement-vehicle interaction: Concrete offers a lower rolling resistance than flexible pavements, leading to increased vehicle mileage and a reduction in fuel consumption. Stiffer pavements in roads with high truck traffic and smoother pavements in roads with high car traffic lead to the highest reduction in fuel consumption (Louhghalam et al. 2014).
- Carbonation: Concrete can absorb CO_2 out of the atmosphere. Although it is a slow process, some research suggests a 5% to 10% absorption of CO_2 from the atmosphere. Diamond grinding can accelerate the process, as it exposes fresh, uncarbonated concrete to the atmosphere. Another carbon sequestration process involves injecting CO_2 into the fresh concrete mixture, where it is then mineralized and reportedly improves strength and long-term durability.

Economic Benefits

Compared to other types of preservation, concrete overlays offer reduced life-cycle costs, primarily due to the long-term performance of the pavement. Maintenance costs are minimized for the life of the concrete. In competitive markets, inter-industry competition may also lower product costs. Thus, in markets with competing pavement types, agencies can experience lower bid costs, allowing them to complete more paving work throughout their network.

Opening a concrete overlay earlier to traffic can reduce user delay costs. In recent years, agencies have experimented with early loading of concrete pavements. Research in Minnesota has showed that early loading did not reveal any long-term detrimental effect on the concrete overlay. Further, a web-based tool was developed to facilitate implementation of this procedure. Pavements in this study were evaluated by international roughness index (IRI), falling weight deflectometer data, and petrographic data (Khazanovich et al. 2020).

Using performance-engineered mixtures (PEM), paste volume is reduced through optimized aggregate gradation. Mixtures can be produced at reduced costs by reduction of the cement volume alone. PEM also improves workability, which typically results in smoother, more durable concrete pavements. Contractors that have tried this approach have reaped the benefits and often look to use PEM on future projects.

Social Benefits

Concrete contributes to the societal aspect of sustainability. Due to the long-term performance of concrete overlays, there are reduced traffic control needs from maintenance operations, resulting in reduced user delays. In addition to the environmental benefits of concrete's high albedo, the higher light reflectivity provides health and safety benefits, as a brighter environment improves visibility and therefore reduces the potential for traffic-related incidents (ACPA 2019).

Accelerated Construction

Concrete overlays are inherently a form of accelerated construction when compared to the construction of full-depth concrete or asphalt pavement. The existing pavement is not disturbed and the subgrade is never exposed to weather except for transition areas near bridges and at the beginning and end of the road section. A significant benefit of concrete overlays is the decrease in total construction time, which reduces road user costs and increases driver safety.

More generally, concrete overlays reduce the indirect time-related costs of road improvements. Not only do concrete overlays reduce construction delays and road closings, which are generally not well accepted by road users (FHWA 2018), but they also offer confidence to agencies that the improvements will provide a long-life pavement.

Concrete overlay construction can be further accelerated through various means. Accelerated construction techniques may be used on critical areas of a project (such as intersections and crossovers), the final segment, or the entire project. While such techniques often involve conventional concrete pavement materials and procedures, key changes such as the following can significantly expedite projects:

- Contract incentives and disincentives
- Material proportioning modifications
- Accelerated curing methods
- Alternative construction staging
- Approved changes to pavement joint layouts to facilitate maximum use of slipform placements
- Adjustments to the criteria for opening to traffic
- Use of accelerated concrete mixtures in critical areas

Opening to Traffic

It should be noted that opening to traffic does not require reaching the design strength. While opening compressive strengths in the range of 3,000 to 4,000 psi have been common historically, research has shown that this magnitude of strength is not required for opening to construction traffic or normal operations because the concrete will continue to gain strength and ultimately reach the design strength (Roesler et al. 2000).

Because of the efficiency that results from building on an existing pavement structure, overlay projects can usually be completed in approximately a quarter of the time needed for a full reconstruction project (Cackler 2021). Due to thinner slab thicknesses, saw cutting capacity rather than plant capacity often controls overall progress. Production rates of two-thirds of a mile and up to more than a mile per day are not uncommon depending on overall paving width and thickness.

Case Study of Iowa Highway 3 in Plymouth County: Can a Concrete Overlay be Constructed Successfully Under an Accelerated Schedule Using Increased Safety Measures?

**Get In,
Get Out,
Stay Out**

In July 2022, a 6 in. thick concrete overlay was constructed on Iowa Highway 3 between Le Mars and Remsen. The traffic on this existing 10 in. asphalt pavement section was 3,940 vehicles per day for the 9 mi section. The project included 2 in. profile milling of the asphalt surface, a 6 ft by 6 ft joint spacing design, and integral widening with 6 ft paved shoulders to bring the total width of the pavement to 36 ft. The project included incentives and disincentives to complete the project within a 28-calendar day schedule.

An accelerated staging concept was developed focusing on quick completion of the mainline roadway and shoulders. Through traffic was detoured away from the construction while local traffic retained full access before and after the paving operations. A mobile lidar survey was used to establish the paving profile and avoid impacts to traffic. Profile milling was allowed under lane closures and pilot cars. Sideroad connections were separate sites completed after mainline traffic was restored to the highway.

The contractor used a mixture comprised of three aggregates, 448 lb/yd^3 Type I/II cement with 20% fly ash replacement, and a water-to-cementitious materials ratio of 0.40. The flexural strength for opening to traffic was lowered from 500 to 325 lb/in.^{2} by special provision with verification by the maturity method. The concrete was able to open to traffic after 13 to 16 hours. In Iowa, sealing operations are allowed when the pavement reaches a flexural strength of 150 lb/in.^{2}.

The contractor elected to locate the batch plant in the middle of the project and work in two directions paving toward the plant. Real-time smoothness was used during paving. The IRI achieved was approximately 50 in./mi. A study of joint activation was conducted and showed that within a week of paving, cracks developed beneath saw cuts at approximately every other transverse joint. Loaded trucks were running on the pavement at 24 and 48 hours, and strain gauges installed in one slab showed acceptable strain levels under those loadings.

The Iowa Highway 3 concrete overlay (Figure 4) was studied to determine whether accelerated concrete overlay construction can be successfully completed while maintaining a quality project using increased safety measures. Overall the accelerated project was a success. The contractor was able to complete approximately 9 mi of 6 in. overlay with integral 6 ft wide concrete shoulders, 4 ft wide rock shoulders, rumble strips, and paint in 25 calendar days. One challenge included the strain on labor forces, as the project required 54 trucks to haul materials to the batch plant, haul the mix to the paver, and complete shouldering operations.

Due to some material supply and labor constraints, paving did not occur every day. However, the project was still completed ahead of schedule. Furthermore, the project was completed with increased safety due to the mainline-focused concept. Shifting traffic away from the construction work for a short period and concentrating on accelerating the work needed to get traffic back to the new improved surface improved safety, not only for the construction workers but also for the traffic that would be interacting with the roadway improvements. Looking ahead, future design considerations to use in similar projects may include the use of macrofibers and 12 ft by 12 ft panels.

Performance

In the early years of development and implementation of concrete overlays, expected service life was approximately 20 years based on National Cooperative Highway Research Program (NCHRP) *Synthesis of Highway Practice 204* (McGhee 1994). *NCHRP Research Report 1007: Evaluation of Bonded Concrete Overlays on Asphalt Pavements* concluded that bonded concrete overlays on asphalt are a viable option for the rehabilitation of applicable asphalt pavements (Pierce et al. 2022). As the popularity of concrete overlays has grown, many states have documented successful concrete overlay project experience, with some agencies seeing performance life exceeding 20 years. The following discussion identifies agency experience along with examples of concrete overlay performance.

Eric Ferrebee, ACPA, used with permission

Figure 4. PCC overlay on Iowa Highway 3 in Iowa

NCHRP Evaluation of Bonded Concrete Overlays on Asphalt (BCOAs)

In 2022, *NCHRP Research Report 1007: Evaluation of Bonded Concrete Overlays on Asphalt Pavements* was completed (Pierce et al. 2022). This report includes performance prediction curves for BCOAs, also referred to as COA–B by the National Concrete Pavement Technology Center (CP Tech Center). The curves are based on laboratory and field investigations for determining best practices for the development of BCOAs. This study included concrete overlays on asphalt with thicknessess ranging from 3 to 7 in. The literature search revealed important factors affecting the performance of BCOAs, including use of synthetic macrofibers, slab (or panel) size, concrete-asphalt interface, existing asphalt condition, and joint seal condition.

A survey of state highway agencies was completed to understand the extent of BCOA use, selection criteria, evaluation methods, and BCOA design methods and construction and maintenance practices. Based on the survey, 19 projects were identified for site evaluations. The projects ranged in age from 7 to 26 years, had design layer thicknesses ranging from 4 to 6 in., and had panel sizes ranging from 4 ft by 4 ft to 12 ft by 12 ft. The total length of the projects studied was 175 mi. Automated pavement conditions surveys were performed to determine IRI, faulting, and cracking. Some of the study's conclusions include the following:

- In general, most of the segments evaluated were in good condition. Approximately 90% of the tested segments had IRI values less than 170 in./mi, with nearly 50% of segments having IRI values less than 95 in./mi. Most segments had maximum faulting of 0.10 in. or less (average 0.04 in.), and less than 5% of slabs showed corner breaks, longitudinal cracks, and transverse cracks.
- Faulting is influenced by slab size, BCOA layer thickness, and the interactions between slab size and BCOA layer thickness. Increasing the asphalt layer thickness reduces the potential for faulting. Synthetic macrofibers and joint sealing showed no effect on faulting.
- Corner breaks are influenced by slab size, in-service age, synthetic macrofibers, equivalent single axle loads (ESALs), and the interactions of slab size with BCOA thickness and asphalt layer thickness with BCOA thickness.
- Longitudinal, transverse, and total cracking and transverse joint spalling are not influenced by any of the factors evaluated.
- Longitudinal joint spalling is influenced by in-service age, synthetic macrofibers, and the interaction of the BCOA with asphalt layer thickness. As in-service age increases, increased spalling is observed, but the use of synthetic macrofibers reduces the amount of spalling.
- Total spalling is influenced by in-service age.

Some of the areas of future research include the following:

- Influence of joint sealing on BCOA performance
- Initiation and progression of faulting in BCOA pavements
- Improved characterization of the bond between concrete and asphalt in the design models
- Consideration of comprehensive pavement management data to be collected to support improvement of performance prediction curves and subsequently improve design procedures

California

The California Department of Transportation (Caltrans) has partnered with the FHWA on TOPS to promote concrete overlay projects in California, document past project performance, evaluate the current state of the practice, and help further develop sustainable concrete pavement. Caltrans has built several COC overlay projects on I-80 since the 1990s. These projects were jointed plain concrete pavement (JPCP). In 2017, Caltrans built its first continuously reinforced concrete pavement (CRCP) overlay. The agency began constructing its first COA overlay projects in 2019.

As part of TOPS, Caltrans is developing a tracking list and monitoring the performance of a few past concrete overlays using automated pavement condition survey data. Key relevant information from these concrete overlays will be shared with the Overlays Explorer database maintained by the American Concrete Pavement Association (ACPA).

As noted by Caltrans Senior Concrete Pavement Engineer Dulce Feldman, "Concrete overlays can be a cost effective and sustainable strategy because the existing pavement can be used as a base, avoiding pavement removal and placement of a new base."

Colorado

Colorado has constructed over 1.5 million yd^2 of 6 in. thick concrete overlays and over 10 million yd^2 of concrete overlays of all thicknesses on the state and federal highway system. Many concrete overlay projects in Colorado apply profile milling operations to obtain a tighter yield on concrete volume. The Colorado Department of Transportation (CDOT) has used PEM on concrete overlays using optimized aggregate gradation and Class F fly ash for reduced cementitious content and reduced cost. A typical practice in Colorado allows for the construction of concrete overlays under traffic based on two 19 to 20 ft paving sections resulting in 12 ft wide travel lanes and a 7 to 8 ft wide paved shoulder.

In CDOT Region 2, the US Highway 287 corridor from the Oklahoma border to milepost 122 has received multiple concrete overlays from 1996 through 2021, with thicknesses ranging from 7 to 12 in. (Figure 5). The projects have performed very well, with current IRI values ranging from approximately 80 to 120 in./mi based on publicly available performance data on the CDOT website. The oldest section has some areas in need of panel replacement after 25 years of service.

Illinois

In Illinois, thin concrete overlays on asphalt pavements have traditionally been referred to as ultra-thin whitetopping (UTW). The success of UTW projects in Illinois has been attributed in part to the use of macrofibers (Figure 6) and their desirable results. Macrofibers have proved very effective in providing extra structural capacity and maintaining joint load transfer efficiency in UTW pavements, as assumed in the thickness design procedure (King and Roessler 2014). Additionally, for UTW, smaller panel sizes of 5.5 ft have shown less cracking and faulting than larger sizes of 11 ft.

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Figure 5. US Highway 287 overlay

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Figure 6. Synthetic macrofibers

A study on Illinois Department of Transportation concrete overlays was completed in 2018 (Heckel and Weinrank 2018). The study included an evaluation of 11 projects comprised of two COC–B projects on CRCP, eight COC–U projects on JPCP and CRCP, and one ultra-thin COC–B on CRCP. The study concluded the following:

- Bonded concrete overlay performance varied widely and should only be used with caution. Of the two COC–B projects, the existing pavement with more distress prior to the overlay did not perform as well as the other project that had less pre-overlay distress.
- Unbonded concrete overlays consistently performed well, with all observed pavements exceeding or expected to exceed their design lives and design traffic factors.
- All of Illinois's unbonded overlays placed to date were designed at or above the NCHRP report's recommendations for interlayer thickness and new CRCP pavement thickness (ERES Consultants, Inc. 1999). As a result, good performance has been attained.

Iowa

In 2017, the CP Tech Center published a guidance document titled *Concrete Overlay Performance on Iowa's Roadways* based on the results of Iowa Highway Research Board Project TR-698 (Gross et al. 2017). A summary of results showed that Iowa's overlays performed very well, with service life trends exceeding previously defined expectations for concrete overlays. For this study, the researchers analyzed concrete overlay performance using the pavement condition index (PCI) from the Iowa Pavement Management Project and the IRI. The research included PCI and IRI performance data from 384 concrete overlays from 1,201 projects on 1,493 mi of roadway, encompassing 14 years of data collection. Concrete overlays in Iowa have been primarily constructed on the secondary road network (87%), with 94% of the projects evaluated in the study having 2,000 or fewer vehicles per day.

IRI was used as a performance measurement referencing the following FHWA acceptance levels: less than 95 in./mi is good, 95 to 170 in./mi is acceptable, and greater than 170 in./mi is unacceptable. The study concluded that 93% of all concrete overlays had IRI values of 170 in./mi or less. PCI was also used as a performance measure, with 89% of all concrete overlays having PCI values of 60 or better (good to excellent). Service life trends from the IRI and PCI data set showed an acceptable life of 35 years (Figure 7). Further investigation of outlying data from poorly performing projects showed that distress tended to be based on a combination of project-specific material- and construction-related issues rather than inherent overlay design issues. Addressing the causes of these issues may further improve the performance life of concrete overlays.

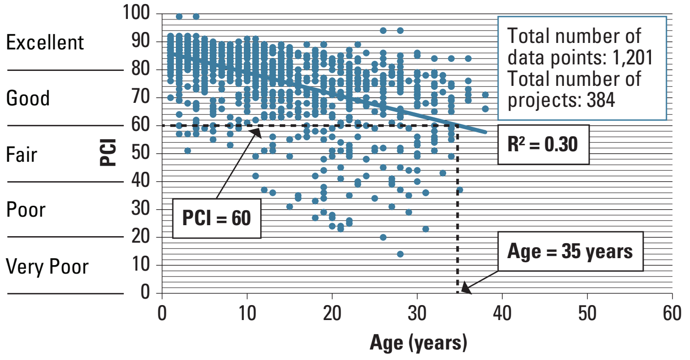

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Figure 7. PCI performance data

Minnesota

A 2020 study sponsored by the Minnesota Department of Transportation (MnDOT) reviewed the performance of unbonded concrete overlays on the state's roadway system (Izevbekhai et al. 2020). In the study, performance curve fitting was performed. This included the following:

- Comparison of the current deterioration curves with previous patterns toward a default performance curve
- Stepwise regression to identify performance variables associated with and predictive of remaining service life (RSL)
- Reliability (Weibull) analysis to examine the reliability and other performance characteristics of unbonded overlays in Minnesota

The reliability analysis resulted in an RSL (scale parameter) of 36 years, which was reasonably consistent with the 35.5-year RSL derived from the MnDOT Highway Pavement Management Analysis.

The threshold time to failure showed that unbonded overlays have a 7-year window before minor distresses begin to appear. If joint sealing and other preventive maintenance activities are conducted within this window, the unbonded overlay sections could experience improvements beyond the computed 35.8 years of service life (Izevbekhai et al. 2020).

Another Minnesota performance study (Burnham et al. 2019) was completed in 2019 and focused on the development of performance curves for bonded concrete overlays on asphalt (whitetopping). The study included 26 projects that were evaluated from 2015 to 2018. Five projects are owned by MnDOT and 21 projects are owned by Minnesota counties.

As a result of the study, two predictive performance models based on IRI were developed for undoweled whitetoppings in Minnesota. The following list includes some of the observations from the study:

- Whitetoppings in Minnesota are performing well. Most projects, which are less 9 years old, have not received maintenance since they were constructed. If a project received maintenance, it was related primarily to the repair of construction errors.
- Longitudinal cracking is more prevalent than transverse cracking and occurs due to three main factors: overlay thickness, heavy loading, and doweling.
- Although rare, some projects have experienced minor buckling.
- It generally appears that there is good bond between the layers up through 5 years of service. After that time, the bond degrades, first near the transverse joints. While there were too few projects to confirm cause and effect, there were several projects with unsealed transverse joints that demonstrated higher frequencies of debonded layers in the core samples that were taken near the joints.
- Faulting of transverse joints has developed in four projects, with one requiring corrective action at a young age of 5 years old.
- There appears to be some correlation between overlay thickness and change in ride quality, with thicker sections having lower IRI values after 6 years. For the same time period, there is no clear correlation between overlay thickness and the amount of observed cracking.
- It was noted that not all sawed joints deploy on projects with smaller panel sizes.

Predictive performance curves were developed using two curving fitting models based on IRI data from seven of the projects. One model uses seven design parameters. The other model is an exponential model based on age. The basis for terminal service was an IRI value of 170 in./mi.

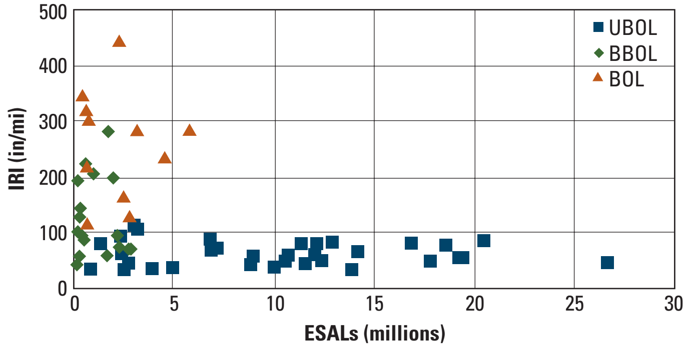
Based on the study, some of the recommendations were as follows:

- Data collection, analysis, and revision of the proposed performance prediction models should continue until several projects reach the need for major repairs or terminal serviceability. Ride quality restoration techniques, such as diamond grinding, should be trialed and studied to determine their impact on whitetopping performance curves.
- The performance of newer whitetopping projects utilizing fibers should be studied to determine whether service life can be extended by enhanced load transfer.
- The practice of intentionally matching overlay joints to underlying asphalt cracks should be discouraged to prevent the development of early-age full-depth joint faulting.
- Joints should be filled or sealed on whitetopping projects with gravel shoulders to reduce the potential for buckling.
- More suitable sealant materials should be examined for better performance.
- It is recommended that all whitetopping projects use ground penetrating radar testing and coring during the preliminary design phase.
- The lack of maintenance events on whitetoppings in Minnesota should be considered in future cost, safety, and sustainability analyses.
- The impending release of new concrete overlay faulting models from other studies should be considered for incorporation into the improved models developed during the next phase of this study.

Missouri

In 2020, a Missouri Department of Transportation (MoDOT) research study (Grogg et al. 2020) was completed with the purpose of evaluating the performance of concrete overlays for pavement rehabilitation. Three types of concrete overlays were evaluated: unbonded overlays on asphalt or concrete (UBOLs) typically 8 in. and greater, unbonded big block overlays (BBOLs) typically 5 in. thick with 6 ft by 6 ft panels on existing asphalt or concrete, and bonded overlays (BOLs) typically 4 in. thick with 4 ft by 4 ft panels bonded to existing asphalt or concrete. The projects were evaluated using smoothness and distress data. A total of 41 projects were evaluated: 26 UBOL projects, 9 BBOL projects, and 6 BOL projects.

It was determined that UBOLs exhibited the best ride quality, with an overall average IRI value of 64 in./mi. BBOL and BOL projects exhibited higher mean IRI values of 131 in./mi and 263 in./mi, respectively (Figure 8). It is noted that BOL projects were constructed at intersections where handwork and forms were used. UBOL projects with geotextile separation layers generally exhibited less cracking than those using an existing or new HMA separation layer. UBOL projects with widened portland cement concrete shoulders did not display as much cracking as the projects with HMA shoulders. Future monitoring of this is recommended, as traffic levels were low. The most predominant cracking in UBOLs was longitudinal cracking, which may be due to excessive slab width or inadequate support in the outer portion of the driving lane.



Recreated from Grogg et al. 2020

Figure 8. ESALs versus 2018 mean project IRI

Recommendations for improvement included the following:

- Design thickness procedures for UBOL and BBOL projects should be site-specific and build on mechanistic design procedures for pavements.
- UBOL and BBOL construction quality control practices should be revised to better control minimum thicknesses.
- MoDOT should continue to use geotextile separation layers on UBOL projects (Figure 9).

The following research was recommended to improve concrete overlay performance:

- Additional consideration of field and records forensics to determine the condition of the underlying pavement as well as investigation of good and poor performing concrete overlays to determine key design and base support
- Additional engineering for BOL projects to improve ride and underlying pavement and base support
- Additional research on the failure mode for BOL projects
- Additional research to optimize design and selection of geotextiles for separation layers

Dan King, CP Tech Center

Figure 9. Light-colored nonwoven geotextile separation layer

Resources

The CP Tech Center and ACPA provide technical resources that further detail various aspects of concrete overlay selection, design, and construction. The Concrete Overlays webpage is a one-site source of abundant information on concrete overlays: https://cptechcenter.org/concrete-overlays/.

Guide to Concrete Overlays (Fourth Edition) (iastate.edu)

This 2021 guide by Fick et al. presents the basic principles that a pavement engineer needs to design and construct concrete overlays on existing asphalt, composite, and concrete pavements. Intended for both experienced engineers and less experienced users, the material in the guide is presented in the form of expert guidance meant to supplement readers' own professional experience and judgment.

Guide Specifications for Concrete Overlays (iastate.edu)

This 2016 document by Fick and Harrington provides guidance for the development of project specifications that are tailored for concrete overlay projects. The guidance is based on a given agency's standard specifications for concrete pavements.

Guide for the Development of Concrete Overlay Construction Documents (iastate.edu)

This 2018 document by Gross and Harrington provides guidance on the development of construction documents for concrete overlay projects. The guide includes a range of material essential to the design and construction of successful concrete overlay projects, including examples of construction drawings, guidance on the development of specifications, information on the costs involved in concrete overlay construction, and lessons learned in concrete overlay design.

History of Concrete Overlays in the United States

This forthcoming technical summary demonstrates the applicability of concrete overlays as an asset management solution on a wide array of existing pavement types and roadway classifications. The document provides a brief history of concrete overlay construction in the United States, summarizes performance information for 17 concrete overlay projects across the country, and includes a short list of additional resources.

Performance Assessment of Nonwoven Geotextile Materials Used as the Separation Layer for Unbonded Concrete Overlays of Existing Concrete Pavements in the US (iastate.edu)

This 2018 report by Cackler et al. summarizes the national performance experience of unbonded concrete overlays constructed since 2008 using geotextile separation layers, provides an overview of lessons learned, and highlights ongoing efforts to optimize the design and construction requirements for concrete overlay applications.

The report also includes nine case studies that provide detailed performance information on overlays built with geotextile separation. Based on the performance of over 10 million yd² of concrete overlay placed using geotextile separation since 2008, the report concludes that nonwoven geotextile fabric works very well as a separation layer.

Fiber-Reinforced Concrete for Pavement Overlays: Technical Overview (iastate.edu)

This 2019 report by Roesler et al. summarizes the state of the art regarding the different fiber types, test methods, structural design considerations, and construction modifications required for the use of fiber-reinforced concrete materials in concrete overlays.

Guide to Concrete Overlays of Asphalt Parking Lots (Second Edition) (iastate.edu)

The material in this 2022 guide by Gross and Smith reflects advancements in technology and research, offers a simplified approach to assessing existing pavements, includes modifications to the material on design and construction based on lessons learned, and presents project profiles demonstrating the principles of this guide.

Concrete Overlays—The Value Proposition (iastate.edu)

This 2021 technical summary by Cackler provides an overview of the value that concrete overlays offer in terms of cost, performance, safety, sustainability, and customer satisfaction.

Concrete Overlays—A Proven Technology (iastate.edu)

This 2021 document by Cackler et al. is intended to familiarize the reader with concrete overlay technology. The material includes a technical overview of concrete overlays, guidance on effective deployment, lessons learned from decades of projects, an annotated list of additional resources, and 11 case histories demonstrating the versatility of concrete overlays.

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