National Concrete Pavement Technology Center

Guide to

Concrete Overlays

Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements

A practical approach to understanding and successfully using concrete overlays, from selection to opening

Second Edition September 2008

On the Cover

Urban concrete overlay construction with limited paving clearance (Photo courtesy of Kevin Klein, Gomaco)

Rural concrete overlay construction with widening (Photo courtesy of Gordon Smith, P.E., Iowa Concrete Paving Association)

Interstate highway concrete overlay construction (Photo courtesy of Dan DeGraaf, P.E., Michigan Concrete Paving Association)

Urban concrete overlay construction (Photo courtesy of Kerry Sutton, P.E., Michigan Concrete Paving Association)

Completed concrete overlay of rural roadway with paved shoulders (Photo courtesy of Gordon Smith, P.E., Iowa Concrete Paving Association)

Completed concrete overlay on interstate highway (Photo courtesy of Matt Zeller, P.E., Concrete Paving Association of Minnesota)

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Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements

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About This Guide

This *Guide to Concrete Overlays* (second edition) is a product of the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University, with partial funding from the American Concrete Pavement Association. It was developed to fill a "knowledge gap" identified in the National Concrete Pavement Road Map, a coordinated, long-term research plan for improving concrete pavements. In September 2007, the Road Map's national executive committee designated overlays as a priority topic for research and technology transfer.

In addition to serving a general industry need, this publication will be a major resource for a field application program, led by the National Concrete Pavement Technology Center. This program is intended to advance overlays' effective use by answering pavement owners' questions and increasing their knowledge about and confidence in concrete overlays.

With the advice and support of national expert teams, six regionally diverse states will design, construct, and demonstrate different types of concrete overlay solutions. Through this process, the six states will become regional hubs of concrete overlay expertise. They will share their knowledge and experience with surrounding states by hosting visits to the demonstration sites and/or making presentations at various events. Innovations learned from the field applications will be incorporated into annual updates of this guide.

Acknowledgments

This document is a testimony to the value of agency-industry-university partnerships in research and technology transfer activities. The National Concrete Pavement Technology Center at Iowa State University is sincerely grateful to the knowledgeable, experienced, and dedicated concrete pavement professionals, public and private, who contributed to the development of this guide, both the original version in 2007 and this expanded edition.

While the authors generated the overall content, it was the technical advisory committee's reviews of drafts, thoughtful discussions, and suggestions for revisions and refinements that make this guide a comprehensive resource for practitioners. The members' broad expertise regarding the use of concrete overlays as pavement resurfacing and rehabilitation solutions is reflected in every page. CP Tech Center staff appreciate the committee's invaluable assistance. In particular, we thank Dan DeGraaf and Randy Riley, representing the Michigan and Illinois concrete pavement industry associations, respectively, for their tireless attention to this project.

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ACPA	American Concrete Pavement Association
ASR	alkali-silica reactivity/reaction/reactive
ASTM	American Society for Testing and Materials
CRCP	continuously reinforced concrete pavement
CTE	coefficient of thermal expansion
FHWA	Federal Highway Administration
FWD	falling weight deflectometer
IRI	International Roughness Index
JPCP	jointed plain concrete pavement
M-E PDG	Mechanistic-Empirical Pavement Design Guide
MRD	material-related distress
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
PCA	Portland Cement Association
PCC	portland cement concrete
SCM	supplementary cementitious material
TRB	Transportation Research Board
TCP	traffic control plan

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For technical assistance regarding concrete overlays, contact your state or regional paving association, American Concrete Pavement Association (ACPA) chapter (find contact information with the My Locator tool at www.pavement.com), ACPA National Office, or the National CP Tech Center.

For Additional Copies

The American Concrete Pavement Association is distributing this guide. For additional copies, contact your state paving association/ ACPA chapter (find contact information with the My Locator tool at www.pavement.com); ask for **ACPA publication no. TB021.02P**.

Disclaimers

CP Tech Center Mission

The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the goal of advancing concrete pavement technology through research, technology transfer, and technology implementation.

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Introduction

The need has never been greater for engineered strategies to preserve and maintain the nation's pavements. With shrinking budgets, ever-increasing traffic volumes and loads, and the critical emerging focus on infrastructure sustainability, highway agencies are being asked to do more with less in managing their pavement networks.

Agencies need proactive, sustainable pavement maintenance and rehabilitation strategies that last longer at reasonable cost.

In many situations, concrete overlays represent such strategies. They offer cost-effective, versatile, short- and long-term solutions for the full range of concrete, asphalt, and composite pavement needs (figure 1). In addition, they contribute to more sustainable construction practices by preserving pavement service for several decades beyond the original design life.

The goal of the *Guide to Concrete Overlays* is to answer pavement owners' questions and increase their knowledge about engineered concrete overlay maintenance and rehabilitation strategies. With this information, owners can confidently include concrete overlays in their toolbox of pavement solutions and make more informed decisions about using concrete overlays for specific pavement conditions.

The first edition of this guide (2007) described concrete overlay types, applications, and general issues related to design and construction. This second, expanded edition enhances the original material and adds detailed guidelines for several new topics:

- Evaluating existing pavements to determine if they are good candidates for concrete overlays
- Selecting the appropriate overlay system for specific pavement conditions
- Managing concrete overlay construction work zones under traffic
- Accelerating construction of concrete overlays when appropriate

This guide is not a complete step-by-step manual, nor does it provide prescriptive formulae or specifications for designing and constructing concrete overlays. As the title suggests, this booklet provides expert guidance that can supplement practitioners' own professional experience and judgment.

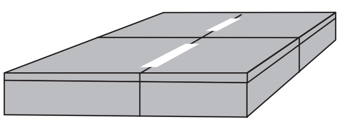
Bonded Overlay Systems

(Resurfacing/Minor Rehabilitation)

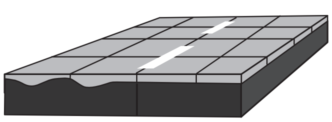
In general, bonded overlays are used to add structural capacity and/or eliminate surface distress when the existing pavement is in good structural condition.

Bonding is essential, so thorough surface preparation is necessary before resurfacing.

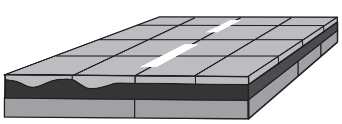
Bonded Concrete Overlays of Concrete Pavements
–previously called bonded overlays–



Bonded Concrete Overlays of Asphalt Pavements
–previously called ultra-thin whitetopping–



Bonded Concrete Overlays of Composite Pavements



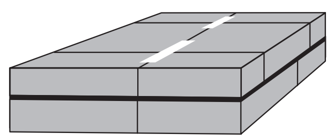
Unbonded Overlay Systems

(Minor/Major Rehabilitation)

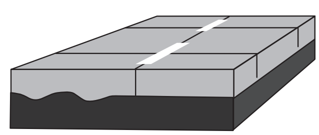
In general, unbonded overlays are used to rehabilitate pavements with some structural deterioration.

They are basically new pavements constructed on an existing, stable platform (the existing pavement).

Unbonded Concrete Overlays of Concrete Pavements
–previously called unbonded overlays–



Unbonded Concrete Overlays of Asphalt Pavements
–previously called conventional whitetopping–



Unbonded Concrete Overlays of Composite Pavements

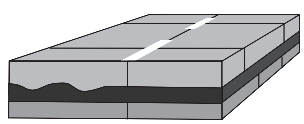


Figure 1. All concrete overlay systems can be categorized as either bonded or unbonded

Versatile Solutions

Many concrete overlays have been in service for decades, extending the life of the original pavement structure for 30 years or more. Because concrete distributes traffic loads over a wide area, the underlying pavement does not experience highly concentrated stresses. As long as the original pavement remains stable and uniform, a concrete overlay can be placed, replaced, or recycled as needed for maintenance and/or rehabilitation cycles.

In this way, concrete overlay pavement systems can be sustainable for 100 years or longer. Rather than removing and reconstructing the original pavement, the owner maintains and builds equity in it, realizing a return on its original investment as long as the original pavement remains part of the system.

Benefits of Concrete Overlays

Despite hundreds of successful concrete overlay projects, some public agencies and contractors hesitate to construct concrete overlays. This may be based on a misconception that concrete overlays are expensive, difficult to build, or appropriate in only a few situations. However, agencies that regularly construct concrete overlays describe several benefits.

1. **Concrete overlays consistently provide cost-effective solutions.** Dollar for dollar, they are one of the most effective long-term maintenance and rehabilitation options for existing pavements.
2. **Concrete overlays can be constructed quickly and conveniently.**
    - **The existing pavement does not need to be removed.** In fact, it is factored into the overlay design to continue to help carry some of the traffic load, either as part of a new monolithic pavement (bonded overlay) or as a base to the overlay (unbonded overlay).
    - **Few or no preoverlay repairs are necessary or even desirable in most cases.** If an agency believes extensive preoverlay repairs are required for a specific project, it should probably rethink its choice of overlay design solutions.
    - **Concrete overlays are placed using normal concrete pavement construction practices.** Attention should be paid to overlay-specific details in this guide.
    - **Many concrete overlays can be opened to traffic within a day of placement.** Nondestructive strength indicators, like maturity testing, enable engineers to take advantage of this benefit.
    - **Accelerated construction practices can be used throughout the normal construction season** as described in this guide.
3. **Concrete overlays are easy to repair.** Repairing concrete overlays, especially thin overlays, is usually much easier than repairing a section of conventional pavement. If a panel is distressed but the ride quality is not compromised, the panel may be left in place. If a ride quality problem develops, the panel or an isolated area should be replaced before any pieces of concrete come loose from the overlay.

    Thin overlays constructed without reinforcement can be easily and economically milled out and replaced with a new concrete surface. Utility repair locations can be restored to original surface elevation and ride quality with ease.
4. **Concrete overlays are a durable rehabilitation tool as well as a cost-effective maintenance tool.** Because of the wide range of overlay thicknesses that can be used, combined with the minimal preoverlay work required, concrete overlays provide cost-effective solutions for almost any pavement type and condition, desired service life, and anticipated traffic loading.
5. **Concrete overlays can serve, in and of themselves, as complete preventive maintenance or rehabilitation solutions, or they can be used in conjunction with spot repairs of isolated distresses.**
6. **Concrete overlays are an effective means to enhance pavement sustainability by improving surface reflectance (albedo), increasing structural longevity, and enhancing surface profile stability.**

For these and other reasons, concrete overlays are cost-effective, sustainable solutions. They provide societal benefits in the form of reliable load-carrying capacity and fewer and shorter disruptions to traffic for pavement resurfacing and rehabilitation.

Two Concrete Overlay Systems

Sometimes, various terms for concrete overlays (e.g., ultrathin whitetopping and conventional whitetopping) have led to confusion because they were not used consistently. As with all developing technologies, simple, consistent terminology is essential. This guide uses straightforward terms that categorize all concrete overlays in one of two basic systems: bonded systems and unbonded systems.

Both bonded and unbonded concrete overlays can be placed on existing concrete pavements, asphalt pavements, or composite pavements (original concrete pavements that have been previously resurfaced with asphalt). Thus, there are a total of six concrete overlay types from which owner-agencies can select the proper solution for nearly any pavement maintenance, resurfacing, or rehabilitation need.

Bonded Overlay Systems

The purpose of bonded concrete overlays is to add structural capacity to and eliminate surface distresses on existing pavements that are in good to fair structural condition. Bonded overlays generally provide resurfacing solutions for routine or preventive pavement maintenance or for minor rehabilitation (figure 2).

Bonded concrete overlays are relatively thin (2 to 5 in. [50 to 125 mm]). Bonded together, the overlay and the existing pavement perform as one monolithic pavement.

Bonding between the overlay and the existing pavement is essential. The bond ensures that the overlay and existing pavement perform as one structure, with the original pavement continuing to carry a significant portion of the load. All bonded overlay projects, therefore, are carefully designed and constructed to achieve and maintain a bond between the overlay and the existing pavement.

Most bonded overlay projects are more challenging than unbonded overlay projects. Therefore, it is important to pay close attention to details in this guide.

Factors that affect the performance of the resurfaced pavement include the strength and integrity of the underlying pavement, the effectiveness of the bond, the ability of the two layers to move monolithically to maintain the bond, and overlay jointing and curing techniques.

The key to maintaining desired performance is to ensure the two structures—the existing pavement and the overlay—move as one structure. Therefore, it is important to understand movement-related properties, such as expansion and contraction properties, of both the existing pavement and the overlay. In a bonded concrete overlay on a concrete pavement, for example, the CTE of aggregate in the overlay should be similar to or less than that of the existing concrete pavement.

Unbonded Overlay Systems

The purpose of unbonded overlays is to restore structural capacity to existing pavements that are moderately to significantly deteriorated. Unbonded overlays are minor or major rehabilitation strategies (figure 2).

Unbonded concrete overlays are typically thicker than bonded (4 to 11 in. [100 to 275 mm]) on concrete and composite pavements; typically 6 in. (150 mm) minimum on asphalt pavements less than 6 in. (150 mm) thick after milling. The overlay performs as a new pavement, and the existing pavement provides a stable base.

The term "unbonded" simply means that bonding between the overlay and the underlying pavement is not needed to achieve the desired performance.

When the underlying pavement is asphalt or composite, partial or full bonding between the concrete overlay and the underlying asphalt layer should not cause a problem. In fact, such bonding generally adds some structural carrying capacity to the system. So, unbonded concrete overlays on existing asphalt or composite pavements are not vigorously designed and constructed to prevent bonding between the layers.

However, when the underlying pavement is concrete, unbonded concrete overlays are carefully designed and constructed to prevent bonding between the two concrete layers. That is because any bonding between the two concrete layers may stress the overlay and result in reflective cracking.

Maintenance and Rehabilitation Solutions

Pavement management and pavement preservation activities have become extremely important in managing and accounting for investments in highway pavements.

Many highway agencies are familiar with asphalt maintenance and resurfacing options but are not equally knowledgeable about concrete resurfacing solutions and their benefits. Yet the variety, flexibility, and cost-effectiveness of concrete overlay options make them excellent solutions for a full spectrum of pavement maintenance and rehabilitation needs.

Pavement Preservation

To extend the life of existing pavements and delay any future need for major rehabilitation or reconstruction, highway agencies are increasingly relying on a proactive approach called pavement preservation. A pavement preservation approach involves investing in a carefully planned system of regular routine maintenance, preventive maintenance, and minor rehabilitation activities.

Routine Maintenance

Routine maintenance activities, such as joint resealing and diamond grinding, are important preservation activities that do not involve a new pavement surface.

Preventive Maintenance

Preventive maintenance is a major component of pavement preservation. Basically, it consists of extending the service life of structurally sound pavements by applying cost-effective treatments to the surface or near the surface. Some preventive maintenance treatments, such as joint resealing and diamond grinding, do not necessarily involve resurfacing. Bonded concrete overlays of approximately 4 in. (100 mm) provide excellent preventive maintenance strategies for all types of pavements. On concrete and composite pavements, 4 in. (100 mm) unbonded concrete overlays have also been used for maintenance purposes.

Minor Rehabilitation

Minor rehabilitation is used when some structural capacity needs to be restored to a pavement but major rehabilitation is not required.

One of the major advantages of concrete overlays as maintenance solutions is that they increase the pavement structure's structural capacity, even if that is not the primary objective of the maintenance activity. Bonded concrete overlays provide minor rehabilitation solutions as part of their pavement preservation programs. Thin unbonded concrete overlays also provide minor rehabilitation solutions and can be placed efficiently and opened to traffic very quickly.

Major Rehabilitation

For pavements needing structural improvement, rehabilitation is the approach typically used. Rehabilitation involves structural enhancements that extend the service life of an existing pavement and/or improve its load-carrying capability. In rehabilitation, a new surface layer of 4 in. (100 mm) or greater is usually placed.

Unbonded concrete overlays are an excellent and well-demonstrated major rehabilitation solution for pavement in need of significant structural improvement. They are highly reliable, with longer design lives than rehabilitation with asphalt.

To show the significance of concrete overlays as a rehabilitation strategy, AASHTO (2007) recently stated that "thin unbonded concrete overlays, 4 to 5 in. in depth [100 to 125 mm], have proven to be a rehabilitation option for composite (asphalt over concrete) pavements that exhibit significant deterioration. When properly designed and constructed, unbonded concrete overlays have been shown to increase load-carrying capacity and extend pavement life."

Figure 2 represents a typical pavement condition curve over the life of a pavement. The maintenance, rehabilitation, and reconstruction zones are noted where bonded and unbonded overlays can be used to restore pavement to original or better condition.

On the following pages, figures 3 to 8 and the accompanying dialogs provide brief overviews of each of the six concrete overlay types.

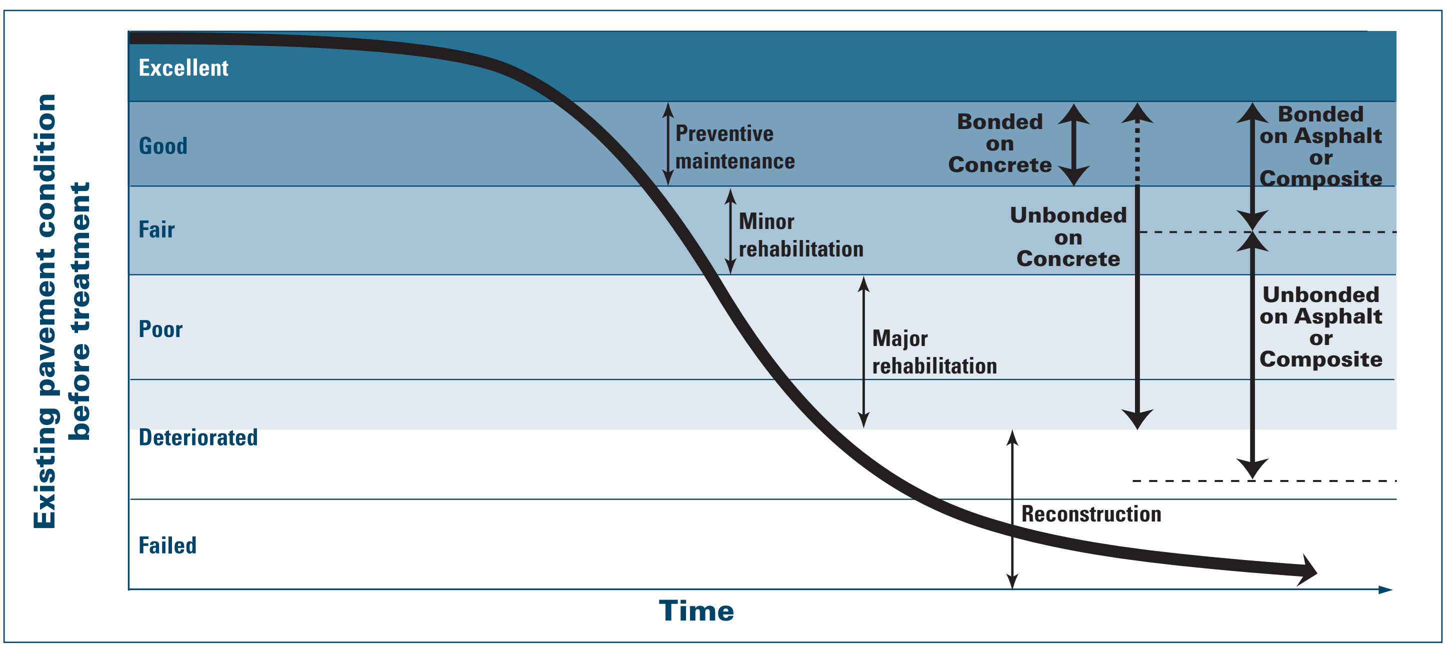


Figure 2. Typical bonded and unbonded concrete solutions for maintenance, rehabilitation, and reconstruction needs

Uses and Key Issues for Each Concrete Overlay Type

Bonded Concrete Overlay System

Typically 2 to 5 in. (50 to 125 mm) thick, depending on desired life (15 to 25+ years), anticipated traffic loading, and condition of underlying pavement
Overlay and existing concrete pavement act as one monolithic pavement (figures 3 to 5).

Bonded Concrete Overlays of Concrete Pavements

–previously called bonded overlays–

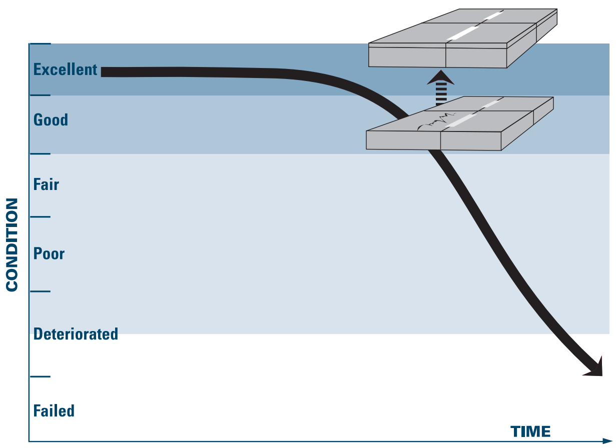


Figure 3. Bonded overlay on concrete pavement

Existing pavement condition

Good structural condition; some surface distress OK

Applications

- To eliminate surface defects such as extensive scaling or surface cracking or to improve surface characteristics like friction, noise, and rideability
- To enhance structural capacity to accommodate increase in traffic loads
- To meet vertical clearances
- To mill and inlay sections

Keys to success

- Existing pavement surface must be prepared to enhance bonding to the overlay
- Overlay's aggregate thermal properties (CTE) must be similar to (or lower than) existing pavement's to minimize shear stress in bond
- Working cracks in the existing pavement should be repaired (or the overlay should be sawed over the crack) to prevent the crack from reflecting through the overlay
- Existing joints must be in fair condition or repaired
- Thinner overlays may shorten sawing window
- Transverse joints in the overlay must be sawed full depth plus .50 in. (12 mm); longitudinal joints must be at least T/2
- Joints in the overlay must align with those of existing pavement because the structure must move monolithically
- Width of transverse joints in the overlay must be equal to or greater than the underlying crack width at the bottom of the existing transverse joint
- Application of curing compound or other curing methods must be timely and thorough, especially at edges

Bonded Concrete Overlays of Asphalt Pavements

–previously called ultra-thin whitetopping–

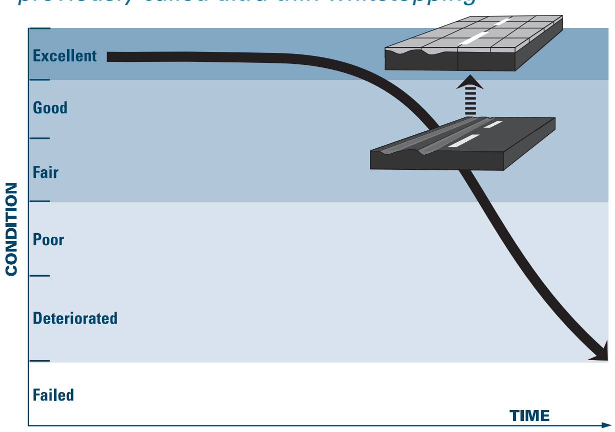


Figure 4. Bonded overlay on asphalt pavement

Existing pavement condition

Fair or better structural condition with surface distress

Applications

- To eliminate surface defects such as rutting and shoving or to improve surface characteristics like friction, noise, and rideability
- To increase structural capacity where traffic loads have increased or will increase
- To meet vertical clearances
- To reduce urban heat island effect by increasing pavement surface albedo

Keys to success

- Milling of existing asphalt may be required to eliminate or reduce surface distortions of 2 in. (50 mm) or more and to help provide good bond; minimal spot repairs may be required
- Minimum 3 to 4 in. (75 to 100 mm) of asphalt should remain after milling
- Asphalt surface temperature must be maintained below 120ºF (49ºC) when placing overlay
- Joints in overlay should be sawed in small, square panels
- Transverse joints must be sawed T/3 (with special attention to thickened overlay over asphalt ruts)
- Joints in the overlay should not be placed in wheel paths, if possible
- Thinner overlays may shorten sawing window; additional saws are likely to be required
- Application of curing compound or other curing methods must be timely and thorough, especially at edges

Bonded Concrete Overlays of Composite Pavements

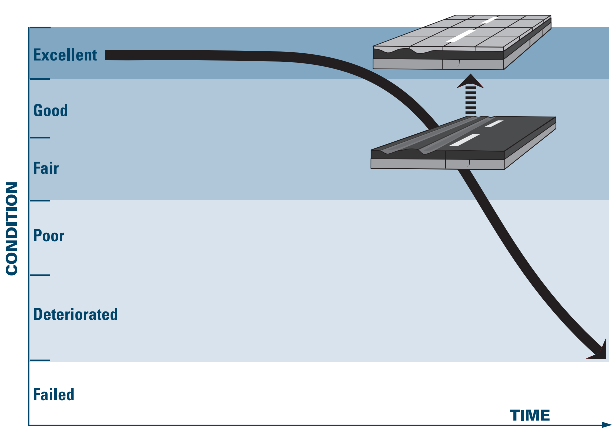


Figure 5. Bonded overlay on composite pavement

Existing pavement condition

Fair or better structural condition with up to severe surface distress

Applications

- To eliminate surface defects such as rutting and shoving or to improve surface characteristics like friction, noise, and rideability
- To increase structural capacity where traffic loads have increased or will increase
- To meet vertical clearances
- To reduce urban heat island effect by increasing pavement surface albedo

Keys to success

- If existing pavement profile indicates isolated vertical distortions in underlying concrete that could signal movement from drainage or material-related distresses, repairs may be necessary
- Milling existing asphalt may be required to eliminate surface distortions of 2 in. (50 mm) or more and to help provide good bond; minimal spot repairs may be required
- Minimum 3 to 4 in. (75 to 100 mm) of asphalt should remain after milling
- Existing asphalt pavement surface temperature must be maintained below 120ºF (48.89ºC) when placing overlay
- Joints in overlay should be sawed in small, square panels
- Transverse joints must be sawed T/3 (with special attention to thickened overlay over asphalt ruts)
- Joints in the overlay should not be placed in wheel paths, if possible
- Thinner overlays may shorten sawing window; additional saws are likely to be required
- Application of curing compound or other curing methods must be timely and thorough, especially at edges

Unbonded Concrete Overlay System

Typically 4 to 11 in. (100 to 280 mm) thick, depending on desired life (15 to 30+ years), anticipated traffic loading, and condition of underlying pavement
In general, an unbonded overlay less than 6 in. (150 mm) thick on an asphalt pavement (not composite) normally requires at least 6 in. (150 mm) of existing asphalt pavement (after milling). If the remaining asphalt is less than 6 in. (150 mm) thick, a bonded overlay should be considered.
Overlay serves as a new pavement on a stable platform (figures 6 to 8).

Unbonded Concrete Overlays of Concrete Pavements

–previously called unbonded overlays–

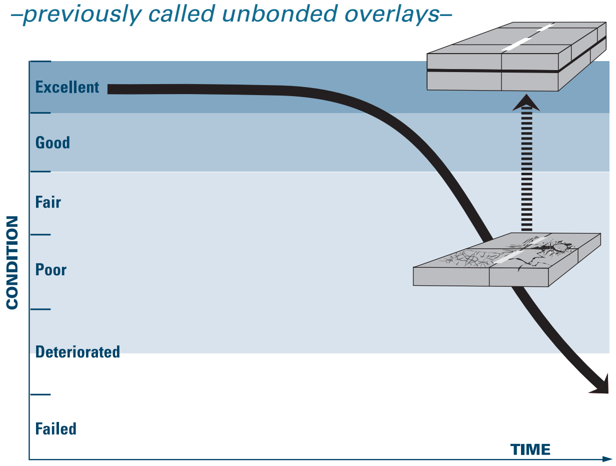


Figure 6. Unbonded overlay on concrete pavement

Existing pavement condition

Poor condition, including material-related distress, but stable and uniform

Applications

- To restore or enhance pavement's structural capacity
- To increase pavement life equivalent to full-depth pavement
- To improve surface friction, noise, and rideability

Keys to success

- Full-depth repairs should be considered only at isolated spots where structural integrity needs restoring
- A separation layer (typically 1 in. [25 mm] asphalt) is required to separate overlay from the existing concrete and eliminate reflective cracking (to reduce pore pressure and minimize stripping of this separation layer under high truck traffic, provide adequate drainage and a more porous asphalt)
- Some states are experimenting with geotextile materials for the separation layer
- Faulting of 0.38 in. (10 mm) or less in the existing concrete pavement is generally not a concern when asphalt separation layer is 1 in. (25 mm) or more
- Joints should be sawed in overlay as soon as possible because the sawing window may be shorter than it is typically
- Shorter joint spacing than normal in the overlay can help reduce curling and warping stress
- It is not critical to match or mismatch overlay joints to the underlying joints

Unbonded Concrete Overlays of Asphalt Pavements

–previously called conventional whitetopping–

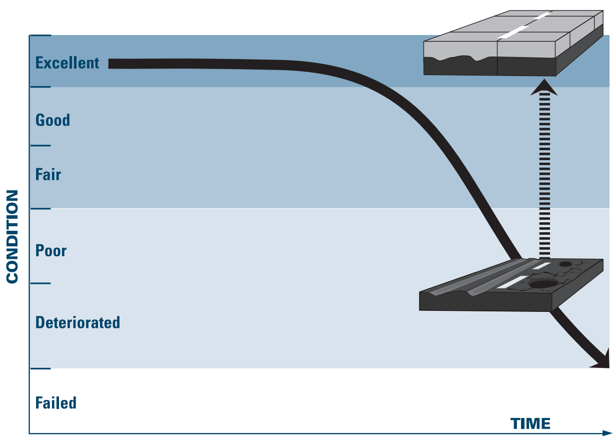


Figure 7. Unbonded overlay on asphalt pavement

Existing pavement condition

Deteriorated (severe rutting, potholes, alligator cracking, shoving, and pumping) but stable and uniform

Applications

- To restore or enhance pavement's structural capacity
- To increase pavement life equivalent to full-depth pavement
- To eliminate deterioration problems
- To improve surface friction, noise, and rideability
- To reduce urban heat island effect by increasing pavement surface albedo

Keys to success

- Milling existing asphalt may be required to eliminate surface distortions of 2 in. (50 mm) or more
- If less than 6 in. (150 mm) of asphalt remains after milling, a 6 in. (150 mm) or greater unbonded overlay (or a thinner bonded overlay) should be considered
- Full-depth repairs should be considered to restore structural integrity in isolated areas
- Concrete patches in the existing pavement should be separated from the overlay with a thin layer of fabric or other bond breaker, or joints should be sawed in the overlay around the concrete patch perimeter
- Overlay joints should be sawed as soon as possible because the sawing window may be shorter than it is typically
- Surface temperature of existing asphalt pavement should be maintained below 120ºF (49ºC) when placing overlay
- Partial bonding between the overlay and the existing asphalt pavement is acceptable and may even improve load-carrying capacity

Unbonded Concrete Overlays of Composite Pavements

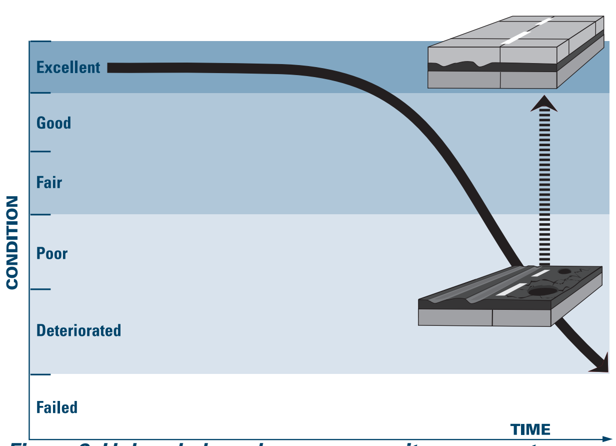


Figure 8. Unbonded overlay on composite pavement

Existing pavement condition

Deteriorated (severe rutting, potholes, alligator cracking, shoving, pumping, and past material-related distress) but stable and uniform

Applications

- To restore or enhance pavement's structural capacity
- To increase pavement life equivalent to full-depth pavement
- To eliminate rutting and shoving problems
- To improve surface friction, noise, and rideability
- To reduce urban heat island effect by increasing pavement surface albedo

Keys to success

- Milling of existing asphalt may be required to eliminate surface distortions of 2 in. (50 mm) or more
- If the existing pavement profile indicates isolated areas of vertical distortion in the underlying concrete that could signal movement from drainage or material-related distresses, repairs may be necessary
- Full-depth repairs should be considered only at isolated spots where structural integrity needs restoring
- Concrete patches in the existing asphalt pavement surface should be separated from the overlay with a thin layer of fabric or other bond breaker; or joints should be sawed in the overlay around the concrete patch perimeter
- Joints should be sawed in overlay as soon as possible because the sawing window may be shorter than it is typically
- Surface temperature of the asphalt layer of the existing composite pavement should be maintained below 120ºF (49ºC) when placing overlay
- Partial bonding between the overlay and the asphalt layer of the existing composite pavement is acceptable and may even improve load-carrying capacity

Evaluating Existing Pavement Conditions

Evaluating the existing pavement condition is an important part of the pavement preservation and rehabilitation process. A comprehensive evaluation provides valuable information about the pavement's performance capabilities and limitations, including the following:

- Presence, type, and extent of distress
- Structural condition and load-carrying capacity
- Functional characteristics of the pavement, such as roughness, friction, and noise
- Characteristics and behavior of in-place pavement materials

Several activities can be performed as part of the pavement evaluation process (see Hall et al. 2001; Hoerner et al. 2001; NCHRP 2007). Specifics will vary from project to project, depending on the project type and relative significance. Generally, the process can be divided into the following steps (Hoerner et al. 2001; NCHRP 2007) (figure 9; appendix A):

1. Historical data collection, records review, and future projections
2. Visual surface examination
3. Core analysis
4. Possible additional tests, including analyses of material-related distresses, drainage, roughness and surface friction, and grade restrictions
5. Condition assessment profile, summarized in condition assessment evaluation report

Historical Data and Future Projections

The first step is to collect data from office files and other historical records associated with the project. The goal is to collect as much information about the existing pavement as possible, such as original design data, construction information, subgrade/subbase data, materials testing data, traffic data, performance data, and so on. Possible data sources for this effort include the following:

- Design reports
- Construction plans/specifications (new and rehabilitation)
- Materials and soils properties from previous laboratory test programs and/or published reports
- Past pavement condition surveys, nondestructive testing and/or destructive sampling investigations
- Maintenance/repair histories
- Traffic measurements/forecasts
- Environmental/climate studies
- Pavement management system reports

The information gathered in this step can be used to divide the pavement into discrete sections with similar design and performance characteristics.

This step also includes determining future performance requirements, like expected traffic loadings and overlay design life.

Visual Examination

The second step is a visual site inspection to gain initial information about the pavement's performance and distress issues. Discussions with local design and maintenance engineers may also be beneficial. Information should be gathered on pavement distress, road roughness, surface friction, shoulder conditions, and moisture/drainage problems, as well as traffic control constraints, obstructions, right-of-way zones, presence of bridges and other structures, and general safety issues.

The FHWA publication *Distress Identification Manual for the Long-Term Pavement Performance Program* (2003a) is useful when identifying pavement distresses and measuring their severity.

Information obtained in this step will be used to determine the type and extent of field testing required. For example,

- Distress observations may help the owner determine the data collection interval, number of surveyors needed, and any additional measurement equipment that might be required.
- Roughness data may dictate the need for a more rigorous measurement program to address any differential sag/swell problems.

One key to successful concrete overlays is ensuring that the underlying pavement and subgrade/subbase provide uniform support. Consideration should be given to any deterioration of an asphalt surface course (existing asphalt or composite pavement), as asphalt is a good reflector of underlying problem areas. Examples include subbase/subgrade problems, material-related distresses such as alkili-silica reaction or D-cracking in a concrete layer, and other defects that result in isolated expansion or loss of support.

A review of the existing profile grade line should be conducted; areas of significant deviation will have to be investigated through analysis of core samples. Evidence of numerous active panel movements in a concrete or composite pavement may indicate potentially unstable or nonuniform subgrade support or material-related distress. These, too, will require detailed pavement analyses to determine the extent of distress and possible corrective action(s). For example, if movement is confined to isolated areas, full-depth repairs in these areas may be considered.

Panel tenting (early stages of blowups) may indicate the presence of a void under a concrete panel in an existing concrete or composite pavement. Sections with significant tenting can be repaired to relieve the pressure and provide uniform support.

Pavement Coring

The third step is to take cores from the existing pavement. The cores help owners determine layer thickness and identify the pavement's support value, the kind and condition of layer materials, depth of distress(es), and, if the existing pavement is composite, the condition of the existing bond between layers. Cores that penetrate into the subgrade may show evidence of unstable conditions, such as the beginning of fine soil migration into open-graded subbase layers that can lead to plugging and instability. Cores also provide samples for possible laboratory analyses.

Optional Analyses

Various factors affect the necessity for and extent of additional pavement evaluation tests. These factors include the existing pavement condition and performance as determined during the first three steps of the evaluation process; network-level performance data; roadway classification; current and future traffic volumes, especially truck traffic; current and future service life; budgetary constraints; and type of overlay being considered. For example, additional analysis may not be required for lower road classifications, such as local streets.

An effective pavement condition evaluation is always necessary to confirm the validity of either a bonded or unbonded overlay solution. In general, however, more information about the existing pavement condition is required when bonded overlay systems are being considered or designed. There are several reasons for this:

- The performance of bonded concrete overlays is more dependent on the condition of the existing pavement.
- Because bonded overlays are relatively thin, they are somewhat more susceptible to stresses, and the very nature of a bond imposes stress.
- The existing pavement will become part of a monolithic, overlaid pavement structure (not just a base for an unbonded overlay), so it needs to contribute a certain level of strength and integrity and be capable of developing and maintaining a bond with the overlay.

Therefore, when evaluating a pavement's suitability for a bonded concrete overlay, it is particularly important to characterize the existing cross section and pavement characteristics and the type, severity, and extent of distress(es).

Laboratory testing may not be required on every project. Lab tests may be conducted to confirm or clarify results from the visual examination, reveal distress mechanisms, and provide additional information needed to identify feasible treatments. Examples of information determined from lab tests include the following:

- Concrete strength data
- Stiffness of existing concrete and asphalt and of composite layers
- Petrographic testing and analysis of material-related or other durability distress
- Support values of the subgrade and subbase
- Concrete permeability
- Asphalt stripping
- CTE of concrete

Material-Related Distress

A detailed engineering evaluation of the type, degree, and state of MRD may be warranted to determine if an overlay is feasible. Unbonded overlays on concrete or composite pavements with material-related distress can be expected to have a long life, equal to a full-depth concrete pavement, if the overlays are designed correctly, taking into account any nonuniformity in the existing pavement.

Thicker unbonded overlays (6 in. [150 mm] or greater) have been used successfully on ASR distressed concrete pavement (alone or as part of an existing composite pavement) in a variety of climates and for a wide range of highway classes. These overlays perform extraordinarily well when the reactive aggregate expansion is near completion or is relatively uniformly spread throughout the existing pavement.

However, extreme variation in degree of ASR distress along the length of pavement (particularly when distress is concentrated at the joints) can result in nonuniform support and consequent performance challenges for the overlay.

Since D-cracking normally occurs at or near concrete joints, bonded concrete overlays on concrete pavements with D-cracking (or composite pavements in which the concrete layer has D-cracking) have had mixed performance results. Localized joint movement and even failure can occur in the underlying pavement. This may cause cracking in the bonded overlay as a result of the nonuniform base support.

Distress Surveys

Information gained from distress surveys will have the greatest impact on identifying necessary spot repairs and selecting appropriate overlays. Pavement distress in the form of visible defect or deterioration of the pavement is the most basic indication of an existing pavement's current performance and structural condition. To evaluate pavement condition more completely, the type, severity, and extent of distresses should be examined in detail:

- Types of distress are determined primarily by occurrence and appearance and can indicate the underlying causes of deterioration.
- Severity of distress represents the criticality of the distress in terms of progression; more severe distresses will require more extreme rehabilitation measures.
- The extent of each distress type and severity level must be measured.

Pavement deflection testing is an effective way to assess a pavement's structural capabilities. Again, pavement deflection tests are not required for all pavements, especially those in fair or better condition and on lower volume roads.

Several deflection devices are available, but all operate in basically the same manner. A known load is applied to a pavement surface, and the resulting deflection is measured. The FWD, or any device capable of applying loads similar in magnitude and duration to that of a moving wheel load, is commonly used. Deflection test results are also used to develop pavement deflection profiles, back-calculate layer properties, determine load transfer capabilities, and evaluate the potential for voids at slab corners.

Drainage Surveys

Poor drainage conditions are a major cause of distress in pavement structures. Unless moisture-related problems are identified and corrected, the effectiveness of repairs and overlays will be reduced. As part of a pavement distress survey, the overall drainage conditions of the existing pavement should be assessed. Observations of moisture/drainage problems (e.g., pumping, corner breaks, standing water, and so on) may indicate the need for a more intensive FWD test for the support value *k* or a more thorough survey of subsurface drainage conditions. The purposes of a drainage survey are to

- detect and identify moisture-related distress,
- document prevailing drainage conditions (e.g., cross slopes, cut/fill areas, depth and condition of ditches), and
- assess edge drain conditions.

If edge drains are present, their effectiveness should be evaluated by observing their outflow after a rainfall or after water is released from a water truck over pavement discontinuities. Another way to assess edge drain effectiveness is through video inspections (Daleiden 1998; Christopher 2000). A video camera attached to a pushrod cable and inserted into the drainage system at outlets can locate blockages like rodents' nests or areas of crushed pipe. Several states have adopted edge drain video inspection in their pavement evaluation/construction process.

It is especially important to determine the subgrade soil's freeze-thaw and shrink-swell characteristics. Soil strength-related tests using the dynamic cone penetrometer or the standard penetration test provide useful information about subgrade stability.

Possible drainage problems indicated by a drainage survey may suggest the need for in-depth analysis of the pavement structure's drainability. DRIP (Drainage Requirements In Pavements), an FHWA computer program, can assist in such an analysis (Mallela et al. 2002).

Roughness and Surface Friction Tests

Roughness and surface friction are two key indicators of the functional performance of a pavement: its smoothness for comfortable ride and its skid resistance for safety. Roughness testing (expressed in terms of the International Roughness Index) at the project level can be useful to help identify localized areas of roughness and to assess the effectiveness of treatments (pre- and post-treatment roughness comparisons). Friction (skid resistance) testing is not commonly conducted for project-level evaluations but may be meaningful on projects exhibiting a disproportionate number of wet-weather crashes.

Elevations and Grade Restrictions

Constructing concrete overlays will raise the roadway profile grade unless it is lowered through mechanical measures such as milling. Consideration should be given to the effects of grade change, particularly at bridge underpasses and approaches, shoulder areas, and curb and gutter units. Design details for these situations are included on pages 38 to 39.

Condition Assessment Profile

When all aspects of an existing pavement have been evaluated, the critical distresses and drainage conditions should be summarized. One useful way to summarize this information is to plot it on a condition assessment profile, or strip chart (Smith 2008). In bar chart form, this profile visually indicates where various distresses occur over the length of the project, as well as their extent and severity. Distresses such as slab cracking, corner breaks, faulting and spalling, continuous roughness, etc., can be displayed. Areas of poor drainage or significant changes in topography (cut/fill sections) can be overlaid on the strip charts. Such summaries provide critical insight into a pavement's structural and functional performance, helping roadway owners determine if and when pavement preservation or rehabilitation activities are appropriate.

Pavement Evaluation Report

The final evaluation step is summarizing the results of data collection and analyses in an evaluation report. Any critical non-pavement factors, such as shoulder condition, ditches, right-of-way, curves, bridges, ramps, and traffic patterns should be identified in the report. Ultimately, this information will be used in the identification and selection of appropriate spot repairs and overlays (figure 10; appendix A).

Initial Evaluation (steps 1–4)

1 Pavement History and Performance Goals

- Pavement material (including aggregate CTE), design, age, thickness, layers
- Existing traffic and performance level
- Design life
- Remaining life
- Desired traffic and performance level
- Desired design life
- Elevations and grade restrictions
- Other historical information

2 Visual Examination

Concrete | Asphalt / Composite

Figure 9. Examples of existing pavement conditions (Photo courtesy of Snyder and Associates)

3 Core Analysis

- Type of distress
- Depth of distress
- Verification of thickness for pavement base/subbase

4 Optional Analyses

(depending on extent of problems)

4-a. Material-Related Tests

(indicated by core analysis)

Conduct if (a) material or durability issues are indicated or (b) roadway provides service for high levels of traffic, especially if a bonded overlay is being considered.

- Petrography analysis
  - Concrete material-related distress (MRD)
  - Poor air-void system
- Asphalt stripping
- CTE

4-b. Subsurface Tests

Conduct if (a) pavement or subgrade support issues are indicated or (b) roadway provides service for high levels of traffic, especially if a bonded overlay is being considered.

- FWD tests
  - Subgrade/subbase support (*k* value)
  - Subgrade/subbase variability
  - Pavement properties
  - Load transfer efficiency
  - Presence of voids
  - Asphalt stiffness
  - Concrete flexural strength
- Subgrade tests
  - Freeze-thaw characteristics
  - Shrink-swell characteristics
  - Soil strength (dynamic cone penetration or standard penetration test)

4-c. Surface Texture Tests

Conduct if (a) materials or durability issues are indicated, or (b) roadway provides service for high levels of traffic, especially if a bonded overlay is being considered.

- International roughness index (IRI)
- Friction (skid resistance) tests

Initial Evaluation (step 5)

5 Condition Assessment Profile

Concrete

Surface Deficiencies

- Friction loss
- Joint deterioration (low to medium)
- Map cracking (non-ASR)
- Popouts
- Noise
- Scaling
- Roughness (not distress-related)
- Plastic shrinkage cracks
- Thermal shrinkage cracks
- IRI
- Other

Structural Deficiencies

- Corner breaks
- Joint deterioration (severe)
- Tented panels
- Longitudinal cracking
- Pumping/faulting
- Punchout
- MRD (medium to severe)
- Transverse cracking
- Subgrade/subbase condition
- Other

Asphalt / Composite

Surface Deficiencies

- Bleeding/flushing
- Block cracking
- Friction loss
- Noise
- Corrugation
- Joint reflective cracking
- Roughness (not distress-related)
- Rutting
- Weathering/raveling
- Shoving
- Slippage
- IRI
- Other

Structural Deficiencies

- Fatigue (alligator) cracking
- Depressions
- Heaves
- Longitudinal cracking
- Potholes
- Transverse thermal cracking
- Rutting/shoving
- Subgrade /subbase condition
- Other

Pavement Evaluation Report and Pavement Condition Rankings

Figure 9. Examples of existing pavement conditions, continued

Summary of Pavement Evaluation Process

The purpose of evaluating the existing pavement's condition is to collect details about any distresses and performance problems that currently exist and their causes. This information helps the owner-agency determine if a pavement is a good candidate for a concrete overlay and, if so, the extent of spot repairs required before an overlay is constructed. The extent of repairs needed is an important factor in determining if/when either a bonded or unbonded overlay will be a cost-effective solution.

Evaluating the existing pavement's condition involves at least three steps:

1. The first step is to review the pavement's historical design and performance record: pavement thickness and other design attributes, mixture materials and design, construction date and method, traffic loadings, design life, maintenance activities to date, etc.

   Along with looking at the historical records, this step should include recording future performance requirements, like expected traffic loadings and overlay design life.

   This step should include a determination of any elevation limits and/or grade restrictions that signal potential clearance issues for overlay construction.

2. The second step is a visual examination of the pavement's condition, noting visible surface and structural distresses.

3. The third step is a more thorough examination of the pavement structure through a core analysis. This step will identify distresses or performance problems that cannot be determined by a visual exam alone. Core analyses verify pavement thickness, the subgrade/subbase material and thickness, and the depth and perhaps type or cause of distresses.

Based on information learned in steps 1 through 3, the necessity for additional evaluation should be considered. For example, tests related to materials or durability distresses, possible support problems, or surface conditions may be necessary. The following questions can help the pavement owner determine if additional tests are advisable:

- **What is the extent of pavement distresses,** based on the visual evaluation and core analysis?
- **What is the pavement's expected service level and life?** Major highways with significantly high truck volumes and/or long service life require more extensive and comprehensive evaluations than lower volume roadways.
- **Is a bonded or unbonded concrete overlay being considered?** Bonded overlays can represent some additional challenges compared to unbonded overlays.

Results from all initial evaluation steps should be recorded in a Condition Assessment Profile. This profile helps the agency determine the pavement's overall condition and summarize it in a Pavement Evaluation Report.

Selecting Appropriate Concrete Overlay Solution

Several factors should be considered when selecting the type of concrete overlay solution. The condition of the existing pavement is the paramount factor. Generally, existing pavements in relatively good condition, or that can be cost-effectively brought to good condition, are candidates for bonded concrete overlays. In these cases, bonded overlays can improve functionality (e.g., reduce roughness or noise or enhance friction) and/or increase struc-

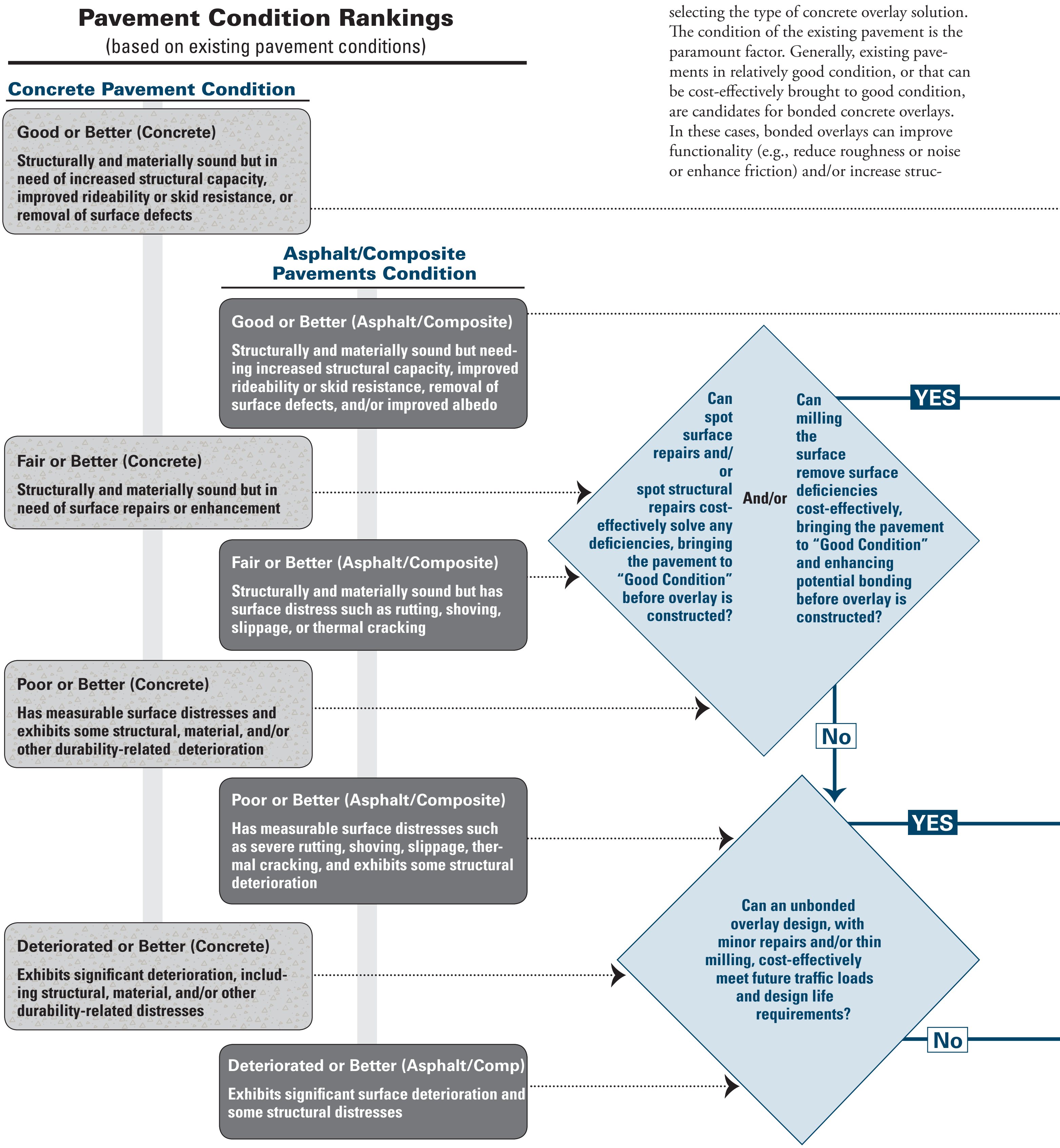


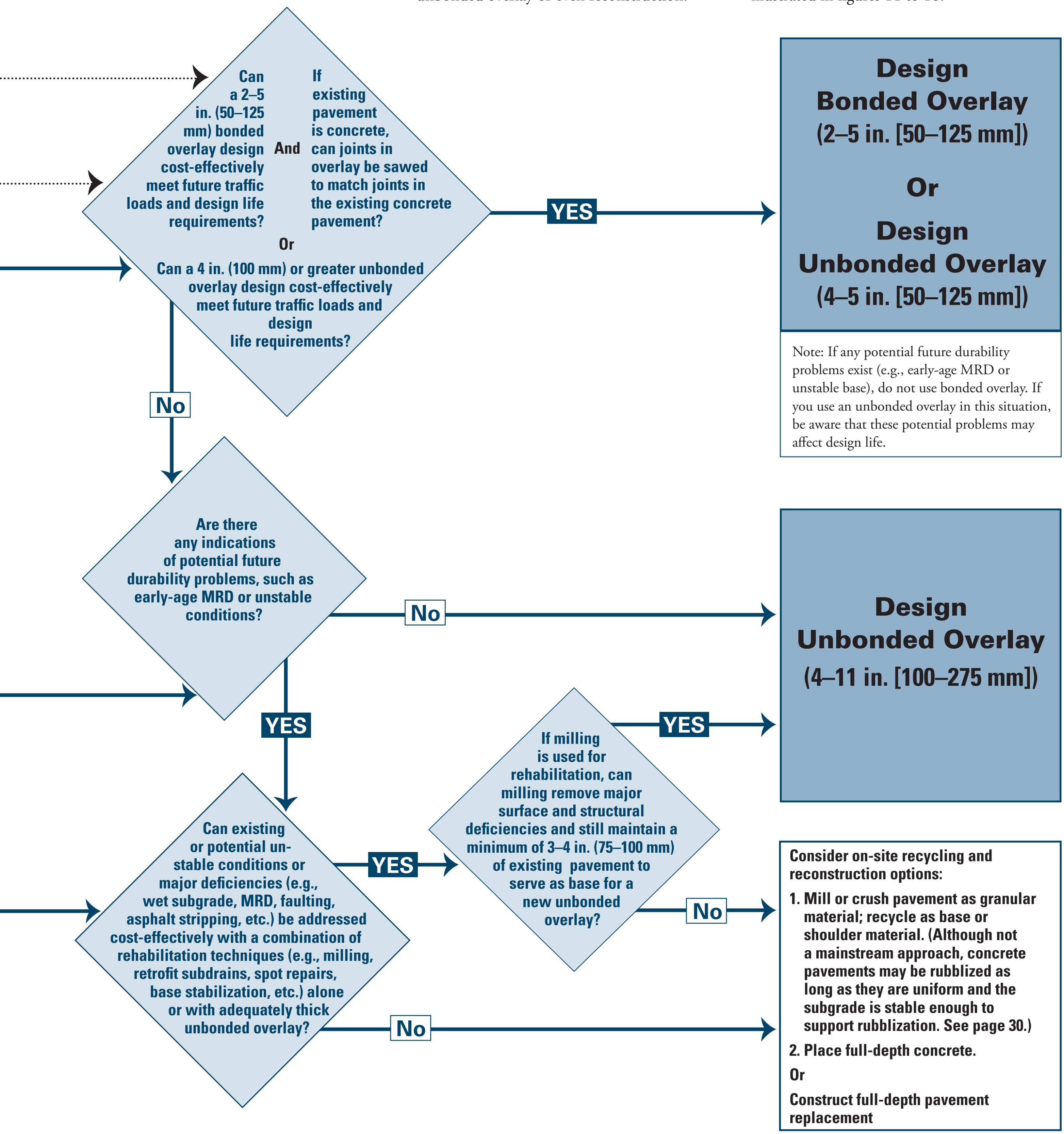
Figure 10. Flowchart process for selecting concrete overlay type

tural capacity (e.g., accommodate anticipated increases in truck traffic loadings). For example, a pavement in fair to poor functional condition due to rutting and shoving can be resurfaced with a bonded overlay, after the pavement has been improved to good condition through spot repairs or milling to remove deficiencies. The bond between the overlay and the existing pavement inherently adds structural capacity. In this situation, however, it may be just as cost-effective to place a slightly thicker unbonded overlay with less preoverlay repair work and not have to depend on the bond.

Generally, existing pavements in poor condition and exhibiting significant structural deterioration are candidates for unbonded overlays. Moreover, the presence of MRD, such as ASR or D-cracking, on an existing concrete pavement also suggests the need for an unbonded overlay or even reconstruction.

Concrete overlays can provide economical short- to long-term solutions. It should be noted, however, that the recommendations provided in the flowchart (figure 10) are generally long-term fixes, on the order of 20 years or more of expected life.

The next several pages provide overviews of the important issues related to designing and constructing each type of concrete overlay, as illustrated in figures 11 to 18.



Bonded Concrete Overlays of Concrete Pavements

—previously called bonded overlays—

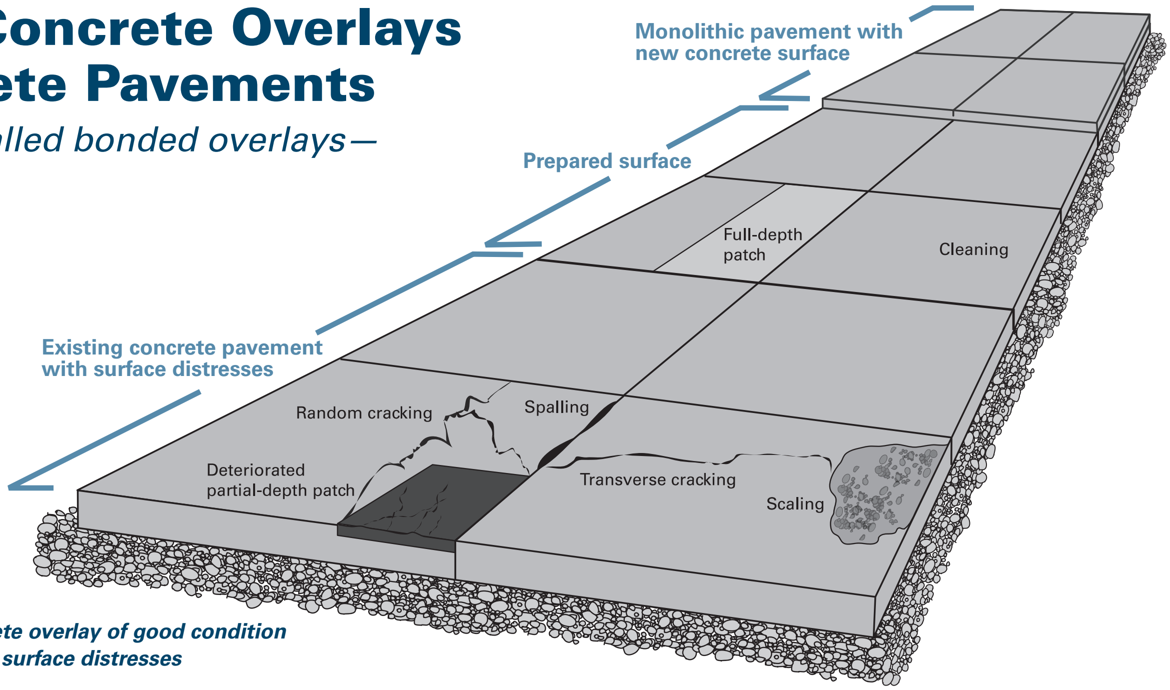


Figure 11. Bonded concrete overlay of good condition concrete pavement with surface distresses

Uses

Bonded concrete overlays should be used on concrete pavements only if the existing pavement is in good or better condition. Concrete pavements that are structurally sound but need increased structural capacity and/or correction of surface defects, such as extensive scaling or surface cracking, can benefit from a 2 to 5 in. (50 to 125 mm) bonded concrete overlay. Resulting enhancements include improved rideability, skid resistance, and reflectivity characteristics.

A bonded concrete overlay relies on the existing concrete pavement to carry some traffic loading. The overlay is bonded to the existing concrete pavement to form a monolithic section, thereby reducing stresses and deflections. Under certain conditions, a mill and inlay can be used if the existing pavement has significant surface issues but is structurally sound and the subbase/subgrade is stable.

Performance

Bonded concrete overlays have been successfully used for over 90 years as a means of strengthening old concrete pavement, providing a new smooth surface, repairing surfaces with popouts, or repairing other surface defects such as spalls, scaled areas, and areas with high steel near the surface.

Overlay Process

1 PAVEMENT EVALUATION

An evaluation of the existing concrete pavement is necessary to ensure that it is a good candidate for a bonded overlay and that, once resurfaced, it will be structurally sound enough to carry anticipated traffic loads. For general information on pavement evaluation, see pages 6 through 9.

If an existing concrete pavement exhibits cracking from expansion caused by MRD, such as ASR or D-cracking, it is not a good candidate for a bonded concrete overlay. An unbonded overlay may be considered.

2 OVERLAY DESIGN

Overlay Thickness

The design thickness for bonded concrete overlays is typically 2 to 5 in. (50 to 125 mm), depending on the desired load-carrying capacity and service life and the structural capacity provided by the underlying pavement. Some states, such as Colorado, use 6 in. (150 mm) bonded overlays on high-traffic roads.

Thickness is commonly determined using an established design procedure such as AASHTO *Guide for Design of Pavement Structures* (AASHTO Guide) (1993, 1998). However, agencies are becoming increasingly familiar with the procedure in the M-E PDG as well. For more information, see table 8 on page 26.

Mixture Design

Conventional concrete mixtures have been successfully used for bonded concrete overlays of concrete pavements. When used in conjunction with mixture additives and accelerated construction techniques, conventional concrete mixtures can be proportioned for rapid strength gain with corresponding minimum expansion and contraction. For additional information on expedited mixtures, see page 34.

The use of high-modulus structural fibers in the mixture can improve the toughness and post-cracking behavior of the concrete and help control plastic shrinkage cracking.

Regarding concrete aggregate, the following issues should be considered:

- A well-graded aggregate will reduce the water and paste content of the mixture, thus reducing potential shrinkage and curling, as well as the related risk of debonding. The maximum aggregate size of the overlay concrete should be one-third of the overlay thickness.
- Aggregate with CTE similar to or lower than that of the existing concrete pavement will help ensure the two layers move together, thus reducing stresses at the interface.
- Pore space in the aggregate should be fully saturated before batching (saturated surface, dry condition); otherwise, the aggregate will tend to pull water from the mixture at early ages, increasing the possibility of shrinkage, which can lead to debonding.

Joint Design

The bonded overlay joint type, location, and width must match those of the existing concrete pavement in order to create a monolithic structure. Matched joints eliminate reflective cracking and ensure that the two layers of the pavement structure move together, helping maintain bonding. To minimize curling and warping stresses, some agencies have successfully created smaller overlay panels by sawing additional transverse and longitudinal joints in the overlay between the matched joints.

An important element in transverse joint design is joint dimensions. The depth should be full depth plus 0.50 in. (13 mm). To prevent debonding, the width of the transverse joint should be equal to or greater than the width of the underlying joint or crack in the existing pavement (figure 12). The width of the exisitng underlying pavement crack may be determined by spot-excavating along the pavement edge. (If the pavement system experiences expansion and the overlay pushes against itself because the width of the transverse overlay joint is less than the width of the underlying existing pavement crack, debonding may occur.)

Some agencies believe that T/2 is sufficient for longitudinal joint depth. Others recommend sawing longitudinal joints full depth plus .50 in. (13 mm) to cut through the bond line.

Tiebars, dowel bars, or other embedded steel products are not used in bonded concrete overlays to minimize restraint forces in the bond.

Except for joint design, bonded overlays on existing CRCP are designed, prepared, and constructed the same way as bonded concrete overlays on plain jointed concrete pavements. Transverse joints are not cut in bonded concrete overlays over CRCP pavements. Acceptable cracking will occur in the bonded overlay, typically (but perhaps not immediately) over existing cracks in the CRCP.

Drainage Repair

During evaluation and design of a bonded concrete overlay project, existing subgrade drainage should be evaluated, as would be done with asphalt resurfacing. If necessary, steps should be taken to ensure adequate drainage in the future.

3 PREOVERLAY WORK

Preoverlay Repairs

Preoverlay repairs of certain distresses may be necessary to achieve the desired load-carrying capacity and long-term durability. The surface should be inspected for isolated pockets of deterioration that require repairs (table 1).

For isolated areas that have wide random cracks or working joints, full-depth repairs may be necessary. When cracks (particularly working cracks) exist in the pavement to be resurfaced, reflective cracking will almost always occur. Crack cages over existing cracks have been successfully used to prevent reflective cracking.

When voids are detected under existing slabs, the slabs should be stabilized through grout injection or other methods. Asphalt patches should be removed and replaced with concrete patches (or simply filled with concrete at the time of overlay placement) to ensure bonding of the concrete layers.

A consideration in performing repairs is whether movement in the underlying pavement will cause movement in the overlay. Any movement in the overlay that does not occur at matched joints could contribute to debonding and subsequent deterioration of the overlay.

Surface Preparation

Surface preparation of the existing concrete pavement is accomplished to produce a roughened surface that will enhance bonding between the two layers. A variety of surface preparation procedures may be used, including shotblasting, milling, and sandblasting. A bonding grout or epoxy is not required. The most commonly used and most effective surface preparation procedure is shotblasting. Although milling will roughen the concrete pavement surface, milling should not be used solely for that purpose because of its potential for causing surface microcracking and fracturing the exposed aggregate. If milling is used to lower the pavement elevation, any resulting microcracking should be removed by shotblasting or high water pressure blasting.

Surface Cleaning

Following surface preparation, the concrete surface should be cleaned to ensure adequate bonding between the existing concrete surface and the new concrete overlay. Cleaning may be accomplished by sweeping the concrete surface, followed by cleaning in front of the paver with compressed air. Airblasting and waterblasting should be used only as supplementary cleaning procedures to remove loose material from the surface after shotblasting, milling, or sandblasting. In no case should standing water or moisture remain on the pavement surface when the overlay is placed. Paving should commence soon after cleaning to minimize the chance of contamination.

Vehicles should be limited on the existing surface after it is prepared. If it is absolutely necessary to have vehicles on the existing concrete, care should be taken that they do not drip oil or other contaminants that could compromise the bond.

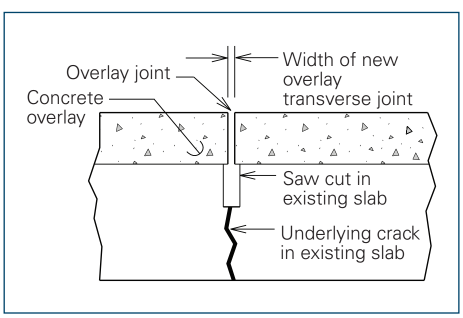


Figure 12. Width of transverse joint in bonded concrete overlay on concrete pavement should be equal to or greater than width of crack in existing pavement

Table 1. Possible preoverlay repairs on existing concrete pavement in preparation for bonded overlay

Existing Pavement Distress	Spot Repairs to Consider
Random cracks	Reflective cracking is likely if no repairs are made; use crack cages or full-depth repairs for severe cracks
Faulting	Slab stabilization
Pumping	Slab stabilization
Asphalt patch	Replace with concrete patch to ensure bonding
Joint spalling	Partial-depth repair
Scaling	Remove with cleaning

4 CONSTRUCTION

Concrete Placement

Grade adjustments may be made to ensure the required thickness of the concrete. Conventional concrete paving practices and procedures are followed for bonded concrete overlays.

Curing

Curing is especially critical on a bonded concrete overlay because its high surface area-to-volume ratio makes the thin concrete overlay more susceptible to rapid moisture loss. Within 30 minutes of placing the overlay, curing compound should be applied at twice the standard rate. The finished product should appear as a uniformly painted solid white surface, with the vertical faces along the edges of the overlay also thoroughly coated.

Joint Sawing

Timely joint sawing is necessary to prevent random cracking. Sawing should begin as soon as the concrete is strong enough that joints can be cut without significant raveling or chipping. Lightweight early-entry saws allow the sawing crew to get on the pavement as soon as possible.

To help match transverse joint locations, place guide nails on each edge of the existing pavement at the joints; after the overlay is placed, mark the joint with a chalk line connecting the guide nails.

Future Repairs

The recommended repair option for bonded concrete overlays on concrete is full-panel replacement. Concrete panels are easily removed and replaced. Another option is simply to mill and fill with concrete. If a panel is cracked or otherwise distressed but the ride quality of the pavement is not compromised, the panel may be left in place.

Key Resources
ACI Committee 325 (2006); Trevino et al. (2004); ACPA (1990a)

Bonded Concrete Overlays of Asphalt Pavements

—previously called ultra-thin whitetopping—

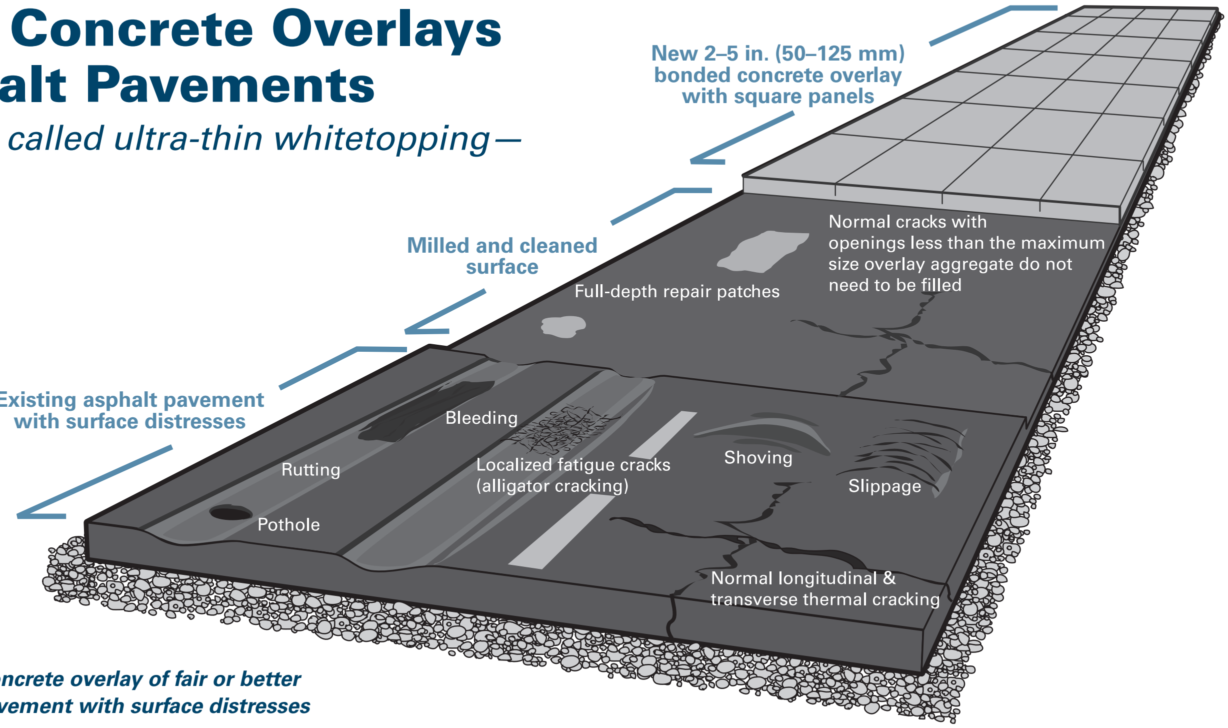


Figure 13. Bonded concrete overlay of fair or better condition asphalt pavement with surface distresses

Uses

Asphalt roads, streets, and intersections that are in fair or better condition structurally can be enhanced with a 2 to 5 in. (50 to 125 mm) bonded concrete overlay if they exhibit surface distresses such as rutting, shoving, slippage, and thermal cracking and/or they could benefit from increased structural capacity.

The bonded concrete overlay relies on the existing asphalt pavement to carry some traffic loading. The overlay is bonded to the existing asphalt pavement to form a monolithic section, thereby reducing stresses and deflections.

Performance

Bonded concrete overlays have been successfully used in many states to maintain and rehabilitate asphalt pavements with surface defects. Numerous studies have shown bonded concrete overlays to provide a durable, reliable surface course as long as there is a sufficient bond between the asphalt surface and the overlay and the existing asphalt pavement is structurally adequate for a bonded concrete overlay.

Factors that affect the performance of the resurfaced pavement system include the strength and integrity of the underlying pavement, the effectiveness of the bond, the ability of the two layers to move monolithically to maintain the bond, and the overlay jointing and curing techniques.

They key to maintaining the performance is to ensure the two structures—the existing asphalt pavement and the overlay—move as one structure.

Overlay Process

1 PAVEMENT EVALUATION

An evaluation of the existing asphalt pavement is necessary to ensure it is structurally adequate to carry the anticipated traffic loads, to determine required milling depths, and to establish the bonded overlay design thickness. For general information on pavement evaluation, see pages 6 through 9.

Asphalt pavements with significant structural deterioration, inadequate or uneven base/subbase support, poor drainage conditions, or stripping of asphalt layers are not good bonded overlay candidates; in such cases, an unbonded concrete overlay should be considered.

2 OVERLAY DESIGN

Overlay Thickness

The design thickness for bonded concrete overlays is typically 2 to 5 in. (50 to125 mm), depending on the desired load-carrying capacity and service life and the structural capacity provided by the underlying pavement. Additional overlay thickness may be required in transition sections to prevent movement of the overlay panels adjacent to the existing asphalt pavement and to reduce the potential for cracking due to traffic impact loadings.

Thickness may be determined using AASHTO Supplement (1998). The most common procedure is an ACPA spreadsheet (revised 2008; www.pavement.com/Concrete_Pavement/Technical/UTW_Calculator/), which incorporates methods to address limitations of the AASHTO procedures. Agencies are also becoming increasingly familiar with the procedure in the M-E PDG. For more information, see table 8 on page 26.

Mixture Design

Conventional concrete mixtures have been successfully used for bonded concrete overlays of asphalt pavements.

When used in conjunction with mix additives and accelerated construction techniques, conventional concrete mixtures can be proportioned for rapid strength gain with corresponding minimum expansion and contraction. For additional information on expedited mixtures, see page 34.

The use of high-modulus structural fibers can improve the toughness and post-cracking behavior of the concrete and help control plastic shrinkage cracking.

Joint Design

The recommended joint pattern for bonded overlays of asphalt is small square panels, typically in the range of 3 to 8 ft (0.9 to 2.4 m), to reduce curling and warping stresses. It is recommended that the length and width of joint squares in feet be limited to 1.5 times the overlay thickness in inches. In addition, if possible, longitudinal joints should be arranged so that they are not in the wheel path. The use of tiebars or dowels is not necessary because of the small panel spacings.

3 PREOVERLAY WORK

Preoverlay Repairs

Areas with potholes; localized, moderate-to-severe alligator cracking; or loss of base/subgrade support may require partial or full-depth spot repairs to achieve the desired load-carrying capacity and long-term durability (table 2). However, new asphalt patches do not bond well with concrete overlays, so new concrete patches are recommended.

Patching with concrete should be completed after milling. Whether a concrete patch is placed separately or poured at the same time as the overlay (i.e., in one paving operation), the result is a spot section of thicker concrete. This thicker section of concrete will move differently from the adjacent asphalt, so no single overlay panel should be over both asphalt pavement and the concrete patch. This will require adjusting the normal jointing pattern of the overlay so the section over the concrete patch is isolated.

Milling

In general, milling should be minimized because it results in loss of structural support. There is no reason to mill off good asphalt that can contribute to composite action and continue to help carry traffic loads.

The main objectives of milling prior to placing a bonded overlay are (1) to remove significant surface distortions that contain soft asphaltic material, which would result in an inadequate bonding surface; (2) to reduce high spots to help ensure minimum overlay depth and reduce the quantity of concrete needed to fill low spots; and (3) to match curb or adjacent structure elevations. Milling may also be considered to roughen the surface, which will likely enhance bonding.

Most surface distresses can be removed through milling (table 2). Milling may be used where surface distortions are 2 in. (50 mm) or greater. The amount of asphalt removed depends on the types and severity of distresses and the thickness of the asphalt. The objective of milling is not to obtain a perfect cross section or to completely remove ruts.

It is important to make sure that the milling depth does not compromise the bonding effectiveness of asphalt tack lines between existing asphalt lifts. Therefore, milling should remove asphalt to the nearest tack line.

A minimum of 3 to 4 in. (75 to 100 mm) of asphalt should remain after milling. An adequate layer of asphalt is required to prevent delamination, thus ensuring that the asphalt will function as a load-carrying portion of the composite section (not as a separation layer or shear plane, as in an unbonded overlay).

While the milling machine is on site, it is important that the pavement surface be inspected to determine if additional milling is required.

Table 2. Possible preoverlay repairs on existing asphalt pavement in preparation for bonded overlay

Existing Pavement Distress	Spot Repairs to Consider
Deep rutting	Milling
Shoving, slippage	Milling
Thermal cracking	Fill crack when opening is greater than maximum size aggregate in the overlay
Fatigue cracking	Full-depth concrete patch
Pothole	Full-depth concrete patch

Further Repairs

After milling, the surface should be inspected for isolated pockets of deterioration that require further repairs. For isolated areas that have a high number of wide transverse thermal cracks, a decision needs to be made whether to bridge the cracks with the bonded overlay or to clean and fill the cracks. Concrete can span normal asphalt longitudinal and transverse cracks. Filling old cracks with fly ash slurry, concrete grout, or other appropriate material is necessary only for cracks that have an opening greater than the maximum size aggregate used in the overlay.

Surface Cleaning

Following repairs, the asphalt surface needs to be cleaned to ensure adequate bonding between the existing asphalt surface and the new concrete overlay. Adequate bonding is very important to the performance of this type of overlay. Cleaning may be accomplished by first sweeping the asphalt surface, then cleaning with compressed air. Pressure washing should be considered only when dust control is mandated or when mud has been tracked onto the milled surface. In no case should water or moisture be allowed to stand on the asphalt pavement prior to overlay placement. To prevent contamination, it is important to avoid a lengthy lag time between final surface cleaning and paving.

4 CONSTRUCTION

Concrete Placement

When the surface temperature of the asphalt is at or above 120°F (48.89°C), surface watering can be used to reduce the temperature and minimize the chance of fast-set shrinkage cracking. No standing water should remain on the surface at the time the overlay is placed. Water trapped in the milled surface can be blown off with compressed air.

Once the surface of the existing asphalt pavement has been prepared, paving is accomplished using either conventional fixed-form or slipform construction, depending on the size of the project and any geometric constraints.

Because of the variation of the thickness of concrete, the concrete material is bid on a cubic-yard basis. Some states also include a bid item for placement on a square-yard basis.

Curing

Curing is especially critical on a bonded concrete overlay because its high surface area-to-volume ratio makes the thin concrete overlay more susceptible to rapid moisture loss. Within 30 minutes of placing the overlay, curing compound should be applied at twice the standard rate. The finished product should appear as a uniformly painted solid white surface, with the vertical faces along the edges of the overlay also thoroughly coated.

Joint Sawing

Timely joint sawing is necessary to prevent random cracking. Joint sawing should commence as soon as the concrete has developed sufficient strength so that joints can be cut without significant raveling or chipping. Lightweight early-entry saws 0.13 in. (3.0 mm) thick may be used to allow the sawing crew to get on the pavement as soon as possible. Extra saws will likely be needed. Transverse joints can be sawed with conventional saws set to a depth of T/4. Transverse joint saw-cut depths for early-entry sawing should not be less than 1.25 in. (31 mm). Longitudinal joints should be sawed to a depth of T/3. Joint sealing may not be required.

Future Repairs

Bonded concrete overlays on asphalt may be easily repaired using full-panel replacement. Another option is simply to mill and fill with concrete. Do not patch with asphalt, because the adjacent concrete panels will move and break the bond. If a panel is distressed but the ride quality of the pavement is not compromised, the panel should be left in place. If a ride quality problem develops, the panel should be replaced before any pieces of concrete become loose from the overlay.

Key Resources
ACI Committee 325 (2006); Rasmussen and Rozycki (2004); ACPA (1999)

Bonded Concrete Overlays of Composite Pavements

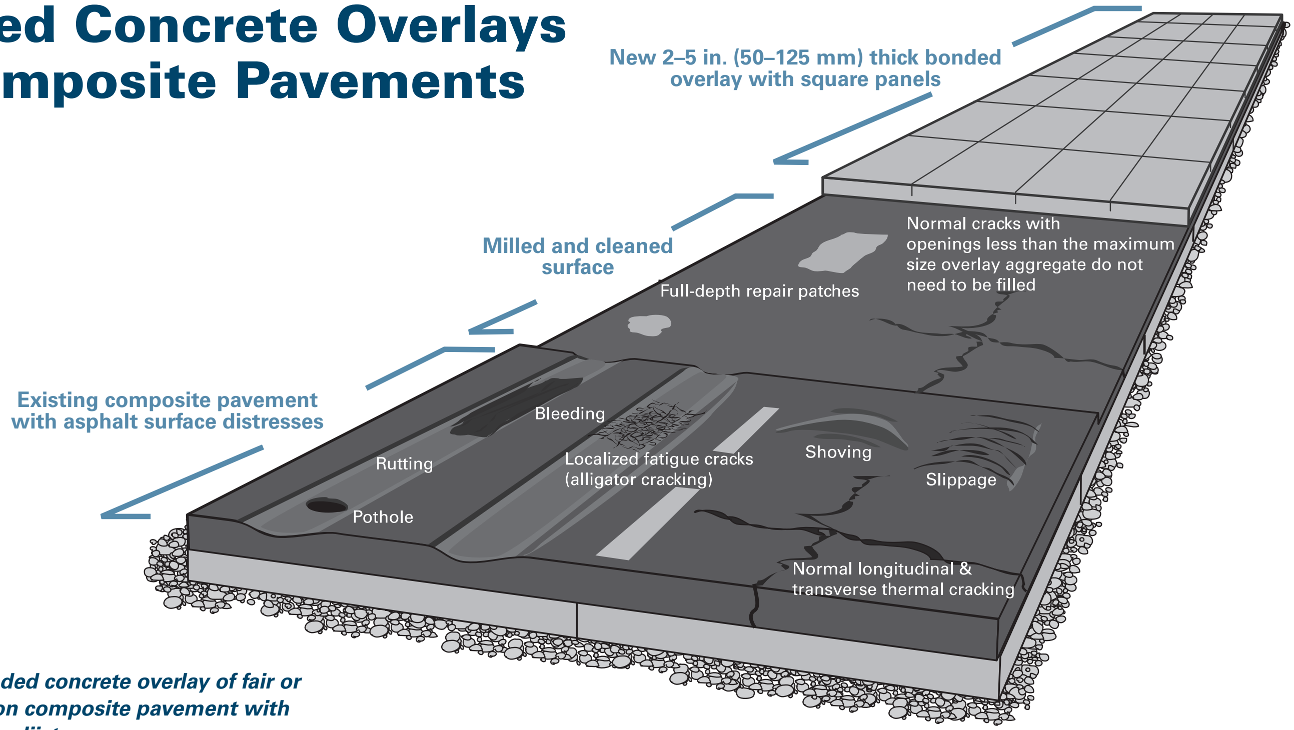


Figure 14. Bonded concrete overlay of fair or better condition composite pavement with asphalt surface diistresses

Uses

Composite (asphalt on concrete) roads, streets, and intersections that are in fair or better condition structurally can be enhanced with a 2 to 5 in. (50 to 125 mm) bonded concrete overlay if they exhibit surface distresses such as rutting, shoving, slippage, and thermal cracking and/or they could benefit from increased structural capacity.

The bonded concrete overlay relies on the existing composite pavement to carry some traffic loading. The overlay is bonded to the existing pavement to form a monolithic section, thereby reducing stresses and deflections.

Performance

Bonded concrete overlays have been successfully used in many states to maintain and rehabilitate composite pavements with surface defects.

Factors that affect the performance of the resurfaced pavement system include the strength and integrity of the underlying pavement layers, the quality of the bond between layers of the existing composite pavement, the effectiveness of the bond between the underlying composite pavement and the new concrete overlay, the ability of the new system to move monolithically to maintain the bond, and the jointing and curing techniques.

The key to maintaining performance is ensuring the two structures—the existing pavement and the overlay—move as one structure.

Overlay Process

1 PAVEMENT EVALUATION

An evaluation of the existing asphalt pavement is necessary to ensure it is structurally adequate to carry the anticipated traffic loads, to determine required milling depths, and to establish the bonded overlay design thickness. For general information on pavement evaluation, see pages 6 through 9.

Composite pavements are not good candidates for bonded overlays of less than 5 in. (125 mm) if they display any of the following problems:

- Significant structural deterioration, inadequate or uneven subgrade/subbase support, poor drainage conditions, or stripping of asphalt layers
- Problems in the underlying concrete (possibly reflected in the asphalt layer) due to MRD
- Indications of possible future durability problems

2 OVERLAY DESIGN

Overlay Thickness

The design thickness for bonded concrete overlays is typically 2 to 5 in. (50 to 125 mm), depending on the desired load-carrying capacity and service life and the structural capacity provided by the underlying pavement.

Thickness may be determined using AASHTO Supplement (1998). The most commonly used prodecure is an ACPA spreadsheet (revised 2008; www.pavement.com/Concrete_Pavement/Technical/UTW_Calculator/), which incorporates methods to address limitations of the AASHTO procedures. Agencies are also becoming increasingly familiar with the procedure in the M-E PDG. For more information, see table 8 on page 26.

Mixture Design

Conventional concrete mixtures have been successfully used for many bonded overlays of composite pavements.

When used in conjunction with mixture additives and accelerated construction techniques, conventional concrete mixtures can be proportioned for rapid strength gain with corresponding minimum expansion and contraction. For additional information on expedited mixtures, see page 34.

The use of high-modulus structural fibers can improve the toughness and post-cracking behavior of the concrete and help control plastic shrinkage cracking.

Joint Design

The recommended joint pattern for bonded overlays of composite pavements is small square panels, typically in the range of 3 to 8 ft (0.9 to 2.4 m), to reduce curling and warping stresses. It is recommended that the length and width of joint squares in feet be limited to 1.5 times the overlay thickness in inches. In addition, if possible, longitudinal joints should be designed outside the wheel path. The use of tiebars or dowels is not necessary because of the small spacings.

3 PREOVERLAY WORK

Preoverlay Repairs

Areas with potholes; localized, moderate-to-severe alligator cracking; or loss of base/subbase/subgrade support may require partial or full-depth spot repairs (table 3) to achieve the desired load-carrying capacity and long-term durability. However, new asphalt patches do not bond well with concrete overlays, so new concrete patches are recommended.

Patching with concrete should be completed after milling. Whether a concrete patch is placed separately or poured at the same time as the overlay (i.e., in one paving operation), the result is a spot section of thicker concrete. This thicker section of concrete will move differently from the adjacent asphalt, so no single overlay panel should be over both asphalt pavement and the concrete patch. This will require adjusting the normal jointing pattern of the overlay so the section over the concrete patch is isolated.

Panel tenting (early stages of blowups) may be an indication that a void exists under existing panels. Sections with significant tenting can be repaired to relieve the pressure and provide uniform support before construction of a bonded overlay.

Milling

In general, milling should be minimized because it reduces structural support in the milled sections. There is no reason to mill off good asphalt that can contribute to composite action and continue to help carry traffic loads.

The main objectives of milling prior to placing a bonded overlay are (1) to remove significant surface distortions that contain soft asphaltic material, which would result in an inadequate bonding surface; (2) to reduce high spots to help ensure minimum overlay depth and reduce the quantity of concrete needed to fill low spots; and (3) to match curb or adjacent structure elevations. Milling may also be considered to roughen the surface, which will likely enhance bonding.

Table 3. Possible preoverlay repairs on existing composite pavement in preparation for bonded overlay

Existing Pavement Distress	Spot Repairs to Consider
Deep rutting	Milling
Shoving, slippage	Milling
Thermal cracking	Fill crack when opening is greater than maximum size aggregate in the overlay
Fatigue cracking	Full-depth concrete patch
Pothole	Full-depth concrete patch
Tenting (early stages of blowups)	Full-depth repair

Most surface distresses can be removed through milling (table 3). Milling may be used where surface distortions are 2 in. (50 mm) or greater. The amount of asphalt removed depends on the types and severity of distresses and the thickness of the asphalt. The objective of milling is not to obtain a perfect cross section or to completely remove ruts.

It is important to make sure that the milling depth does not compromise the bonding effectiveness of asphalt tack lines between existing asphalt lifts. Therefore, milling should remove asphalt to the nearest tack line.

A minimum of 3 to 4 in. (75 to 100 mm) of asphalt should remain after milling. An adequate layer of asphalt is required to prevent delamination, thus ensuring that the asphalt will function as a load-carrying portion of the composite section (not as a separation layer or shear plane, as in an unbonded overlay).

Further Repairs

After milling, the surface should be inspected for isolated pockets of deterioration that require further repairs. For isolated areas that have a high number of wide transverse thermal cracks, a decision needs to be made whether to bridge the cracks with the bonded overlay or to clean and fill the cracks. Concrete can span normal asphalt longitudinal and transverse cracks. Filling old cracks with fly ash slurry, concrete grout, or other appropriate material is necessary only for cracks that have an opening greater than the maximum size aggregate used in the bonded overlay.

If there is vertical movement of the underlying concrete adjacent to a crack, the movement can be stopped by replacing or retrofitting the joint. The crack can also be controlled without repairing the underlying pavement by adding fibers to the mixture or, in some cases, by placing reinforcing steel rebar over the joint in the overlay. Typically, 36 in. (900 mm) long no. 4 bars are stapled to the existing pavement at 30 in. (750 mm) spacings, perpendicular to the crack.

Surface Cleaning

Following repairs, the asphalt surface needs to be cleaned to ensure adequate bonding between the existing asphalt surface and the new concrete overlay. Adequate bonding is very important to the performance of this type of overlay. Cleaning may be accomplished by first sweeping the asphalt surface, followed by cleaning with compressed air. Pressure washing should only be considered when dust control is mandated or when mud has been tracked onto the milled surface. No standing water should remain on the surface at the time the overlay is placed. To prevent contamination, it is important to avoid a lengthy lag time between final surface cleaning and paving.

4 CONSTRUCTION

Concrete Placement

When the surface temperature of the asphalt is at or above 120°F (49°C), surface watering can be used to reduce the temperature and minimize the chance of early-age shrinkage cracking. No standing water or moisture should remain on the surface at the time the overlay is placed.

Once the surface of the existing asphalt pavement has been prepared, paving is accomplished using either conventional fixed-form or slipform construction, depending on the size of the project and any geometric constraints. Because of the variation of the concrete thickness, the concrete material is bid on a cubic-yard basis. Some states also include a bid item for placement on a square-yard basis.

Curing

Curing is especially critical on a bonded concrete overlay because its high surface area-to-volume ratio makes the thin concrete overlay more susceptible to rapid moisture loss. Within 30 minutes of placing the overlay, curing compound should be applied at twice the recommended rate. The finished product should appear as a uniformly painted solid white surface, with the vertical faces along the edges of the overlay also thoroughly coated.

Joint Sawing

Timely joint sawing is necessary to prevent random cracking. Joint sawing should commence as soon as the concrete has developed sufficient strength so that joints can be cut without significant raveling or chipping, typically within 3 to 6 hours of concrete placement. Lightweight early-entry saws with 0.13 in. (3.0 mm) wide blades may be used to allow the sawing crew to get on the pavement as soon as possible. Extra saws will likely be needed. Transverse joints can be sawed with conventional saws to a depth of T/4. Transverse joint saw-cut depths for early-entry sawing should not be less than 1.25 in. (31 mm). Longitudinal joints should be sawed to a depth of T/3. Joint sealing is not required.

Future Repairs

Bonded concrete overlays on composite pavements may be easily repaired using full-panel replacement. Another option is simply to mill and fill with concrete. Do not patch with asphalt, because the adjacent concrete panels will move and break the bond. If a panel is distressed but the ride quality of the pavement is not compromised, the panel should be left in place. If a ride quality problem develops, the panel should be replaced before any pieces of concrete become loose from the overlay.

Key Resources
ACI Committee 325 (2006); Rasmussen and Rozycki (2004); ACPA (1999)

Unbonded Concrete Overlays of Concrete Pavements

—previously called unbonded overlays—

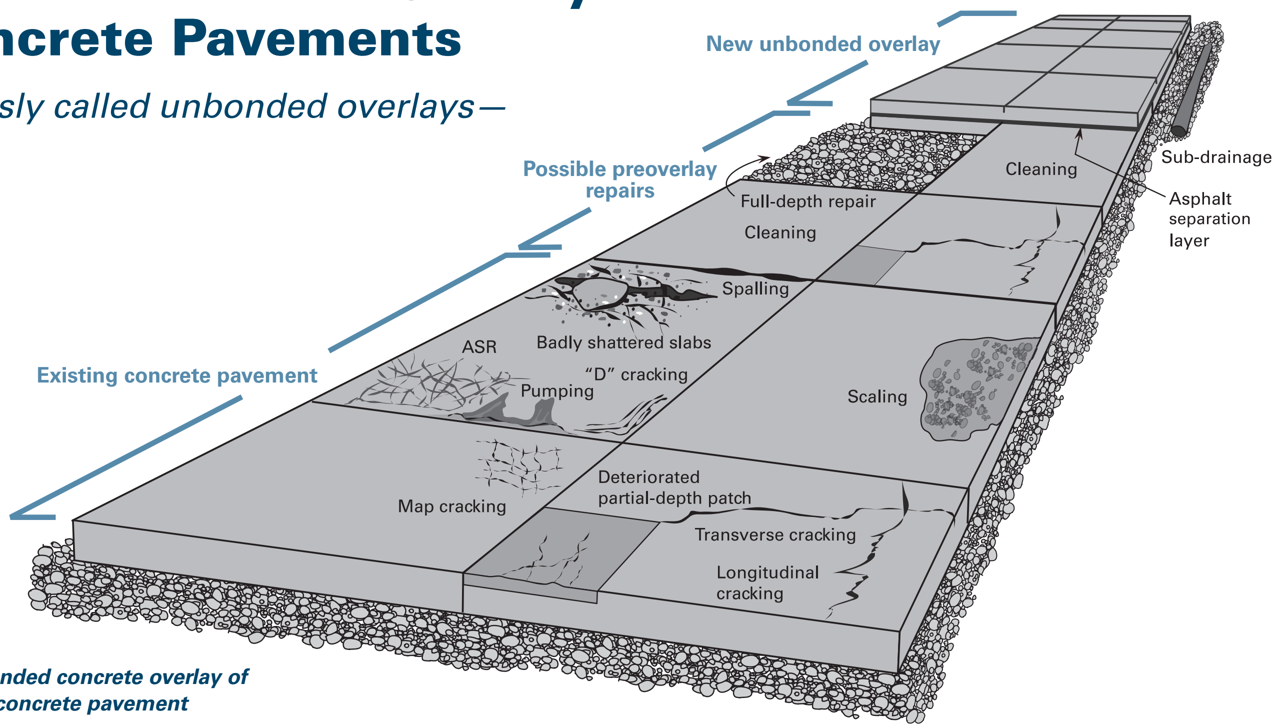


Figure 15. Unbonded concrete overlay of poor condition concrete pavement

Uses

Unbonded concrete overlays are an excellent rehabilitation option for concrete pavements that exhibit some structural deterioration. An unbonded overlay of an existing concrete pavement can reestablish the strength lost through deterioration, provide a surface with desired rideability and other characteristics, and extend the performance life capable to carry existing and future traffic loads.

This type of overlay is designed essentially as a new concrete pavement on a stabilized subbase, assuming an unbonded condition between the layers. Unbonded overlay projects are typically 4 to 11 in. (100 to 275 mm) thick, depending on the type and amount of traffic loads and the condition of the existing pavement. Unbonded overlays can be designed as JPCPs or CRCPs. A properly designed and functioning separation layer is critical to the performance of this overlay type.

Unbonded concrete overlays typically do not require extensive preoverlay repairs, though spot repairs of certain severely deteriorated areas may be necessary to minimize the risk of localized failure in the overlay.

Performance

Unbonded overlays of concrete pavements have been successfully used in many states, with over 30 years of good to excellent performance. Critical factors that affect the performance of unbonded overlays include separation layer design, overlay thickness, joint spacing layout, and load transfer design. In addition, weak subgrades can cause looseness and shifting of fractured concrete, especially under saturated conditions, resulting in surface failure.

Overlay Process

1 PAVEMENT EVALUATION

An evaluation of the existing concrete pavement is necessary to determine whether the existing concrete and its subbase can provide uniform support and, if not, what actions are necessary to obtain that uniformity if an unbonded overlay is to be used. The evaluation also determines the existing pavement's structural contribution as a stable base. For general information on pavement evaluation, including specific information about material-related distresses, see pages 6 through 9.

For faulted pavements, the cause can usually be attributed to the combination of some loss of load transfer between slabs and some loss of subgrade/subbase support. If the subgrade/subbase is stable, the increase in the carrying capacity of the unbonded overlay has proven to be adequate to overcome faulting. Faulting is generally not a concern when a separation layer of 1 in. (25 mm) or greater is used. Retrofitted edge drains have been successfully used to reduce the progression of faulting.

Panel tenting (early stages of blowups) may be an indication that a void exists under the slab. Sections with significant tenting should be repaired to relieve the pressure and provide uniform support before unbonded overlay placement.

2 OVERLAY DESIGN

Unbonded overlays are designed similarly to new concrete pavements on a stabilized subbase, assuming a separated condition between the layers.

Overlay Thickness

On primary roads, unbonded overlay thicknesses typically range from 6 to 11 in. (150 to 280 mm); on lower volume roads they can be as thin as 4 in. (100 mm). The required overlay thickness is affected by the desired load-carrying capacity and service life, as well as the condition of the concrete pavement.

Both AASHTO Guide (1993, 1998) and the M-E PDG consider the effects of the separation layer. See basic highlights of and differences among the various procedures in table 8 on page 26.

Separation Layer Design

The separation layer design is one of the primary factors influencing the performance of unbonded overlays on concrete pavements. The separation layer provides a shear plane that helps prevent cracks from reflecting up from the existing pavement into the new overlay. In addition, the separation layer prevents bonding of the new pavement with the existing pavement, so both are free to move independently.

The most common and successful separation layer is a conventional 1 in. (25 mm), well-drained asphalt surface mixture, which provides adequate coverage over irregularities in the existing pavement. The thickness can be slightly increased when irregularities are large enough to impact placement operations. The separation layer does not provide significant structural enhancement; therefore, the placement of an excessively thick layer should be avoided.

If scouring is a problem due to poor drainage and high truck traffic, some states use a modified, more porous asphalt mixture, reducing the sand content and increasing the volume of 0.38 in. (10 mm) chip aggregate.

Some states are experimenting with geotextile separation layer materials that are commonly being used in Germany. See discussion on page 35.

Mixture Design

Conventional concrete mixtures are typically used for unbonded overlays of poor condition concrete pavements. These mixtures can be used with accelerator admixtures to provide the early strength required to place traffic on the unbonded overlay within a short time period. Early opening can also be aided by use of maturity measurements.

Joint Design

Load transfer is better in unbonded overlays of concrete pavements than in new JPCPs because of the load transfer provided by the underlying pavement. Doweled joints are used for unbonded overlays of pavements that will experience significant truck traffic, typically pavements 8 in. (200 mm) and thicker.

Shorter joint spacing should be used to reduce the risk of early cracking due to enhanced curling caused by the stiff support provided by the underlying pavement (table 4). Many states do not intentionally mismatch joints and have not experienced any adverse effects. However, some states still intentionally mismatch joints, according to previous guidance, to maximize the benefits of load transfer.

Using lane tiebars may be appropriate in open-ditch (or shoulder) sections of unbonded overlays if the overlay is 5 in. (125 mm) or greater. In this category, a no. 4 tiebar (0.50 in. [13 mm]) may be appropriate. The use of tiebars in confined curb-and-gutter sections should be considered if the overlay is 6 in. (150 mm) or greater.

Unbonded plain jointed concrete overlays over CRCP are designed and constructed the same as unbonded overlays on plain jointed concrete pavements. Texas has completed some CRCP unbonded overlays over existing CRCP and plain jointed pavements, sometimes increasing the asphalt separation layer thickness to greater than one inch.

Table 4. Typical transverse joint spacing

Unbonded Resurfacing Thickness	Maximum Transverse Joint Spacing
< 5 in. (125 mm)	6 x 6 ft (1.8 x 1.8 m) panels
5–7 in. (125–175 mm)	Spacing in feet = 2 times thickness in inches
> 7 in. (175 mm)	15 ft (4.6 m)

Drainage Considerations

Without good drainage of the separation layer, pore pressure builds up from heavy truck traffic and can cause stripping of the asphalt separation layer. Properly designed, constructed, and maintained edge drains may help reduce pumping, asphalt stripping, faulting, and cracking. Deeper edge drains (subdrains) are used to help stabilize subgrades/subbases. It is becoming more acceptable to daylight free-draining granular subbase material in lieu of placing edge drains.

Edge Support Design

If shoulders are to be paved, tied shoulders may be preferable to widened overlays in unbonded overlay construction because of the increase in load transfer. Widened unbonded overlay slabs have increased risk of longitudinal cracking because of the high curling stresses resulting from stiff support conditions. Since some shoulder work is required for unbonded overlays, tied concrete shoulders can be included as part of the overlay project.

3 PREOVERLAY WORK

Preoverlay Repairs

Typically, only distresses that cause a major loss of structural integrity require repair. If significantly distressed areas are not shifting or moving and the subgrade/subbase is stable, costly repairs typically are not needed, particularly with an adequately designed overlay (table 5). As an alternative to numerous repairs, some states increase the unbonded overlay thickness to provide additional strength and therefore increase the load-carrying capacity.

Table 5. Possible preoverlay repairs on existing concrete pavement in preparation for unbonded overlay

Existing Pavement Condition	Possible Repairs to Consider
Faulting 0.25–0.38 in. (6–10 mm)	None
Faulting > 0.38 in. (10 mm)	Thicker separation layer
Significant tenting	Full-depth repair
Badly shattered slabs	Full-depth repair
Significant pumping	Full-depth spot repair and drainage improvements
Severe joint spalling	Clean
CRCP with punchouts or other severe damage	Full-depth repair

Separation Layer

Use of a sufficient separation layer can help ensure good performance of the unbonded overlay. Before separation layer placement, the existing pavement surface should be swept clean of any loose material either with a mechanical sweeper or an air blower. Conventional placement practices and procedures should be followed for placing the separation layer.

4 CONSTRUCTION

Concrete Placement

When the surface temperature of the asphalt separation layer is at or above 120°F (49°C), surface watering can be used to reduce the temperature and minimize the chance of early-age shrinkage cracking. No standing water should remain on the surface at the time of overlay placement.

Conventional concrete paving procedures are followed for placing, spreading, consolidating, and finishing the unbonded overlay. Anchoring dowel baskets to the underlying concrete pavement is important. Alternatively, pavers equipped with dowel bar inserters can be used. Because of the variation of the concrete thickness, the concrete material is bid on a volume (cubic-yard) basis. Some states include a bid item for placement, measured on a square-yard basis.

Curing

Good curing practices are especially critical to thin unbonded overlays because of their high surface area-to-volume ratio. This is accomplished by applying a curing compound immediately after surface texturing; if the unbonded overlay is 6 in. (150 mm) or thinner, use twice the usual rate of curing compound. The finished product should appear as a uniformly painted solid white surface, with the vertical faces along the edges of the overlay also thoroughly coated.

Joint Sawing

Timely joint sawing is necessary to prevent random cracking. Transverse joints can be sawed with conventional saws to a depth of between T/4 (minimum) and T/3 (maximum), but not less than 1.25 in. (31 mm). Transverse joint saw-cut depths for early-entry sawing should not be less than 1.25 in. (31 mm). Saw longitudinal joints to a depth of T/3.

Future Repairs

The recommended repair options for unbonded overlays are the same as for standard concrete pavements.

Key Resources
ACI Committee 325 (2006); FHWA (2002b); ACPA (1990b)

Unbonded Concrete Overlays of Asphalt Pavements

—previously called conventional whitetopping—

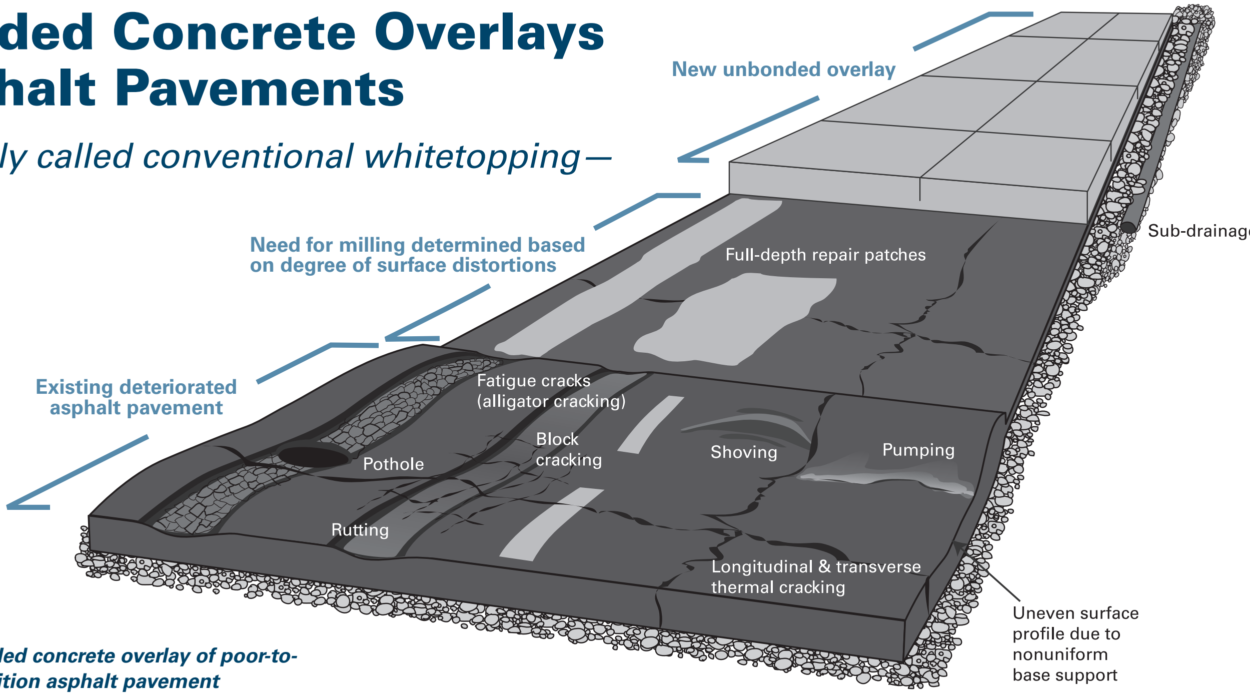


Figure 16. Unbonded concrete overlay of poor-to-deteriorated condition asphalt pavement

Uses

Unbonded concrete overlays are an excellent rehabilitation option for asphalt pavements that exhibit significant deterioration such as severe rutting, potholes, alligator cracking, subgrade/subbase issues, shoving, and pumping. When properly designed and constructed, an unbonded overlay will increase the load-carrying capacity and extend the pavement life significantly.

This type of overlay is designed essentially as a new concrete pavement on a stable base course, assuming an unbonded condition between the layers. Unbonded concrete overlay projects are typically 4 to 11 in. (100 to 280 mm). (On thinner asphalt pavements [less than 6 in. [150 mm], an unbonded overlay should be at least 6 in. [150 mm] thick, or a bonded overlay should be considered; see pages 14 and 15.) Unbonded overlays can be designed as JPCPs or CRCPs.

Unbonded concrete overlays typically do not require extensive preoverlay repairs, but spot repairs of certain severely deteriorated areas may be necessary to minimize the risk of localized failure in the overlay.

Performance

Unbonded overlays of asphalt pavements have been successfully used in many states, with over 30 years of good to excellent performance in states such as California and Iowa. Uniform support is an important factor affecting performance.

Though this overlay type does not rely on bonding, some partial bonding between the overlay and existing asphalt pavement may occur and can contribute to better performance of the pavement.

Overlay Process

1 PAVEMENT EVALUATION

An evaluation of the existing asphalt pavement is necessary to ensure it is a good candidate for an unbonded overlay, to determine what if any preoverlay repairs are required, to determine the existing pavement's structural contribution as a stable platform, and to determine key inputs to the overlay design. For example, the foundation support value should be determined to establish a thickness design that accounts for the contribution of the asphalt layer(s). For general information on pavement evaluation, see pages 6 through 9.

Asphalt pavements are good candidates for unbonded overlays if the existing asphalt layer(s) can provide, or can be repaired cost-effectively to provide, a uniform, stable platform for the overlay.

2 OVERLAY DESIGN

Existing Pavement as Base

In an unbonded overlay design, the existing asphalt pavement is considered as a stable base, and the overlay is designed similarly to a new concrete pavement. The design assumes an unbonded condition between the layers. There are two approaches to assessing the potential structural contribution of the existing asphalt pavement to the new pavement system. The approach in AASHTO' Design Guide (1993, 1998) considers the modulus of subgrade reaction (*k*-value). The M-E PDG considers both friction and *k*-value.

Overlay Thickness

Unbonded overlay thicknesses typically range from 4 to 11 in. (100 to 280 mm). However, the design of unbonded overlays on asphalt (not composite) pavements requires special attention, particularly if the unbonded overlay needs to be less than 6 in. (150 mm) thick for clearance purposes or other requirements. In this situation, the existing asphalt pavement should be at least 6 in. (150 mm) thick, or a bonded overlay should be considered.

AASHTO Guide (1993, 1998) and M-E PDG provide design procedures. See basic highlights of and differences among the various procedures in table 8 on page 26.

Mixture Design

Conventional concrete mixtures are typically used in unbonded overlays of deteriorated asphalt. These mixtures can be used with accelerator admixtures to provide the early strength required to place traffic on the overlay within a short time period. Early opening can also be aided by use of maturity measurements.

Joint Design

The load transfer design is the same as for new concrete pavements. Doweled joints are used for unbonded overlays of pavements that will experience significant truck traffic, typically pavements 8 in. (200 mm) and thicker.

For pavements 6 in. (150 mm) thick or greater, a maximum joint spacing in feet of 2 times the slab thickness in inches is often recommended for unbonded overlays. A 6 in. (150 mm) overlay would thus receive a maximum 12 ft (3.7 m) joint spacing. The maximum recommended spacing is typically 15 ft (4.6 m). For pavements less than 6 in. (150 mm) thick, the maximum spacing in feet is 1.5 times the slab thickness in inches. The use of tiebars for unbonded overlays should follow conventional use for pavements 5 in. (125 mm) thick or more.

Using lane tiebars may be appropriate in open-ditch (or shoulder) sections of unbonded overlays if the overlay is 5 in. (125 mm) or greater. In this category, a no. 4 tiebar (0.50 in. [13 mm]) may be appropriate. The use of tiebars in confined curb-and-gutter sections should be considered if the overlay is 6 in. (150 mm) or greater.

Drainage Considerations

Properly designed, constructed, and maintained edge drains help reduce pumping, faulting, and cracking. All drainage conduits must have an adequate outlet. It is becoming more acceptable to daylight granular subbase material in lieu of placing edge drains.

Designing Different Sections

Portions of a project with significantly different existing pavement and subbase conditions can be broken into separate sections and designed to specifically address those given conditions.

3 PREOVERLAY WORK

Preoverlay Repairs

Unbonded overlays generally require only minimal preoverlay repairs of the existing asphalt (table 6). If significantly distressed areas are not shifting or moving and the subgrade/subbase is stable, costly repairs typically are not needed, particularly with an adequately designed overlay.

Direct Placement

Direct placement without milling is recommended when rutting in the existing asphalt pavement does not exceed 2 in. (50 mm). Any ruts in the existing pavement are filled with concrete, resulting in a thicker overlay above the ruts.

Table 6. Possible preoverlay repairs on existing asphalt pavement in preparation for unbonded overlay

Existing Pavement Condition	Possible Repairs to Consider
Area of subgrade/subbase failure	Remove and replace with stable material; correct water problems
Severe distress that results in variation in strength of asphalt	Remove and replace with stable material; correct water problems
Potholes	Fill with asphalt
Shoving	Mill
Rutting ≥ 2 in. (50 mm)	Mill
Rutting < 2 in. (50 mm)	None or mill
Crack width ≥ 4 in. (100 mm)	Fill with asphalt
Crack width < 4 in. (100 mm)	None

Milling

If surface distortions in the existing pavement are 2 in. (50 mm) or greater, milling may be considered prior to placing an unbonded overlay. Milling can (1) reduce high spots to help ensure minimum overlay depth and (2) remove significant surface distortions that contain fractured asphalt material.

Spot milling only significant distortions, typically 1 to 2 in. (25 to 50 mm), is often adequate. The objective of milling is not to obtain a perfect cross section, and it is not necessary to completely remove ruts. There is no reason to mill off good asphalt that can help carry traffic loads.

An adequate layer of asphalt (3 to 4 in. [75 to 100 mm] minimum) must remain to ensure that the asphalt will function as a load-carrying base for the unbonded overlay structure. In general, an unbonded overlay less than 6 in. (150 mm) thick on an asphalt pavement (not composite) requires at least 6 in. (150 mm) of existing asphalt pavement (after milling); if the remaining asphalt is less than 6 in. (150 mm) thick, a bonded overlay should be considered.

It is important to make sure that milling depth does not compromise the bonding effectiveness of asphalt tack lines between existing asphalt lifts. Therefore, milling should remove asphalt to the nearest tack line.

Patch Preparation

When full-depth concrete patches exist in the underlying asphalt pavement, each concrete patch needs to be isolated to prevent its bonding to the concrete overlay. (Where bonding occurs, the overlay over the patch will be restrained differently than the rest of the overlay over asphalt, potentially resulting in cracking.) To isolate the patch, a debonding agent, fabric, or other bond breaking material should be applied to its surface. If there are only a few patches, an alternative is to saw the overlay around the concrete patch perimeter and, if appropriate, to match overlay joints to patch joints.

Surface Cleaning

Before concrete placement, the asphalt surface should simply be swept. Remaining small particles are not considered a problem.

4 CONSTRUCTION

Concrete Placement

When the surface temperature of the asphalt is at or above 120°F (49°C), surface watering can help reduce the temperature and minimize the chance of early-age cracking. No standing water should remain on the surface at the time of overlay placement.

Conventional concrete paving practices and procedures are followed for placing, spreading, consolidating, and finishing the unbonded overlay. Because of the variation of the thickness of concrete, the concrete material is bid on a volume (cubic-yard) basis. Some states also include a bid item for placement, measured on a square-yard basis.

Curing

Good curing practices are especially critical to thin unbonded overlays because of their high surface area-to-volume ratio. This is accomplished by applying a curing compound immediately after surface texturing; if the unbonded overlay is 6 in. (150 mm) or thinner, use twice the usual rate of curing compound. The finished product should appear as a uniformly painted solid white surface, with the vertical faces along the edges of the overlay also thoroughly coated.

Joint Sawing

Timely joint sawing is necessary to prevent random cracking. Transverse joints can be sawed with conventional saws to a depth of between T/4 (minimum) and T/3 (maximum). When there is evidence of some wheel rutting on the existing asphalt pavement, saw-cut depth is of particular concern for unbonded overlays because the distortions in the underlying asphalt pavement can effectively increase the slab thickness (figure 17). Longitudinal joints should be sawed to a depth of T/3. As mentioned before, always match overlay joints to the joints in any concrete patches in the existing asphalt pavement and cut the joints full depth.

Future Repairs

The recommended repair option for unbonded overlays is the same as for standard concrete pavements.

Key Resources
ACI Committee 325 (2006); FHWA (2002a); ACPA (1998)

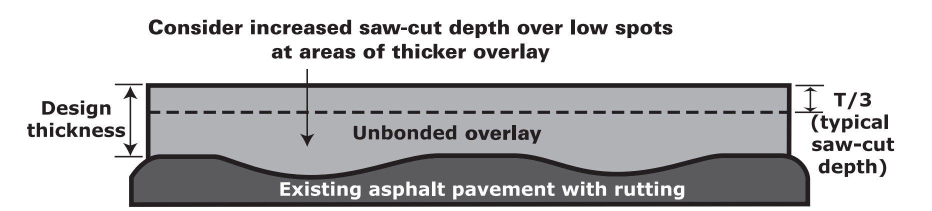


Figure 17. Consider asphalt rut depth when determining saw-cut depth (ACPA 1998)

Unbonded Concrete Overlays of Composite Pavements

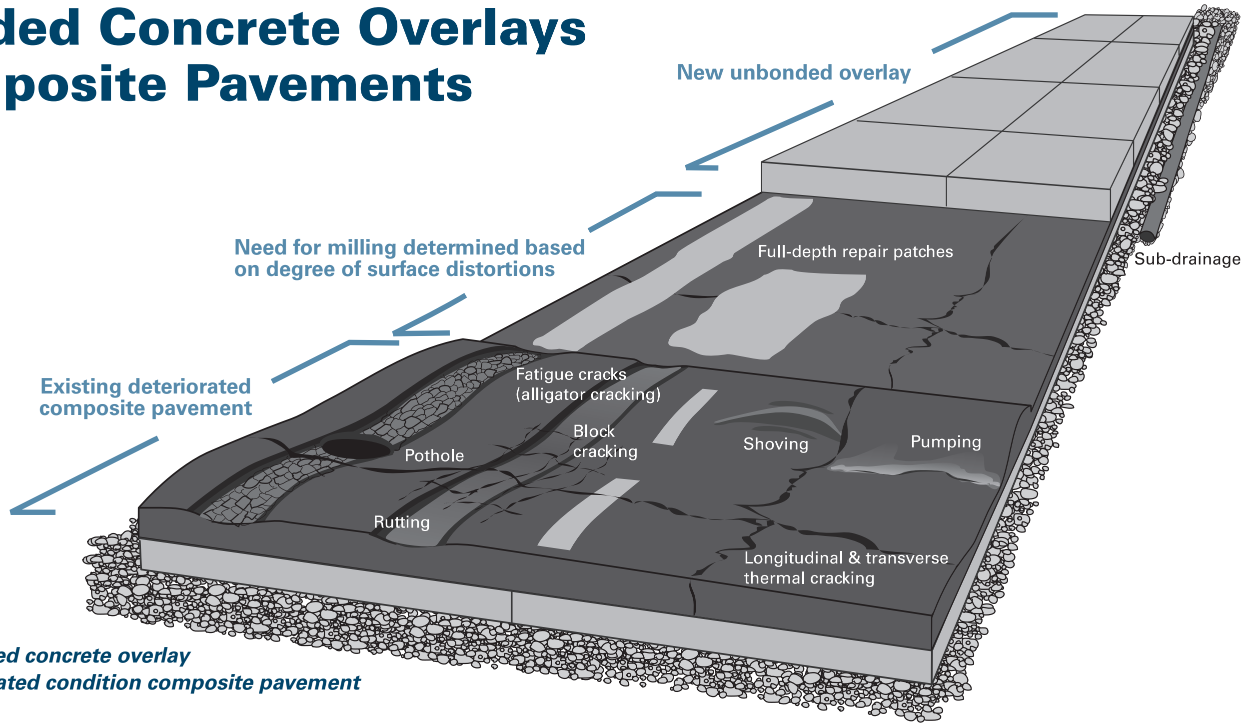


Figure 18. Unbonded concrete overlay of poor-to-deteriorated condition composite pavement

Uses

Unbonded concrete overlays are an excellent rehabilitation option for composite (asphalt on concrete) pavements that exhibit significant deterioration such as severe rutting, potholes, alligator cracking, shoving, and pumping. When properly designed and constructed, an unbonded overlay will increase the load-carrying capacity and extend the pavement life significantly.

This type of overlay is designed essentially as a new concrete pavement on a stable and uniform base course, assuming an unbonded condition between the layers.

Unbonded concrete overlay projects are typically 4 to 11 in. (100 to 280 mm). Unbonded overlays can be designed as JPCPs or CRCPs.

Unbonded concrete overlays typically do not require extensive preoverlay repairs, but spot repairs of certain severely deteriorated areas may be necessary to minimize the risk of localized failure in the resurfacing.

Performance

Unbonded overlays have the potential to greatly extend the life of existing composite pavements. Uniform base support is an important factor affecting performance. Though this overlay type does not rely on bonding, some partial bonding between the resurfacing and existing asphalt pavement can contribute to better performance of the pavement.

Overlay Process

1 PAVEMENT EVALUATION

An evaluation of the existing pavement is necessary to determine whether it can provide a uniform platform for the unbonded overlay and, if not, what actions are necessary to obtain that uniformity. In addition, the evaluation determines the existing pavement's structural contribution as a stable platform and key inputs to the overlay design. For general information on pavement evaluation, including specific information about material-related distresses, see pages 6 through 9.

Composite pavements are good candidates for unbonded overlays if the existing composite section can provide, or can be repaired cost-effectively to provide, a uniform, stable platform for the overlay. Special consideration should be given to the following:

- The condition of both layers of the composite pavement
- Deterioration of the asphalt surface course (asphalt is a good reflector of problems in the underlying concrete)
- Existing profile grade line (possible evidence of active panel movements)
- Panel tenting, which may indicate the existence of a void under the panel
- Foundation support value

2 OVERLAY DESIGN

Existing Pavement as Base

In an unbonded overlay design, the existing composite pavement is considered as a stable base, and the overlay is designed similarly to a new concrete pavement. The design assumes an unbonded condition between the layers.

There are two approaches to assessing the potential structural contribution of the existing composite pavement to the new pavement system. The approach in AASHTO Guide (1993, 1998) considers the modulus of subgrade reaction (*k*-value). The M-E PDG considers both friction and *k*-value.

Overlay Thickness

Unbonded overlay thicknesses typically range from 4 to 11 in. (100 to 280 mm). The required overlay thickness is affected by the desired load-carrying capacity and service life, as well as the condition of the underlying pavement.

AASHTO Guide (1993, 1998) and M-E PDG provide design procedures. See basic highlights of and differences among the various procedures in table 8 on page 26.

Mixture Design

Conventional concrete mixtures are typically used in unbonded overlays of deteriorated composite pavements. These mixtures can be used with accelerator admixtures to provide the early strength required to place traffic on the overlay within a short time period. Early opening can also be aided by use of maturity measurements.

Joint Design

The load transfer design is the same as for new concrete pavements. Doweled joints are used for unbonded overlays of pavements that will experience significant truck traffic, typically pavements 8 in. (200 mm) and thicker.

For pavements 6 in. (150 mm) or greater, a maximum joint spacing in feet of 2 times the slab thickness in inches is often recommended for unbonded overlays. A 6 in. (150 mm) overlay would thus receive 12 ft (3.7 m) joint spacing. The maximum recommended spacing is typically 15 ft. (4.6 m). For pavements less than 6 in. (150 mm) thick, the maximum spacing in feet is 1.5 times the slab thickness in inches. The use of tiebars for unbonded overlays should follow conventional use for pavements 5 in. (125 mm) thick or more.

Using lane tiebars may be appropriate in open-ditch (or shoulder) sections of unbonded overlays if the overlay is 5 in. (125 mm) or greater. In this category, a no. 4 tiebar (0.50 in. [12 mm]) may be appropriate. The use of tiebars in confined curb-and-gutter sections should be considered if the overlay is 6 in. (150 mm) or greater.

Drainage Considerations

Properly designed, constructed, and maintained edge drains help reduce pumping, faulting, and cracking. It is becoming more acceptable to daylight free-draining subbase material in lieu of placing edge drains.

Designing Different Sections

Portions of a project with significantly different existing pavement and subbase conditions may be broken into separate sections and designed to specifically address those given conditions.

3 PREOVERLAY WORK

Preoverlay Repairs

Unbonded overlays generally require only minimal preoverlay repairs of the existing composite pavement. If significantly distressed areas are not shifting and the subgrade/subbase is stable, costly repairs typically are not needed, particularly with an adequately designed overlay (table 7).

Note that concrete overlays will bond with any concrete patches on the underlying pavement.

Table 7. Possible preoverlay repairs on existing composite pavement in preparation for unbonded overlay

Existing Pavement Condition	Possible Repairs to Consider
Area of subgrade/subbase failure	Remove and replace with stable material; correct water problems
Severe distress that results in variation in strength of asphalt	Remove and replace with stable material; correct water problems
Reflective faulting or panel tenting	Full-depth repair
Potholes	Fill with asphalt
Shoving	Mill
Rutting ≥ 2 in. (50 mm)	Mill
Rutting < 2 in. (50 mm)	None or mill
Crack width ≥ 4 in. (100 mm)	Fill with asphalt
Crack width < 4 in. (100 mm)	None

Therefore, it is important to match the overlay joints to the patch joints and to cut the joints full depth. If there are many concrete patches, consideration might be given to placing a separation layer.

Direct Placement

Direct placement without milling is recommended when rutting in the existing asphalt pavement does not exceed 2 in. (5.08 cm). Any ruts in the existing pavement are filled with concrete, resulting in a thicker overlay above the ruts.

Milling

If surface distortions in the existing pavement are 2 in. (5.08 cm) or greater, milling may be considered prior to placing an unbonded overlay. Milling can (1) reduce high spots to help ensure minimum overlay depth and (2) remove significant surface distortions that contain fractured asphalt material.

Spot milling only significant distortions, typically 1 to 2 in. (25 to 50 mm), is often adequate. The objective of milling is not to obtain a perfect cross section, and it is not necessary to completely remove ruts. There is no reason to mill off good asphalt that can help carry traffic loads.

It is important to make sure that milling depth does not compromise the bonding effectiveness of asphalt tack lines between existing asphalt lifts. Therefore, milling should remove asphalt to the nearest tack line. When milling composite pavements, the condition of the remaining asphalt surface should be examined for large fractured or separated layers. If the remaining old asphalt is too brittle or broken up to provide adequate separation, a new separation layer should be constructed. Without an adequate separation layer, working cracks from the underlying concrete could cause reflective cracking of the unbonded overlay.

Patch Preparation

When full-depth concrete patches exist in the existing composite pavement, each concrete patch needs to be isolated to prevent its bonding to the concrete overlay. (Where bonding occurs, the overlay over the patch will be restrained differently than the overlay over asphalt, potentially resulting in cracking.) To isolate the patch, a debonding agent or material, such as asphalt emulsion coating, needs to be applied to its surface. If there are only a few patches, an alternative is to saw the overlay around the concrete patch perimeter and, if appropriate, to match overlay joints to patch joints.

Surface Cleaning

Before concrete placement, the asphalt surface should simply be swept. Remaining small particles are not typically considered a problem.

4 CONSTRUCTION

Concrete Placement

When the surface temperature of the asphalt is at or above 120°F (49°C), surface watering can help reduce the temperature and minimize the chance of early-age shrinkage cracking. No standing water should remain on the surface at the time of overlay placement.

Conventional concrete paving practices and procedures are followed for placing, spreading, consolidating, and finishing the concrete overlay. Because of the variation of the thickness of concrete, the concrete material is bid on a volume (cubic-yard) basis. Some states also include a bid item for placement, measured on a square-yard basis.

Curing

Good curing practices are especially critical to thin unbonded overlays because of their high surface area-to-volume ratio. This is accomplished by applying a curing compound immediately after surface texturing; if the unbonded overlay is 6 in. (150 mm) or thinner, use twice the usual rate of curing compound. The finished product should appear as a uniformly painted solid white surface, with the vertical faces along the edges of the overlay also thoroughly coated.

Joint Sawing

Timely joint sawing is necessary to prevent random cracking. Transverse joints can be sawed with conventional saws to a depth of between T/4 (minimum) and T/3 (maximum). When there is evidence of some wheel rutting on the existing asphalt pavement, saw-cut depth is of particular concern for unbonded overlays because the distortions in the underlying asphalt pavement can effectively increase the slab thickness (figure 17). Transverse joint saw-cut depths for early-entry sawing should not be less than 1.25 in. (31 mm). Longitudinal joints should be sawed to a depth of T/3.

As mentioned before, always match overlay joints to the joints in any concrete patches in the existing pavement and cut the joints full depth.

Future Repairs

The recommended repair option for unbonded overlays is the same as for standard concrete pavements.

Key Resources

ACI Committee 325 (2006); FHWA (2002a); ACPA (1998)

Design of Concrete Overlays

With today's limited highway funding and aging highway network, and given the cost-effectiveness of concrete overlays for pavement maintenance and rehabilitation, it is likely that pavement engineers will be designing concrete overlays more often and for a greater variety of existing pavements and pavement conditions. This section provides clear, reliable guidance for designing high-quality concrete overlays and an outline of strategies and resources necessary to implement concrete overlay projects as part of an overall pavement maintenance and rehabilitation program.

The information in this section has been collected from several valuable resources published by ACI, AASHTO, FHWA, World Road Association (PIARC), NCHRP, ACPA, PCA, the U.S. Army Corps of Engineers, Federal Aviation Administration, and various state departments of transportation. Existing procedures are based on a variety of underlying assumptions and design strategies. It is important for concrete overlay designers to understand the interaction of design with both the selection of mixture materials and the construction process. Perhaps the most critical design principle is that the concrete overlay and the underlying pavement should be viewed as a system.

Design Objectives

Bonded Overlay Systems

Bonded concrete overlay systems are intended primarily to improve pavements that are structurally sound but need increased structural capacity and/or correction of surface defects. Functional performance, including tire–pavement noise, friction or skid resistance, and albedo, can also be improved through the use of bonded overlays.

Unbonded Overlay Systems

Unbonded concrete overlay systems are usually designed to provide a service life more typically associated with new pavements. A key advantage to constructing an unbonded overlay versus reconstruction is the elimination of a significant amount of excavation work; thus, a greater portion of the available funds are spent directly on the roadway surface.

Unbonded overlays not only provide structural enhancement, they have the added benefit of eliminating existing surface distresses. Unbonded overlays are typically designed with the intent of being able to tolerate excess joint degradation, existing cracking, and localized failures in the underlying pavement structure. Proper characterization of the underlying structure will result in the best balance between cost and performance.

Overlay System Design Inputs

Regardless of the overlay system and design procedure used, the analysis begins with recognition of a number of common inputs to the design process. It is important to first define the scope of the intended project and its intended structural performance requirements. Deciding whether the overlay is to last 15 years or 30 years will affect both the extent of repairs required on the existing pavement and the design inputs. These in turn influence the thickness, the amount of repair, and thus the cost of the overlay (figure 19). The engineer is also required to characterize and understand the existing pavement structure (see pages 6 through 9), the anticipated traffic loading, and the materials expected to be used. In some cases, climatic influences may play a role, particularly with a bonded concrete overlay system.

Existing Pavement Characterization

The design and performance of a concrete overlay is affected by the condition of the existing pavement structure. Although both bonded and unbonded overlay systems benefit from the load-transfer capabilities of the existing pavement, bonded overlays are influenced to a greater degree by the underlying pavement condition. In addition, the relative thinness of bonded overlays plus the bond's stress on the new overlay tend to make these projects more challenging than unbonded overlays.

Therefore, effective characterization of the existing pavement condition is important in selecting the proper type of concrete overlay to build.

Surface Considerations

The first step in designing a bonded overlay project is a thorough characterization of the existing pavement. At the very least, the existing pavement section should be verified with cores or historical records. Sometimes, however, the historical records or plans do not represent the actual in-place pavement, so field verification of the records is important. In addition, the existing pavement structure should be evaluated for its overall current condition, which will influence both the selection of overlay system (bonded or unbonded) and the type, location, and extent of any preoverlay repairs needed, if any.

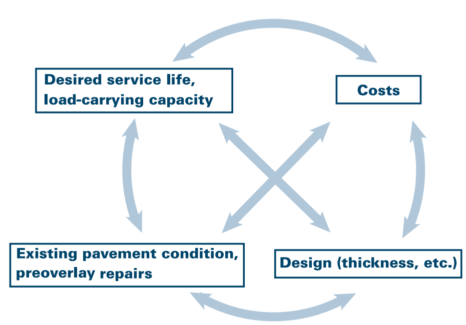


Figure 19. Design factors that affect one another

For a bonded overlay to be a practical solution on an existing asphalt surface, at least 3 to 4 in. (75 to 100 mm) of existing asphalt pavement structure should remain after any necessary preoverlay repairs and milling. If the asphalt surface is milled, the engineer should immediately inspect the condition of the remaining pavement. Areas showing spot distress after milling should be removed and the thickness of the overlay increased in these locations, but only if it is cost-effective to do so. If not cost-effective, an unbonded overlay design should be considered.

If the initial evaluation finds the existing pavement is in poor condition with many localized failures, significant base failures may be indicated. Depending on the potential costs of these repairs, a bonded overlay may not be advisable. An unbonded overlay that is less sensitive to the underlying pavement condition may be more cost-effective.

Condition evaluation permits the pavement engineer to determine the quantity and location of preoverlay repair required.

Structural Considerations

For unbonded overlays of concrete pavements, some agencies note the underlying pavement joint locations and intentionally place the joints in the new overlay away from those joints such that they are mismatched. The rationale for this is that load transfer will be improved. Other agencies discount this idea in favor of a more construction-friendly approach. In this case, joints are simply placed where they would normally be according to the type of design being built. Both strategies have resulted in good performance.

For bonded and unbonded overlays of existing asphalt or composite pavements, the layer moduli should be determined through nondestructive FWD testing. Cores are recommended for all overlay projects that involve an existing asphalt surface. If possible, a measure of the efficiency of the joints and other discontinuities to load transfer should also be measured using an FWD.

When overlaying composite pavements, the condition of the asphalt layer is a good indicator of the existing base support. If the joints and other discontinuities of the underlying concrete are visible and extremely distressed or exhibiting evidence of severe faulting, these should be characterized. Excessive or visibly large deflections under truck loading may require attention prior to resurfacing.

It should be noted that random cracks in the underlying pavement do not necessarily lead to reduction in service life. Many miles of unbonded concrete overlays have been built that have performed very well with little regard or consideration to repairing the cracking in the underlying platform.

Given this basic information about the existing system and then accounting for the possible costs of preoverlay repair, the engineer can determine the required thickness of the overlay.

Traffic Characterization

To develop a proper pavement design, the anticipated future traffic loading should be known as accurately as reasonably possible. Care must be taken not only to measure or predict current traffic characteristics, but also to assign reasonable growth characteristics.

A prediction of the number of trucks should be made over the design life. Measures sometimes include a prediction of the number of equivalent single-axle loads based on the anticipated traffic distribution. This approach is taken in AASHTO's *Guide for Design of Pavement Structures* (1993) and is used by many state departments of transportation. In this case, the designer should not approach traffic estimates with conservative estimates. It is better to make a reasonable estimate and adjust for uncertainty later.

Alternative mechanistic-empirical pavement design procedures use a distribution of traffic loading. This loading describes the number, weight, and geometries of the associated axle loads. Sometimes this is further distributed by the time of day and even the season. Highly sophisticated models include the distribution by lane and the wander of the wheel within the lane.

It is sometimes difficult to obtain information at this level of detail. Additional traffic characterization information quickly crosses a point of diminishing returns where it no longer has significant impact on the design thickness but will take substantial efforts to characterize. A number of typical distributions available in the M-E PDG (NCHRP 2007) may be adequate for most situations.

Material Properties

Certain properties of the overlay concrete should be known or estimated prior to the design process. This provides the designer additional flexibility to adjust the designs to available material options that can be used to reduce costs without compromising performance.

Regardless of the design procedure used, the designer should also define the degree of support directly beneath the structural layers. In terms of what is defined as a "structural layer" (as opposed to part of the support system), departure from the AASHTO Guide (1993, 1998) is becoming increasingly common, particularly in overlays. For example, using the conventional AASHTO Guide (1993, 1998) for new concrete pavements, an asphalt layer is considered a support layer. The property defining this support, the modulus of subgrade reaction, or *k*-value, describes the response of the material immediately beneath the concrete pavement. When using the design procedures, it is important to understand at what location in the pavement structure the *k*-value is being considered. In other approaches to design, principally with concrete overlay of asphalt, the flexural capacity of the asphalt layer is considered as a structural component. The specific contribution of the asphalt layer depends on the degree of bond with the concrete. In this case, the *k*-value would describe the support provided by the materials beneath the asphalt.

Strength of the concrete is one of the key design inputs, but this too is often misunderstood. The designer should use a strength that is consistent with the assumptions of the design method being used. For example, all AASHTO methods require third-point flexural strength in 28 days, yet it is not uncommon for designers to erroneously use the strength found in the construction specifications. Since this value is often lower, it can result in an unnecessarily thick overlay that drives up cost.

Some methods require an estimate of the modulus of elasticity of the materials. This is often of secondary importance in unbonded overlays and has negligible impact in terms of thickness. However, this property becomes more important in bonded overlay designs.

In some mechanistic-based procedures, the CTE of the concrete is also used. Though the effect of this property is increasingly being considered in thicker overlays and even new pavements, it can have a much more significant effect on the thickness of bonded overlay designs.

In designing bonded concrete overlays for existing concrete pavements, it is critical that the CTE of aggregates selected for the concrete overlay mixture design be the same as, or lower than, the CTE of the underlying pavement. This helps ensure that both layers experience similar thermal movements, thus reducing stress on the bond between the two layers.

Climatic Factors

Overlay system performance depends on climatic factors, both during construction and during the service life of the overlay. Relatively thin bonded overlay sections are more susceptible to adverse weather conditions that may affect the ability of the concrete to retain moisture, prevent excessive heat buildup, or prevent freezing. Materials should be selected that are compatible with the anticipated climate and freeze/thaw conditions. Joints and load transfer systems should be designed to accommodate the movements of the joints due to seasonal changes in pavement temperature. For example, shorter joint spacing may be appropriate.

Curling and warping are also considerations for pavement designers. Controlling large variations in temperature and relative humidity during construction can help improve overlay performance.

Constraints

Potential constraints such as surface drainage should be considered in the design.

Curb and gutter (C&G) sections may pose challenges with respect to how to design a concrete overlay. Projects might include removal and replacement of the existing C&G, construction of an inlay with the final pavement elevation matching the existing C&G, or even an encasement of the existing C&G with a new system. Barriers and ditches can lead to similar design challenges.

Overhead clearance is also another potential constraint. Depending on the location of the design, various regulations for minimum overhead clearance may apply. The final pavement elevation and thickness may need to be limited or measures taken to raise overhead obstacles. Alternatively, it may be preferred to conduct full-depth reconstruction or build an alternative section at such locations.

Adding new lanes or shoulders can also present issues unique to concrete pavement design, especially if there is a change in the underlying support of the overlay, or if the overlay is to join a full-depth concrete pavement. Joint load transfer systems are frequently used in these cases. Tiebars are used to help ensure aggregate interlock. Additional measures should be taken in the design to minimize differential settlement or water infiltration at these locations. For the same reasons, intersections and blockouts for utilities need to be understood, and joint patterns developed that will minimize uncontrolled cracking.

When construction will be completed under traffic and certain lanes need to carry additional traffic, various options regarding preoverlay spot repairs should be considered. For example, if spot repairs can be made quickly (and, if appropriate, a separation layer can be placed immediately after the repairs), then it is normally acceptable to put temporary additional vehicle traffic on the existing pavement until the overlay is constructed.

Another option is to wait and make final spot repairs after the temporary additional traffic is moved off the existing pavement. This approach should be used only when the extent of additional repairs needed, the additional thickness of overlay required, and related costs are clearly understood.

Another option is to temporarily close the roadway (preferably during off-peak hours), make the critical repairs and complete the overlay at least on one lane, and open it to traffic as soon as possible.

When high superelevation corrections are required, adequate information on the depth of material to meet superelevation is required. The type of fill materials to use (concrete, asphalt, flowable fill, cement-treated base, etc.) should be decided based on the depth of fill, installation and construction issues, initial costs, and future removal costs. Some projects combine overlays with full-depth reconstruction to address extreme superelevations.

Designers are sometimes charged with making decisions based on limited amounts of information. This is particularly true in rehabilitation project designs. Decisions on the design selection should be logical and defendable. The designer should be aware of the impact that selecting the reliability level can have on the final design thickness. In AASHTO Guide (1993, 1998), the reliability level and the overall standard deviation result in an increase in the design traffic used in determining the thickness. Appropriate selection of these parameters can build in a predictable level of risk.

Distress Mode

An understanding of the modes of distress as defined by the design procedures is also important. Pavement engineering is currently undergoing rapid changes in this area. Existing methods in AASHTO Guide (1993, 1998) are based on a "serviceability" model. This model predicts an index or designs for a change in the index under a stated set of conditions. The index describes a general overall condition that encompasses many factors associated with pavement deterioration. These typically include faulting, cracking, patching, and pavement roughness.

Advancements in computing hardware and the desire to better understand what is occurring as pavements fail has led to newer AASHTO and industry-developed methods that, in essence, break apart the serviceability model into its individual components. Pavement designs are evaluated for "multimodal" deterioration techniques that consider one or more of the parameters.

Multimodal deterioration techniques carry a number of advantages. They may aid in forecasting potential maintenance, and they may assist in developing more effective and cost-efficient designs.

Design Selection

In most cases, the designer will have an idea of the likely feasible alternatives based on the initial survey of the project. However, in selecting the final design, it is important for the engineer to anticipate the condition of the existing section at the time of actual construction of the new concrete surface. In many cases, construction will not begin for at least two or three years. Some degradation of the existing structure should be anticipated and considered in the analysis. Allowing for this continued degradation in the surface condition, the designer can begin the process of considering feasible design alternatives using the procedures recommended in table 8.

Table 8. Summary of design considerations for different types of concrete overlay systems

Type	Current Design Methods	Design Failure Mode	Deficiencies, Shortcomings, or Items to Note	Includes Fiber Models	Joint Spacing is a Design Consideration	*k*-value Location
Bonded Overlays System						
Bonded Overlays of Concrete Pavements	AASHTO Design Guide 1993, 1998	Serviceability (thickness of the new overlay is equal to the difference between the thickness of the entire new pavement needed to carry traffic minus the effective thickness of the existing pavement)	The procedure assumes complete bond and does not assess stresses at bond plane. The effective thickness of the existing pavement is based on either observed distress conditions or the amount of traffic carried to date, which are either subjective or uncertain.	N	N	Top of subbase
	M-E PDG	Mechanistically-based multimodal; fatigue driven	The procedure assumes complete bond. However, in the procedure no assessment is made of bond plane limiting stresses.	N	Joint spacing is assumed to match existing structure	Top of subbase
Bonded Overlays of Asphalt Pavements	AASHTO Design Guide 1998	Serviceability	The 1993 version does not apply to concrete overlays bonded to asphalt because it does not account for the bond between concrete and asphalt. However, the 1998 version can account for bond between the concrete and asphalt, but it does not account for the short joint spacing in overlays less than 6 in. thick. In both versions, the composite *k*-value is utilized and results in conservative thickness design.	N	N	Top of asphalt
	ACPA 2008 (master spreadsheet will be incorporated into ACPA's StreetPave software in the future)	Mechanistically-based multimodal; corner crack bond plane failure and asphalt fatigue	The procedure addresses both bond and the influence of asphalt fatigure. However, further refinements are needed.	Y	Y	Top of non-stabilized, unbonded base or subgrade layers
	M-E PDG	Mechanistically-based multimodal; fatigue driven	The procedure uses full friction values, which is considered equivalent to bond. User can set the period of time of effective bond, but the default value is only 10 years.	N	Y	Top of asphalt

Table 8. Summary of design considerations for different types of concrete overlay systems, continued

Type	Current Design Methods	Design Failure Mode	Deficiencies, Shortcomings, or Items to Note	Includes Fiber Models	Joint Spacing is a Design Consideration	*k*-value Location
Bonded Overlays of Composite Pavements	AASHTO Design Guide 1998	Serviceability	The 1993 version does not apply to concrete overlays bonded to asphalt because it does not account for the bond between concrete and asphalt. However, the 1998 version can account for the bond between concrete and asphalt, but it does not account for the short joint spacing in overlays less than 6 in. thick. In both versions, the composite *k*-value is utilized and results in conservative thickness designs.	N	1993: N 1998: Y	Top of asphalt
	ACPA 2008 (master spreadsheet will be incorporated into ACPA's StreetPave software in the future)	Mechanistically-based multimodal	The procedure addresses bond, but further refinement is needed. Influence of asphalt fatigue is addressed, but further refinement is needed. The procedure is not theoretically correct, but has been demonstrated to provide workable reasonable answers that have proven satisfactory in practice.	Y	Y	Top of non-stabilized, unbonded base or subgrade layers
	M-E PDG	Mechanistically-based multimodal; fatigue driven	In the procedure, bond is handled as all or nothing with allowance for loss of bond over time. Procedure implies bond is short term. No assessment is made of bond plane limiting stresses.	N	Y	Top of asphalt
Unbonded Overlays System						
Unbonded Overlays of Concrete Pavements	AASHTO Design Guide 1993, 1998	Serviceability (thickness of the new overlay is equal to the difference between the thickness of the entire new pavement needed to carry traffic minus the effective thickness of the existing pavement)	The 1993 procedure assumes no friction between the overlay and the separation layer. Although the 1998 version can account for a bond or partial bond because it allows for a friction value, it does not allow for loss of bond over time. (To account for this limitation, the friction value is typically set at zero.) Under both versions, the effective thickness of the existing pavement can be based on observed distress conditions, which are subjective or uncertain. Unlike the bonded overlay design, there are no adjustment factors for durability or fatigue damage of the existing pavement because of the minimum effect on the performance of the new unbonded overlay. The effective thickness can also be based on the amount of traffic carried to date.	N	N	Top of separation layer
	M-E PDG	Mechanistically-based multimodal; fatigue driven	Bond is handled as all or nothing with allowance for loss of bond over time.	N	Y	Top of separation layer
Unbonded Overlays of Asphalt Pavements	AASHTO Design Guide 1993, 1998	Serviceability	The 1993 procedure assumes no friction between the asphalt pavement and the concrete overlay. In principle, the 1998 version can account for friction by assigning the appropriate friction factor. In both versions, the composite *k*-value is used and results in conservative thickness designs.	N	N	Top of asphalt layer
	M-E PDG	Mechanistically-based multimodal; fatigue driven	In the procedure, bond is typically handled using zero friction.	N	Y	Top of asphalt layer
Unbonded Overlays of Composite Pavements	AASHTO Design Guide 1993, 1998 (in addition, ACPA [1998] has developed simple design charts for selecting thickness)	Serviceability	The 1993 procedure assumes no friction between the asphalt pavement and the concrete overlay. In principle, the 1998 version can account for friction by assigning the appropriate friction factor. In both versions, the composite *k*-value is used and results in conservative thickness designs.	N	N	Top of asphalt layer
	M-E PDG	Mechanistically-based multimodal; fatigue driven	In the procedure, bond is typically handled using zero friction.	N	Y	Top of asphalt layer

Design of Bonded Overlay Systems

With bonded concrete overlays, the bond between the overlay and the underlying pavement assists the horizontal shear transfer at the bond plain. This horizontal shear transfers stresses into the underlying layers, thereby decreasing tensile stresses in the bonded overlay. Somewhat different considerations are required depending on if the overlay is bonded to existing concrete or to existing asphalt. However, all bonded concrete overlay systems depend on the integrity of the underlying pavement.

Bonded Overlays of Concrete Pavements

The AASHTO Guide (1993, 1998) procedure for bonded overlays of concrete pavements uses a "design deficiency" or "remaining life" approach. The mode of failure most commonly used is serviceability. This is largely due to the fact that most pavement engineers today are comfortable with the concept. The existing pavements in these cases have not failed. However, it is assumed that some of the pavement life has been consumed in either fatigue or serviceability, depending upon the design procedure being used.

First, standard design methods are used to determine the required thickness of a new pavement based on the anticipated traffic, planned materials to be used, and other parameters typically considered in new pavement design.

Having determined the overall required pavement thickness, the pavement thickness equivalent after adjusting for the life consumed of the existing section is estimated. This thickness corresponds to the thickness required to carry the number of loadings to failure as defined by AASHTO. In the AASHTO Guide (1993, 1998) and earlier terminology, this is simply the change in serviceability and corresponds to the "remaining life." Additional minor adjustments may also be made having to do with observations of existing pavement condition, but these are somewhat subjective. After the adjustments, the resulting number represents how much effective pavement thickness is still actually available to be further "consumed" or used in the new pavement system in addition to the new overlay.

The difference in the thickness calculated for a new pavement and this effective section is the "design deficiency" or the required thickness of the new section that should be bonded to the existing pavement. For further information see the AASHTO Guide (1993, 1998).

Critical to the performance of this type of overlay is the development of a bond between the two layers. Existing design procedures for bonded overlays do not specifically address bond strength, treating it primarily as a construction issue. If the section is built correctly and proper curing procedures are used, bond strength is usually not a problem. However, extreme daytime to nighttime temperature swings can sometimes trigger premature delamination failures. If temperature differentials in excess of 20˚F (7˚C) are anticipated, the section should be protected or paving at night should be considered.

Maintaining the bond is especially critical during the first few days when the overlay is susceptible to curling and warping stresses, especially at the pavement edges. Therefore, the bond must be protected through thorough curing practices, minimizing relative humidity and temperature differentials between the two layers, and keeping early traffic away from the pavement edges until adequate bond strength has been achieved (usually when opening strength has been achieved).

Joints in designs of this type are matched to the existing section. Transverse joints should be cut full depth of the overlay plus a 0.50 in. (13 mm) and must be as wide as or greater than the crack below the joint in the underlying pavement. Longitudinal joints should be cut at least T/2. (See miscellaneous details, page 31.) Designs for overlays of existing CRCPs are also possible. In the case of CRCPs, however, there is no need to match the transverse joints since none exist with the exception of terminal joints or lugs.

The use of steel reinforcement or dowels is not usually a consideration for bonded overlays on concrete pavements unless the overlay is thicker than usual, new shoulders are being tied, or there is also a desire to retrofit load transfer.

Properly built, bonded overlays can reasonably be expected to provide a minimum service life of 15 years before maintenance is required. The first indication of problems on these overlay projects is usually delamination at the bond plane, quickly followed by classic fatigue failure at isolated joint locations. These can be repaired using partial-depth repair techniques if the underlying slab remains sound.

Bonded Overlays of Asphalt Pavements

A unique design consideration for bonded overlays on asphalt pavements is the joint spacing to mitigate curling and warping stresses in the bonded overlay. ACPA's original 1998 design procedure for this overlay type was based on a single mode of failure—the corner break. ACPA's 2004 revised procedures incorporated probabilistic methods into concrete fatigue models, but the procedure for this overlay type continued to be based only on the corner break mode of failure.

The corner break model has worked adequately. In recent years, however, it has been recognized that the two most common precursors to failure for bonded concrete overlays on asphalt are delamination stemming from failure in the bond plane or from failure in the underlying asphalt layer. Therefore, the most recent revisions of the design procedure for this type of overlay reflect a "weakest link" approach, applying probabilistic techniques to all three modes of failure.

First, design parameters are input into the design model. Then stresses are calculated using the corner stress model. From that information, strains in the bottom and top of the asphalt layer, plus horizontal stresses inferred at the bond plane, are calculated based on the location of the composite neutral axis.

Concrete corner stresses are then compared against ACPA's 2004 fatigue model for concrete. Strains in the asphalt are compared to Asphalt Institute design fatigue models. Bond plane stresses are evaluated using a horizontal shear data model based on data obtained from Iowa, Florida, and Colorado studies.

The calculated stresses and strains for each mode are then compared against the probabilistic models of each mode to determine which factor is the most likely mode of failure, or the weakest link, driving failure in the overall system.

Bottom line: Understanding the interaction between bond plane stresses and corner break stresses helps designers optimize joint spacing and several other factors in designs for bonded concrete overlays on asphalt pavements.

In addition to the probabilistic adaptation of the mechanistic procedures, new advancements in materials were included, particularly with regard to the inclusion of fibers. The effect of fibers in the models is based on their ability to enhance the fatigue resistance of the concrete. The design procedure for fibers is open ended in that as new fibers are developed and properties are established, these can be incorporated accordingly.

Probably one of the more challenging aspects in the design of bonded overlays of asphalt is the consideration of the supporting platform. For designs of this type, the classic modulus of subgrade reaction or *k*-value described earlier is based on the value at the bottom of the asphalt layer rather than at the bottom of the concrete layer.

The joint design of bonded overlays over asphalt pavement is a distinguishing characteristic when these projects are placed in the field. The transverse and longitudinal joint spacings are always 6 ft (1.8 m) or less in length as determined by the design analysis. It is important that joints in this type of overlay be cut as quickly as possible to minimize the likelihood of curling stresses developing, triggering delamination at the edge of the pavement. Early-entry saws are usually used.

Since existing sections of bonded overlays of asphalt are fairly young, actual service life has yet to be determined, but based on 18 years of performance data, it appears quite likely that 15 to 25 years of service can be expected from this type of overlay, provided it is constructed properly. This technology continues to evolve and is one of the most dynamic areas of interest in concrete paving research at this time.

The design procedure is available from ACPA and its chapter/state association network. The procedure will be incorporated in a future version of ACPA's pavement design software for streets and roads, StreetPave.

Bonded Overlays of Composite Pavements

Of all of the designs in the bonded system, the design of bonded overlays of composite pavements is the most complex. However, it is also the one with the most potential applications, because many miles of existing concrete pavements have been resurfaced with asphalt.

Current generally accepted design procedures (AASHTO Guide [1993, 1998]) assume a serviceability mode of failure and have treated the top of the asphalt layer as a high-strength platform from which the *k*-value is calculated. Enhancement from the bond is ignored. When used, these procedures often result in overly conservative designs that far exceed design expectations.

Reexamination is ongoing at this time but some promise has been shown on work in Illinois using minor adaptations to the procedures for bonded overlays over asphalt pavement. In this approach, the same failure model is used, but the assumption is made that the asphalt layer has the maximum permitted thickness of 6 in. (150 mm), which corresponds to the limits of the current design model. The elastic properties of the asphalt surface are used in the model.

The advantage of this approach is that it allows consideration of bond plane protection and method of preparation, inclusion of fibers, interaction between joint spacing and thickness, and considerations for curling and warping due to use of different aggregates.

Design of Unbonded Overlay Systems

Unbonded overlay designs usually do not consider bond, though in fact some bonding usually occurs. They are essentially designed as new concrete pavements, with the pavement being overlaid acting as a base. Adaptation of existing design procedures is relatively straightforward and construction relatively easy. Unbonded overlays are usually designed to serve 20 to 30 years.

The newer mechanistic-empirical design procedures are far better and more theoretically sound for designs of this type, but these are beyond the scope of this guide.

Existing guidance for the design of each of the unbonded overlay types can be found in AASHTO Guide (1993, 1998). The selection of the load transfer coefficient in the AASHTO procedure should be made with recognition of the character of the underlying layer in addition to the intended load transfer system for the overlay. Consideration should be given to the underlying structure providing additional load transfer, which is not necessarily true of new concrete pavements. The designer should not arbitrarily pick a "conservative" value, as this is not the intent of the design procedure. ACPA's WinPAS software program (based on AASHTO Guide 1993) includes an entire section for use in designing these types of systems.

Care must be exercised to ensure that the saw depth of the unbonded overlay is adequate, particularly when the overlay thickness varies, such as in super transitions, dropoffs, etc., or when there is embedded steel.

Unbonded Overlays of Concrete Pavements

In many cases, an existing concrete pavement—even one in poor condition—can provide a cost-effective base for a new concrete overlay. This is one reason why rubblizing or crack and seat techniques are generally not recommended; these techniques effectively result in the loss of any structural carrying capacity of the existing pavement.

Suitability of existing pavement as a base

The existing pavement is suitable as a base for an unbonded overlay if it can meet the desired design life requirements for the base. The existing pavement must be stable and uniform; that is, it must not experience significant differential movement and there should not be large areas lacking adequate structural support.

When an entire concrete pavement has begun to break up, it is a good indicator of serious subgrade/subbase problems that need to be addressed before other solutions are considered. If the subgrade is unstable, it may be time to replace the pavement and correct the subgrade/subbase.

Isolated areas of full-depth structural distress are generally not a problem if they can be repaired cost-effectively before placing the overlay. On the other hand, areas of MRD that cause movement from expansion and/or contraction in the existing pavement require careful evaluation.

If MRD-related movement is limited primarily to the joints (e.g., D-cracking movement), and if full-depth joint repairs can be justified from a cost perspective, a pavement may still be a good candidate for an unbonded concrete overlay. Unbonded concrete overlays on concrete pavements with full-depth structural and/or joint repairs have proven performance records as effective bases for unbonded concrete overlays. Some agencies have even had success with infilling deteriorated joints with stable material such as flowable mortar.

When an entire concrete pavement has deteriorated severely along the length of the pavement due to movement, it is probably time to recycle and reconstruct the entire base. A good option is to crush the pavement in place and use it as an unstabilized (granular) subbase for a new, full-depth pavement if the existing subgrade is adequate.

Separation layer

All unbonded concrete overlays on concrete must be separated from the existing concrete pavement by a stress-relief layer, or separation layer, to prevent bond development. The separation layer provides a shear plane that relieves stress and helps prevent cracks from reflecting up from the existing pavement into the new overlay. In addition, the layer prevents bonding of the new pavement with the existing pavement, so both are free to move independently.

Over the years, many stress-relief methods have been used successfully. The most common stress relief is a thin layer of asphalt material. Thickness is not critical, but 1 in. (25 mm) is usually adequate to eliminate potential problems with "keying" of faulted slabs, localized repairs, etc. When constructing CRCP unbonded overlays over both CRCP and plain jointed pavements, Texas has sometimes increased the asphalt separation layer thickness to greater than 1 in (25 mm).

It is important not to use the asphalt separation layer as a leveling course. All grade corrections, including leveling, should be accomplished with the concrete overlay itself.

Occasional problems have been noted with asphalt stripping within the separation layer under repeated loading. This can occur occasionally with high truck traffic volumes in the presence of water. Usually, the stripping takes several years to develop. The best preventive solutions are the following:

- Using anti-strip additives in the asphalt
- Using materials other than asphalt that are not subject to stripping phenomena
- Providing a clear path to allow moisture to leave without the assistance of pore pressure

Other materials for stress-relief layers are possible and have been used. Recent work in the United States and Europe has included the use of geotextiles as a stress-relief layer. If the separation layer is particularly thin, attention should be paid to the potential for "keying" of the overlay to the existing section, stemming from existing severe faulting. It is thought that the keyed locations may have some potential to reflect into the new weaker concrete layer early in the life of the section, though not much data exist to confirm or refute this hypothesis.

Joint design

Due to the high stiffness of the underlying platform (the existing concrete pavement) in unbonded overlays on concrete, it is necessary to shorten joint spacing in the overlay compared with normal designs. The shorter joint spacings accommodate additive stress from temperature curling combined with loading. Note that existing AASHTO methods do not consider this in design. Rule-of-thumb guidance for joint spacing for unbonded overlays using these methods is based largely on experience (see page 19, table 4, for maximum joint spacings).

Newer procedures, in particular the M-E PDG, do a much better job of considering the relationship between load, joint spacing, type of load transfer, temperature conditions, and support of the underlying platform. For this reason, these are the procedures of choice and will likely result in more cost-effective solutions.

Joints in the unbonded overlays can be doweled, plain, or, in a continuous reinforced concrete overlay, totally eliminated. A few thin unbonded concrete overlays (less than 5 in. [125 mm]) have been built under fairly heavy traffic situations using very short joint spacings, usually 6 ft (1.8 m) or less. The shorter joint spacings are necessary to reduce the risk of early cracking due to curling and warping stresses.

Rubblization and Crack and Seat

Some agencies have experimented with recycling severely deteriorated concrete pavements through rubblization. The practice of rubblization was developed primarily to prepare concrete pavements for asphalt overlays. The concept was to minimize the potential for reflective cracking through the asphalt by breaking the existing concrete pavement into small, fairly uniform concrete pieces that, individually, experience little contraction or expansion.

Instead of rubblizing, the concrete industry typically deals with deteriorated concrete pavements that are uniform and stable by repairing isolated areas of full-depth structural distress and then placing an unbonded overlay. This process accomplishes the goal of minimizing or eliminating reflective cracking. Plus, the pavement owner makes use of the existing pavement's remaining structural capacity, which would be lost through rubblization, and saves the costs and avoids the potential problems associated with rubblization.

Rubblizing a concrete pavement can result in several problems. First, rubblizing techniques can result in a broad range of sizes of concrete pieces. To provide a uniform base for an unbonded concrete overlay, the size of the rubblized pieces needs to be a consistent 6 to 12 in. (150 to 300 mm) in diameter. Second, the rubblization process can drive concrete pieces into the subgrade, forcing water upward and reducing the subgrade's stability. The ability of a particular pavement to withstand rubblization and retain its drainage and support functions is typically not known until the pavement is actually rubblized. Finally, rubblization results in the loss of the existing pavement's structural carrying capacity, and thus requires a thicker, more costly overlay.

For these reasons, rubblizing deteriorated concrete pavements is not a mainstream recommendation for concrete overlays. If it is decided to rubblize, a relatively thick (minimum 2 to 4 in. [50 to 100 mm]) asphalt or granular layer should be constructed on the rubblized pavement. This thick separation layer can help provide more uniform support for the overlay and reduce the potential for segments of concrete rubble to protrude close to or through the surface of the separation layer, resulting in concentrated areas of stress.

Crack and seat has been tried in place of rubblization, but because it is very difficult to achieve uniformity, it is not recommended as an in-place reconstruction method either.

Unbonded Overlays of Asphalt Pavements

Unbonded overlays of asphalt pavements can address existing sections that have existing crown or ruts in the surface. Placing the concrete directly on the surface places the thickest concrete at the points of highest load in the pavement structure and is therefore one of the more efficient designs. If rutting is extreme (greater than 2 in. [50 mm]) or the change in cross section due to crown is significant, care should be taken to ensure that the design plans call for adjusting the sawed joint depth accordingly.

Due to the variability in thickness across the section if placed directly on the asphalt, the contract documents should include provisions for payment for materials separately from payment for placement. These so called "square-yard cubic-yard" provisions are somewhat out of the norm for concrete pavement operations, but they are important in reducing the contractors' risk and owner cost in bidding the projects.

Unbonded Overlays of Composite Pavements

Unbonded overlays of composite pavements follow the same design guidelines as concrete overlays of concrete pavements. The primary difference is that the stress-relief layer already exists in the form of the existing asphalt layer of the composite pavement.

Widening and Lane Addition Design

Concrete overlay projects provide a good opportunity for the widening of an old pavement with narrow traffic lanes, the addition of new travel lanes, or the extension of ramps.

Adequately designed and constructed widening can improve both faulting and cracking performance of the pavement.

Widened slabs should be used with care with concrete overlays on stiff foundations (such as on concrete pavements) because of the increased risk of longitudinal cracking.

Some rules of thumb for 3 to 6 ft. (0.9 to 1.8 m) widening units (illustrated in design details, figures 29 to 32) are as follows:

- Where possible, keep joints out of wheel paths, especially for bonded overlays on asphalt or composite pavements.
- For concrete overlays 5 in. (125 mm) or thicker at open-ditch (shoulder) sections, tie longitudinal joints with no. 4 tiebars to prevent pavement separation.
- The width of widening rather than depth has more of a positive effect in reducing stresses in the overlay section.

Not every detail shown will fit a specific project. Apply the principles illustrated in the details to address specific project issues.

Lane addition design details are illustrated in figure 33. To prevent cracking related to differential expansion and contraction between a concrete overlay and a full-depth adjacent concrete lane addition, use a butt joint with no tiebars.

Miscellaneous Design Details

Various details are illustrated in figures 20 to 33.

Curbs and Gutters

Curb and gutter sections require additional details since a decision needs to be made about jointing. It is possible to include an integral curb and gutter, but this should be balanced with the extent of this type of section and the equipment that might be available to construct it.

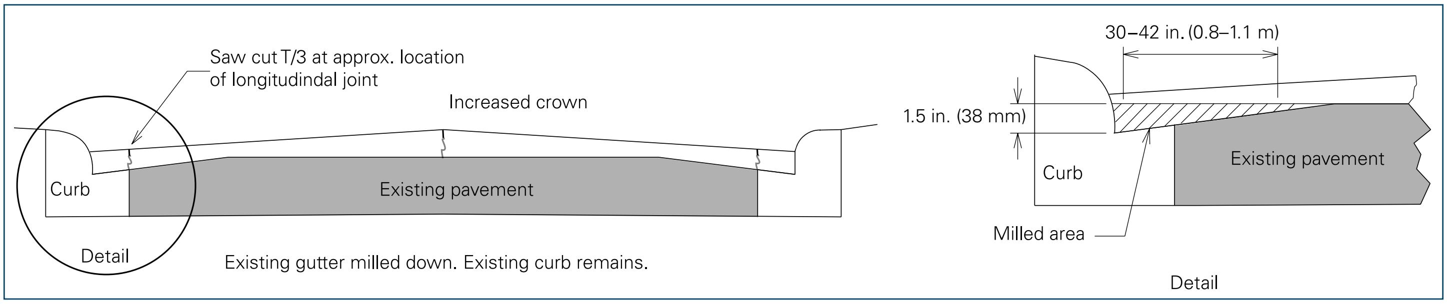


Figure 20. Bonded concrete overlay in urban areas where the existing curbs can remain in place (adapted from ACPA 1990b)

Manhole

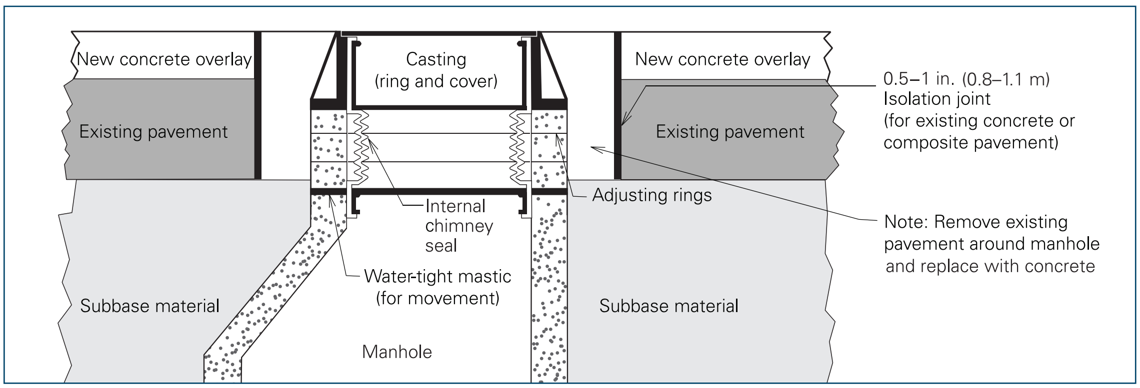


Figure 21. Concrete overlay with standard manhole

Transitions

A concrete overlay design often requires transition details that link the concrete overlay with the pavement structure adjacent to the project length. Since these locations are often subject to additional stress, a variety of alternatives have been used, including thicker concrete sections, conventional reinforcement or wire mesh, and structural steel fibers.

Mill and Fill Transitions for Bonded Concrete Overlays

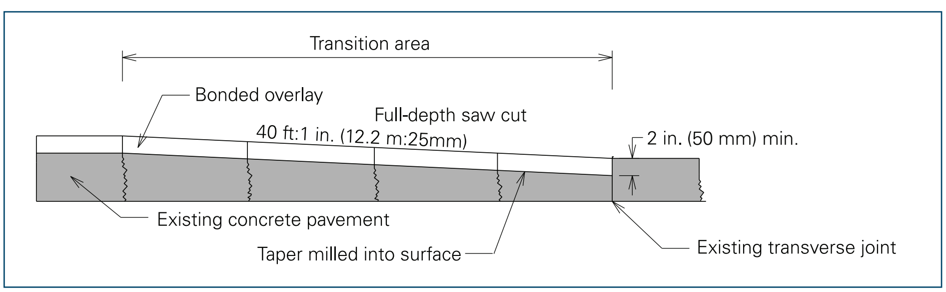


Figure 22. Mill and fill transition for concrete overlay of concrete pavement (adapted from ACPA 1998)

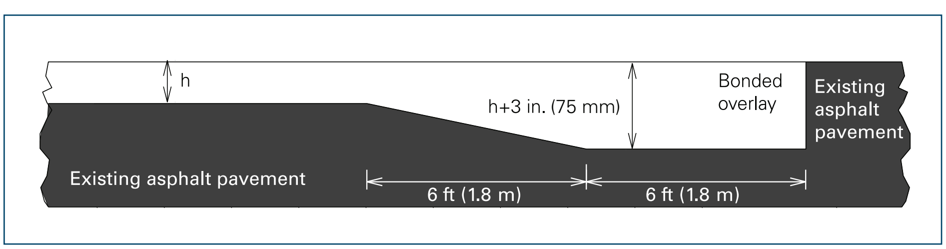


Figure 23. Mill and fill transition for concrete overlay of asphalt or composite pavement (adapted from ACPA 1998)

Transition Details for Bonded Concrete Overlays

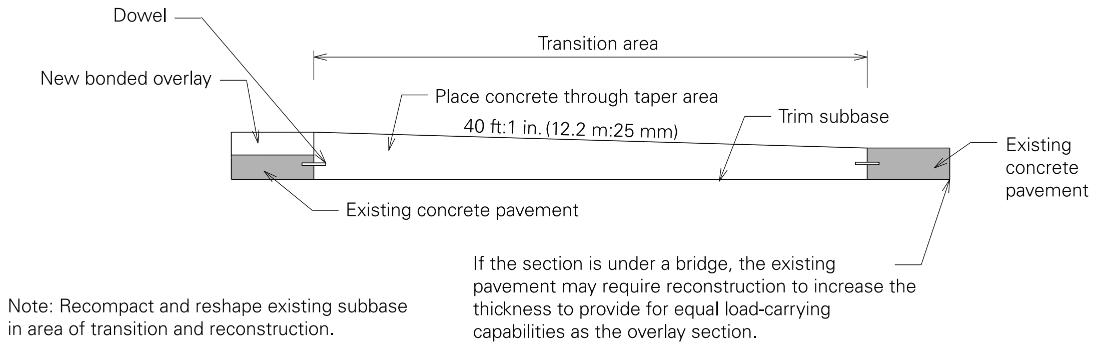


Figure 24. New transition tapers used to meet bridge approach slabs or maintain clearance under bridges with bonded overlay of concrete pavement (adapted from ACPA 1990b)

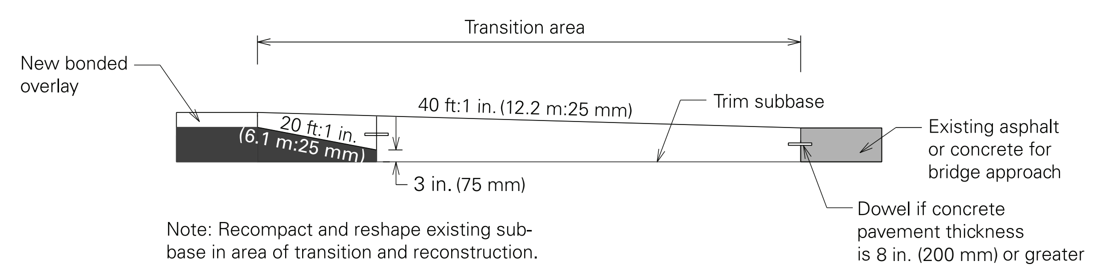


Figure 25. New transition tapers used to meet bridge approach slabs or maintain clearance under bridges with bonded overlay of asphalt pavement (adapted from ACPA 1991)

Transition Details for Unbonded Concrete Overlays

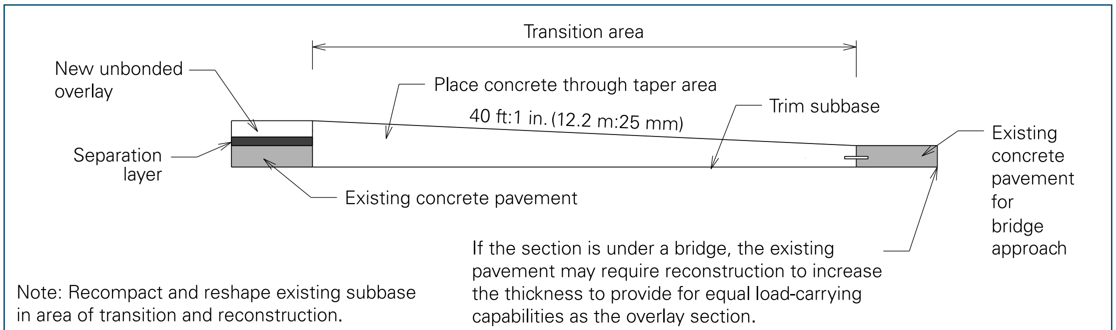


Figure 26. New transition tapers used to meet bridge approach slabs or maintain clearance under bridges with unbonded overlay of concrete pavement (adapted from ACPA 1990b)

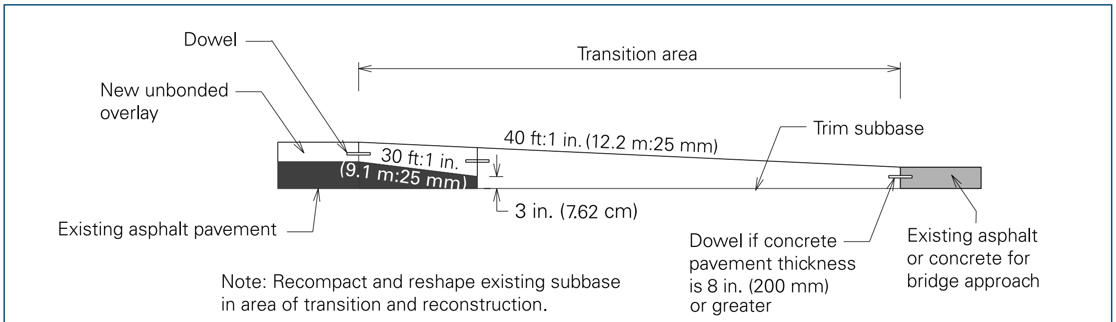
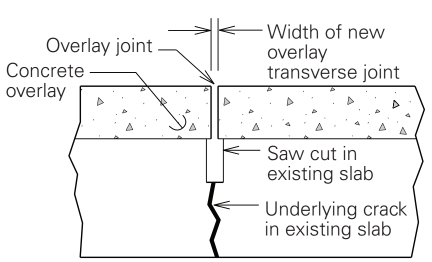


Figure 27. New transition tapers used to meet bridge approach slabs or maintain clearance under bridges with unbonded overlay of asphalt pavement (adapted from ACPA 1991)



Note: Overlay joint width shall be equal to or greater than crack in the existing slab.

If "X" is 0.50 in. (13 mm) or greater, the underlying crack width in the existing slab should be measured. If crack is 0.25 in. (6.4 mm) or greater, and existing pavement does not have dowel bars, the joints should be evaluated to determine if load transfer rehabilitation is required to eliminate faulting. If numerous joints of this type exist, the existing pavement may not be a good candidate for a bonded overlay.

Figure 28. Joint detail in concrete overlay of existing concrete pavement

Widening Unit for Bonded Concrete Overlays

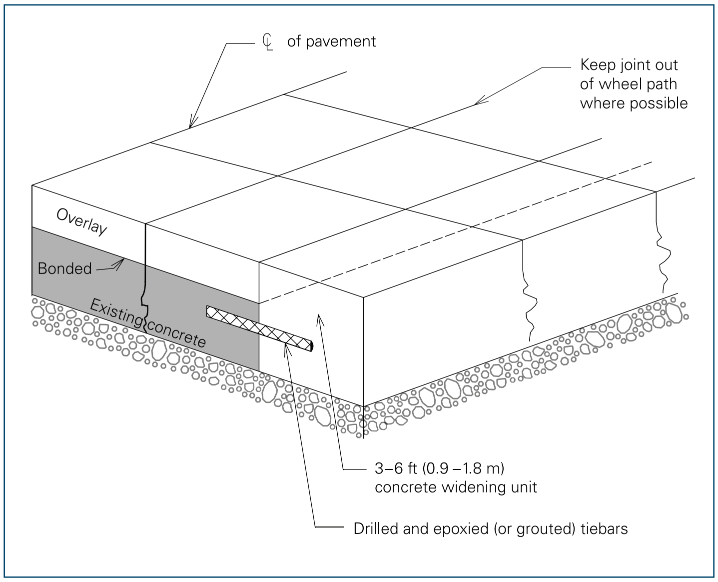


Figure 29. Bonded overlay of concrete pavement with widening unit

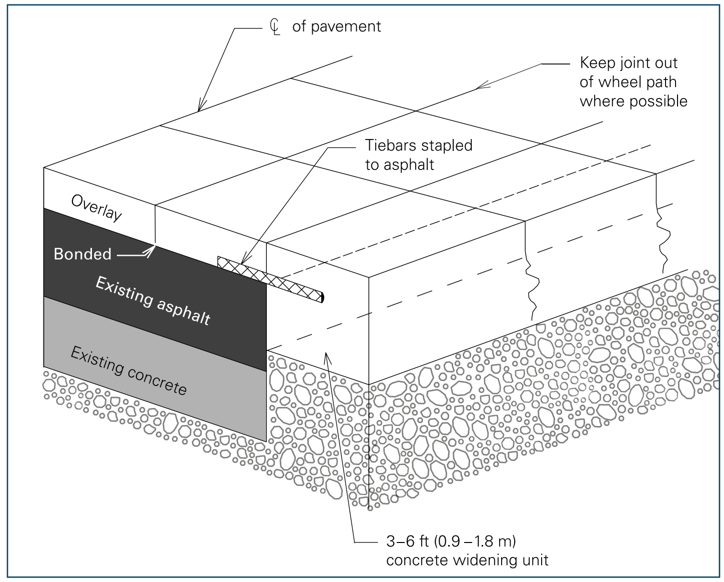


Figure 30. Bonded overlay of asphalt or composite pavement with widening unit

Widening Unit for Unbonded Concrete Overlays

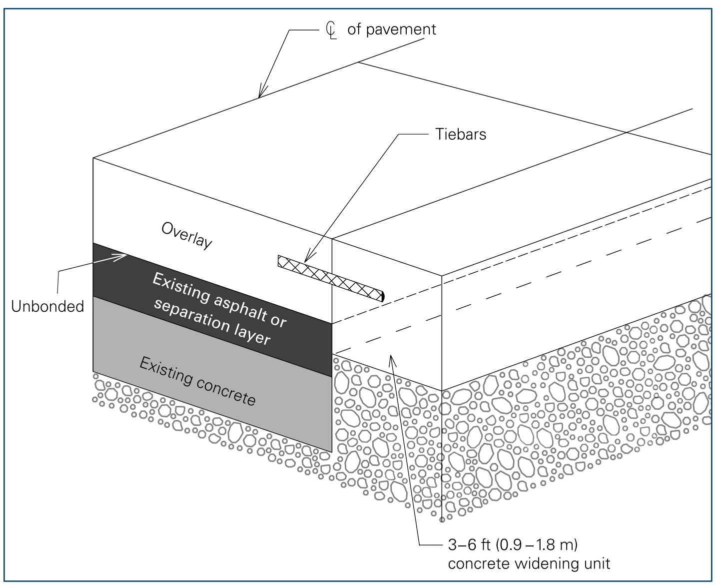


Figure 31. Unbonded overlay of concrete, asphalt, or composite pavement with widening unit

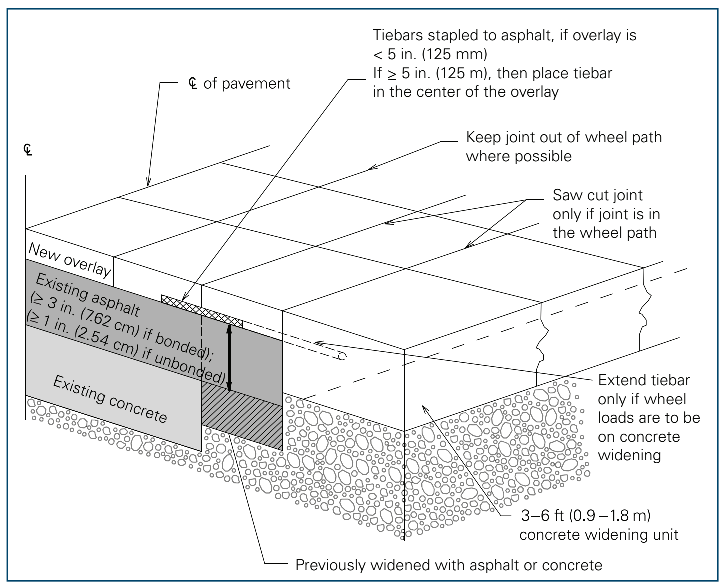


Figure 32. Bonded or unbonded overlay of asphalt or composite pavement (previously widened with asphalt or concrete; to be widened again with new concrete overlay)

Lane Addition

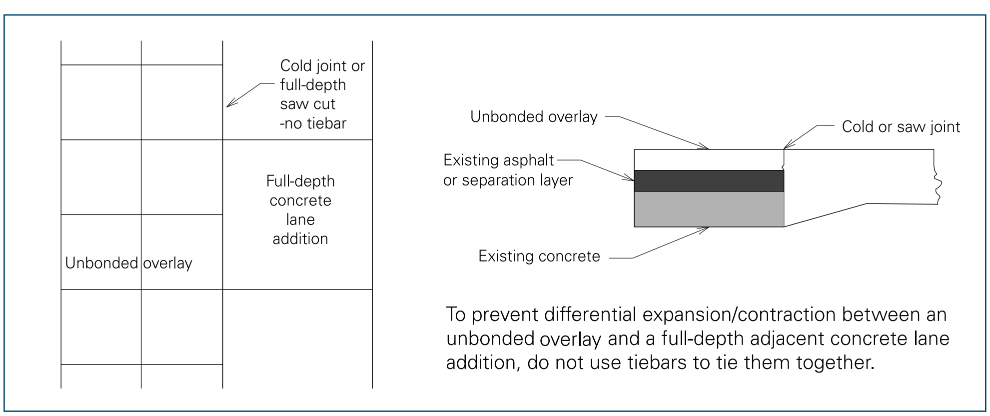


Figure 33. Unbonded overlay of concrete, asphalt, or composite pavement with full concrete lane addition

Concrete Overlay Materials

Decisions about mixture materials are affected by the type of mixture—conventional or expedited—desired for a specific project. In addition to the mixture itself, other important materials for concrete overlays are reinforcing fibers, separation materials, dowel bars and tiebars, curing compound, and joint sealant.

In general, it is better to have a wet, sticky mixture than a dry one for a concrete overlay. The use of high-modulus structural fibers can improve the fatigue resistance, toughness, and post-cracking behavior of the concrete and help control plastic shrinkage cracking.

Type of Mixture

Both conventional and expedited mixtures can be used in concrete overlay projects.

Conventional Mixtures

Conventional concrete paving mixtures are typically used in the construction of concrete overlays. As with conventional concrete pavements, an effective mixture design is essential to the performance of a concrete overlay.

Each of the components used in a concrete mixture should be carefully selected so that the resulting mixture is dense, relatively impermeable, and resistant to both environmental effects and deleterious chemical reactions over the length of its service life.

Most agencies specify a minimum concrete strength requirement for their pavements. Typical values include a 28-day compressive strength of 4,000 psi (27.6 MPa) or a 28-day third-point flexural strength of 650 psi (4.5 MPa).

Expedited Mixtures

Some states use rapid-strength concrete mixtures with a high cementitious material content (though not to exceed 660 lb/yd³ [299 kg/m³]), low water-cementitious materials (w/cm) ratio, and smaller top size aggregate (typically 0.75 in. [19 mm]).

These mixtures can be used with accelerating admixtures to provide the early strength required to place traffic on the overlay within a short time period. A water-reducing admixture is used to reduce the w/cm ratio. The slump range is typically 2 to 3 in. (50 to 75 mm), which provides good bonding grout.

For bonded concrete overlay mixtures, the proper cement content, together with well-graded aggregate, will reduce shrinkage and curling potential and thus the related stresses that can cause debonding.

Although the use of expedited mixtures and expedited paving practices has become more common in bonded overlay projects, there has been some concern regarding potential detrimental effects of quicker setting cements and faster construction times on long-term durability of concrete. Thus, it may be that both speed of construction and long-term concrete durability need to be considered during the mix design phase of a project. In general, emphasis should be given to using the simplest mixture materials that will provide the desired opening times for a specific project.

Expedited paving can be achieved not only through the concrete mixture but also through good planning and coordination of all construction activities to minimize downtime.

Concrete Materials

Concrete materials include cement, supplementary cementitious materials (SCMs), aggregates, water, and admixtures.

Cementitious Materials

Type I and type II cements are commonly used in concrete mixtures for concrete overlays. When high early strength is desired, some agencies use type III cement, which is more finely ground, to promote the development of high early strength.

Since conventional type I and II cements are normally adequate, the use of type III cements with overlays is normally limited to isolated areas that require special attention.

As with conventional paving, SCMs normally improve durability and can enhance the ease of construction.

Aggregates

Aggregates used in concrete mixtures range from crushed stones to river gravels and glacial deposits. To help ensure the longevity of the pavement, the aggregate should not only possess adequate strength but should also be stable physically and chemically within the concrete mixture.

Agencies generally require that aggregates conform to ASTM C 33. Extensive laboratory testing or demonstrated field performance is often required to ensure the selection of a durable aggregate.

The maximum coarse aggregate size used in concrete mixtures for overlays is a function of the overlay thickness. Some thinner concrete overlays may require a reduction in size of the standard aggregate used in concrete paving. It is recommended that the largest practical maximum coarse aggregate size be used in order to minimize paste requirements, reduce shrinkage, minimize costs, and improve mechanical interlock properties at joints and cracks.

Although maximum coarse aggregate sizes of .75 to 1 in. (19 to 25 mm) have been common in the last two decades, smaller maximum coarse aggregate sizes may be required for concrete resurfacing. For nonreinforced pavement structures, a maximum aggregate size of one-third of the slab thickness is recommended.

The use of uniformly graded aggregates reduces shrinkage. This is good practice for all overlays but is especially important for bonded overlays of concrete pavements. For bonded concrete overlays, well-graded aggregate with proper cement content will reduce shrinkage and curling potential and thus reduce the risk of debonding.

When selecting aggregate for a bonded concrete overlay on an existing concrete pavement, the CTE becomes a particularly important parameter. Because aggregate composes a majority of the concrete's mass, its CTE is a good indicator of concrete movement due to thermal expansion and contraction. Using an aggregate in the overlay mixture with CTE similar to that of the existing pavement helps ensure that the two layers move together, thus minimizing stress at the bond line due to differential movement and helping to maintain the bond between the layers. CTE can be determined using AASHTO provisional test TP-60 (Coefficient of Thermal Expansion of Hydraulic Cement Concrete).

If not similar to the CTE of the underlying concrete pavement, the CTE of the overlay should be less than that of the underlying pavement. The overlay surface is exposed to greater temperature swings than the underlying pavement. Therefore, the lower the overlay's CTE, the less the differential movement between the overlay and underlying pavement.

Water-Cementitious Materials Ratio

Guidance on the selection of the appropriate w/cm ratio is provided by ACI and PCA. A maximum w/cm ratio value of 0.45 is common for pavements in a moist environment that will be subjected to freeze-thaw cycles. However, lower w/cm ratio values are often used for concrete overlays to minimize drying shrinkage.

Admixtures

Various admixtures and additives are commonly introduced into concrete mixtures.

These include the following:

- Air entrainment protects the hardened concrete from freeze-thaw damage and deicer scaling. However, air entrainment also helps increase the workability of fresh concrete, significantly reducing segregation and bleeding. The typical entrained air content of concrete for overlays is in the range of 5 to 7 percent.
- Water reducers are added to concrete mixtures in order to reduce the amount of water required to produce concrete of a given consistency. This allows for a lowering of the w/cm ratio while maintaining a desired slump and thus has the beneficial effect of increasing strength and reducing permeability.
- SCMs such as fly ash and ground, granulated blast-furnace slag (GGBFS) may be added to concrete mixtures. These materials may be added to the portland cement or partially substituted for a percentage of the portland cement.

  Since SCMs can retard set time in cold weather, some agencies restrict their use in colder seasons of the year. However, SCMs can aid construction during hot weather by extending the placement time.

  SCMs typically improve the workability of the mix and also increase concrete durability; they also can increase the long-term strength of the concrete, although the short-term strength may be lower.

  In addition, fly ash and GGBFS are effective in reducing alkali-silica reactivity.

Fiber-Reinforced Concrete

Fiber-reinforced concrete (FRC) mixtures have been used in concrete overlays. The principal reason for incorporating fibers is to create concrete composites that are more durable than plain concrete. FRC can provide improved flexural ductility and toughness, fatigue capacity, and abrasion and impact resistance. FRC inhibits crack development and slows crack growth, while it provides increased load capacity in pavements that have already cracked. Another benefit is reduced spalling at contraction joints by keeping them tighter and more stable. FRC mixtures are used in both bonded and thin unbonded overlays.

A wide variety of fiber materials has been used to reinforce concrete. In the United States, steel and synthetic fibers (e.g., polypropylene, polyester, or nylon) are commonly used. Fibers have been used on multiple U.S. paving projects over the last several years. For bonded overlays, polypropylene fibers have been used most commonly in recent years, and their use is increasing steadily.

Fibers are commonly classified into synthetic, steel, and blended types.

Synthetic Fibers (Micro and Macro)

Polypropylene microfibers are produced either as cylindrical monofilaments or fine fibrils with a rectangular cross section. Polypropylene micro fibers can be in monofilament, multifilament, or fibrillated form. At low dosage rates, microfibers are effective in controlling plastic shrinkage and settlement cracking. The fibrillation process greatly enhances the bonding between the concrete and the polypropylene fibers and can provide increased load capacity in pavements that have already cracked.

Polypropylene macrofibers are coarse fibers that allow greater surface area contact within the concrete, resulting in increased interfacial bonding and flexural toughness. Polypropylene macrofibers can be used as secondary reinforcement and can provide greater post-crack strength and concrete slab capacity (Roesler 2004; 2007). Additional benefits include improved impact, abrasion, and shatter resistance.

Polyester fibers are available only in monofilament form. They commonly have relatively low fiber content and are used to control plastic shrinkage–induced cracking.

Steel Fibers

Steel fibers are primarily made of carbon steel, although stainless steel fibers are also manufactured. Perhaps the biggest advantage of steel fibers is their high tensile strength and their ability to bridge joints and cracks to provide tighter aggregate interlock, resulting in increased load-carrying capacity. Steel FRC pavements exhibit excellent toughness and pre- and post-crack capacity.

The aspect ratio is an important parameter influencing the bond between the concrete and the fiber, with longer fibers providing greater bond strength and toughness. Steel fibers may also have certain geometric features to enhance pullout or anchorage within the concrete mix. These features may include crimped or hooked ends or surface deformations and irregularities.

Some concerns have been raised regarding the corrosion of steel fibers, particularly in pavements exhibiting cracks wider than 0.004 in. (0.10 mm).

Blended Fibers

Blended fiber systems combine macrofibers or steel fibers with microfibers.

The microfibers in these systems provide resistance to plastic shrinkage and settlement cracking, while the macrofibers or steel fibers provide long-term secondary reinforcement. Blended systems provide higher levels of fatigue resistance, greater flexural toughness, and improved durability. Additional benefits include improved impact, abrasion, and shatter resistance.

Separation Layer Materials

A separation layer is an important feature of unbonded concrete overlays on existing concrete pavements. The performance of these overlays depends largely upon using a separation layer to separate the two layers.

The separation layer performs two functions. It provides a shear plane that helps prevent cracks from reflecting up from the existing pavement into the new overlay. It also prevents bonding of the new concrete overlay with the existing concrete pavement, so both are free to move independently.

The most common and successful separation layer used in the United States is a conventional asphalt surface mixture. On most projects, a nominal 1 in. (25 mm) thick layer provides adequate coverage over irregularities in the existing pavement. The thickness can be slightly increased when irregularities are large enough to impact placement operations.

The separation layer does not provide significant structural enhancement; therefore, the placement of an excessively thick layer should be avoided.

When a pavement is poorly drained and experiences heavy truck traffic, scouring (stripping) of the asphalt separation layer may occur. In an effort to reduce the scour pore pressure and increase stability, some states modify the asphalt mixture to make it more porous. In particular, the sand content is reduced and the volume of 0.38 in. (10 mm) chip aggregate is increased. This modified mixture has a lower unit weight and lower asphalt content, and is comparable in cost with typical surface mixtures.

Some states have used a few other separation layer materials, including bituminous material, polyethylene sheeting, wax-based curing compounds, liquid asphalts, and hot-mix asphalt, with mixed results:

- Less than 1 in. (25 mm) thick asphaltic separation layers, such as slurry seals, have worked well in some cases, but are generally not recommended because they do not eliminate mechanical interlock, they erode near the joints, and they do not effectively separate the two layers.
- Polyethylene sheeting and curing compounds are also not recommended. They do not prevent working cracks from reflecting through the overlay (ACI Committee 325 [2006]), and they trap moisture in the concrete, which may accelerate freeze-thaw damage.

Some states, such as Missouri, are conducting research on the use of geotextile materials as a separation layer. For several years, Germany has used a geotextile material between cement-treated base courses and concrete pavement with very good results (figures 34 and 35). The thickness of the geotextile is typically about 0.25 in. (6.3 mm) (appendix B).

According to Leykauf and Birmann (2006) of Munich University of Technology, geotextiles have provided uniform, elastic support of the concrete slab, hence reducing stresses due to temperature and moisture gradient. They also reduce pumping processes and prevent origination of reflected cracks from bonded base courses without notching them.

Leykauf and Birmann (2006) also state, "Concrete roads with a separation layer of geotextiles are especially recommended for concrete overlays on old concrete pavements, in tunnels and on rigid base courses."

Incidental Materials

Other materials used in the construction of concrete overlays are essentially the same as used in conventional concrete pavement construction, as summarized below:

- Dowel bars are typically billet steel, grade 60 bars that conform to ASTM A615 or AASHTO M31. The dowel bar size, layout, and coatings should be selected for the specific project location and traffic levels.

  Dowels should be positioned in the middle third of the slab. Target the average thickness and avoid multiple basket heights.

  In some cases, because of the underlying support of the old pavement, dowels are not used or their size is reduced.

- Tiebars are typically billet steel, grade 40 bars that meet ASTM A615 or AASHTO M31 specifications. No. 5 deformed tiebars are typically spaced at 30 in. (76.20 cm) apart, but greater spacing may be used in some cases. When small panel sizes are designed, tiebars are typically not used.

- Joint sealant materials, if used, are either hot-poured rubberized materials conforming to ASTM D6690, AASHTO M301, or per normal design; silicone materials conforming to a governing state specification; or preformed compression seals conforming to ASTM D2628, AASHTO M220, or a governing state specification.

  When small panel sizes are constructed, sealant is often not used.

- Curing materials may include wet burlap, polyethylene, or liquid membrane-forming curing compounds that comply with ASTM C309 or AASHTO M148.

Key Resources

Smith et al. (2002)

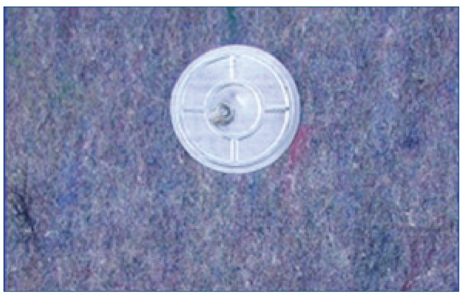


Figure 34. Close-up of geotextile fabric (Photo courtesy of Prof. Gunther Leykauf, Technische Universitat Munchen)

Figure 35. Roll of geotextile fabric being placed prior to overlay (Photo courtesy of Prof. Gunther Leykauf, Technische Universitat Munchen)

Managing Concrete Overlay Work Zones under Traffic

This section discusses several issues related to work zone management, including clearances, traffic control, and staging.

Objectives of Work Zone Management

Managing work zones for concrete overlay projects is no more challenging than for any other paving project under traffic, as long as certain straightforward practices are followed.

Effective work zone management for all concrete pavement projects, including concrete overlays for maintenance and rehabilitation, involves designing a comprehensive plan of action that balances several equally important priorities (figure 36):

- Ensure safety of workers and motorists
- Minimize inconvenience to the traveling public
- Maintain or enhance cost-effectiveness of the project
- Follow best construction practices to maximize pavement performance

The basic elements of these priorities are discussed below. A checklist of considerations in overlay work zone management is provided in table 9.

Safety

Promoting worker and traveler safety should be an integral, high-priority element of every project, from planning through construction. Roadway users (vehicles, bicycles, pedestrians, etc.) must be clearly guided by traffic control devices and markings while approaching, passing through, and leaving temporary traffic control zones. Traffic control elements should be regularly inspected. All people involved in selecting, placing, and maintaining work zones should be trained in safe traffic control practices.

The exposure of highway workers and travelers to safety risks can be minimized by reducing

Figure 36. Managing work zones effectively involves balancing several priorities

Table 9. Concrete overlay work zone management considerations

Areas of Consideration	Items to Consider
Traffic Management	1. Capacity analyses—lanes required, length of queues anticipated 2. Time restrictions—peak hours, seasonal peaks 3. Limits to work areas 4. Capacity of detour routes 5. Work vehicle access and worker parking 6. Bicycle and pedestrian traffic 7. Warning sign locations—detours, long queues, intersecting roads 8. Railroad crossings and train schedule 9. Nighttime delineation and illumination 10. Signals, turning lanes, bus stops 11. Traffic service—residential/business 12. Future rehabilitation
Concrete Pavement Construction Requirements	1. Accelerated construction—planning, concrete materials, construction requirements, curing, jointing 2. Opening to traffic—maturity, pulse velocity, strength requirements, cure time 3. Rehabilitation considerations 4. Off-peak traffic hours for increased production 5. Phasing of work—length of work zone, project limits 6. Special conditions such as dropoffs, sign bridge installation, etc. 7. Pre-paving and paving restrictions 8. Special contract provisions needed 9. Short duration closures anticipated 10. Temporary drainage 11. Lights for night work 12. Temporary roadway lighting
Safety	1. Work zone crash rates 2. Traffic management strategies 3. Interstate system 4. Congestion 5. Nighttime 6. Large trucks 7. Workers on foot 8. Pedestrians 9. Local experience
Constructibility	1. Structural capacity of bridges, shoulders, and pavement 2. Timing of phases versus probable starting date 3. Strategy to allow contractor to finish project 4. Status of existing traffic control devices—signals, signs, railroad crossings, etc. 5. Wintertime restrictions—snow removal, etc.
Emergency Planning	1. Incident management plans 2. Emergency medical assistance 3. Accidents, breakdowns, tow trucks 4. Severe storms and storm water runoff 5. Emergency closures 6. Utility interruptions 7. State police 8. Local law enforcement
Public Information Coordination	1. Public information—public hearings, media, motorist service agencies, residents, local businesses, motor carriers 2. Local officials—police, fire, hospitals, schools, environmental agencies, utilities, toll facilities, ferries, railroads, airports 3. Special events 4. Intra-agency coordination—maintenance crews, permits section, adjacent project 5. Transit

Adapted from multiple sources

the frequency that work zones are established, reducing the length of time work zones are in place, and where possible reducing the volume of traffic through the work zone.

A detailed emergency response plan should be in place to deal with any injury that might occur in the work zone. The plan should include protocols for emergency medical services.

Traffic Flow

Minimizing disruption to traffic in work zones requires a proactive, partnership approach to work zone management. By involving officials and the public during early stages of project planning, the designer and contractor can gain a better understanding of traffic issues related to the project. As a result, they can develop better, more coordinated solutions. In addition, broadly publicizing the work zone well before construction begins helps ensure that motorists have every opportunity to plan travel routes and times accordingly.

Cost-Effectiveness

Strategies used to manage traffic in work zones can significantly affect project costs. Therefore, it is important to carefully evaluate road use demands and select the most cost-effective strategies to accommodate the demands. For example, partly or completely closing a work zone to traffic can help minimize traffic management costs, but when a roadway cannot be closed, higher costs are probably justifiable. Possible ways to manage costs include, where possible, reducing traffic volume through work zones, reducing the frequency and duration of work zones, and minimizing detours and crossover construction elements.

Pavement Performance

To ensure that concrete overlays provide durable, long-lasting maintenance and rehabilitation solutions, basic good design and construction practices must be followed. These include designing an overlay that is appropriate for the situation, accomplishing appropriate preoverlay repairs and preparation of the existing pavement, and using good construction practices like proper jointing and curing. With thorough planning, work zones can be managed to accommodate these activities without sacrificing project safety, traffic flow, or cost-effectiveness.

Work Zone Space Considerations

Constructing any overlay requires occupying some part of the traveled portion of the roadway to accommodate work activities and provide traffic control and other safety provisions for workers and motorists. This will affect traffic capacity through the work zone for the duration of the work activities. In some cases, safety considerations may require partial or even complete closure of the roadway.

When overlay projects are constructed under traffic, space and traffic capacity considerations impact three primary elements of a work zone management strategy: construction clearances, traffic control, and project staging.

Paving Equipment Clearances

When work zones are set up under traffic, adequate clearance must be provided to accommodate the paving machine's tracks and frame, as well as the paving stringline. For a standard concrete paver operation, the typical paving equipment clearance is 4 ft (1.2 m) on each side of the paving machine (3 ft [0.9 m] for the paver track and 1 ft [0.3 m] for the paver control stringline) (figure 37). Paving equipment clearances do not include space for traffic control devices or workers or space for highway users (vehicles, pedestrians, bicycles, etc.). Additional clearances needed should be determined on a project-by-project basis.

In some situations—narrow roadways, minimum or no shoulders, traffic in adjacent lanes, obstacles like retaining walls or safety barriers—paving equipment clearances may need to be reduced. These situations are fairly common with all maintenance and rehabilitation projects. With adequate planning, zero paving equipment clearance can be achieved to accommodate specific project needs, such as paving next to a median barrier (figure 38). (As with asphalt paving, zero paving equipment clearance in concrete paving does not include the 6 to 8 in. [150 to 200 mm] for the paving machine edge form.)

Reducing Clearance with Paver Modifications

Paving machine manufacturers have developed special paving machines designed to execute minimum clearance projects (figure 38). In addition, many contractors around the country have made various modifications to standard pavers to achieve zero clearances (figure 39). Instead of specifying a certain manufacturer's machine, owner-agencies are advised to define the maximum allowable clearance zone and let the contractor select or modify the equipment and operation to meet project needs.

Figure 37. Typical clearance on a concrete overlay project (Photo courtesy of Matt Ross, P.E., Missouri/Kansas Chapter ACPA)

Figure 38. A three-track, zero-clearance paver placing concrete along a median barrier (Photo courtesy of Kevin Klein, Gomaco)

Figure 39. A typical, four-track paver modified to three tracks, providing zero clearance in a curb-and-gutter situation in Oklahoma (Photo courtesy of Jim Duit, Duit Construction Co., Inc.)

Reducing Clearance with Alternative Control Options

Alternative paving control options may be used to reduce clearance as long as smoothness criteria are met. For example, an average profiler, a movable stringline, or a ski can be used in tight areas, each relying on the smoothness of an existing lane to ensure a smooth profile on the new pavement (figures 40 and 41). Use caution when allowing heavy truck traffic on part of the lane being overlaid because vibrations may affect results, particularly of bonded overlays.

Advanced technologies may eventually eliminate the need for stringlines or other physical control methods. Three-dimensional equipment controls, for example, are already available. Guidance technologies based on global positioning systems (GPS) are showing great promise, although more development is necessary before they are accurate enough to allow contractors to consistently earn smoothness incentives.

Other Clearances

In addition to paving equipment clearances on all construction operations, clearance must be allowed for traffic control devices and construction workers. The width of this clearance zone varies depending on adjacent traffic volume, traffic speed, and agency requirements. In addition, the location of workers with long-handled floats should be restricted to the non-traffic side of the pavement.

Construction Traffic Control

All work zone traffic control, including speed restrictions, should follow jurisdictional requirements and the latest MUTCD (FHWA 2003b). The fundamental principles of work zone traffic control are given in Section 6B. In addition, the *Traffic Management Handbook for Concrete Pavements Reconstruction and Rehabilitation* (ACPA 2000a) is a good reference on traffic control strategies for common roadway rehabilitation categories, including overlays. See, in particular, chapter 4 on traffic control strategies for concrete pavement.

ACPA's handbook explains that, "as traffic volumes increase, the 'window' of time where the traffic demand is below the capacity of the work zone will become smaller. When the time is too short to allow for daytime work, the work is usually moved to nighttime. In some cases even the nighttime hours are restricted."

For situations such as recreational routes, the peak traffic hours may be on Friday and Sunday afternoon. The allowable window of time for road construction in this case may be noon Monday to 6:00 p.m. Thursday.

The limitation of work hours and the number of lanes closed results in a piecemeal type of project that can increase the duration of the project as much as 100 percent or more. This approach also requires planning flexible traffic control strategies that can be adjusted for peak hours or days when the roadway is entirely open to traffic.

For roadways under high traffic demands, a traffic analysis should be conducted to identify which parts of the roadway can be occupied by construction and public traffic at any point during the construction time period. The goal is to identify congestion points that could affect traffic capacity and safety as well as construction production levels.

Such an analysis answers specific questions:

- Is the capacity of the existing roadway adequate for existing traffic levels?
- How will capacity be affected if some lanes are shut down and other lanes kept open?
- Comparing existing traffic levels to the under-construction capacity, are there any capacity deficiencies?

The analysis should consider both the lateral clearance (availability and need) and the length of roadway needed to provide efficient, cost-effective paving production. It must also factor in peak and off-peak traffic flows.

If deficiencies will occur, the work zone management plan must address them to prevent congestion and increased project costs. For example, the plan might include variable work times (e.g., off-peak hours, nighttime) or construction sequencing to meet production and safety demands.

An increasingly popular alternative is to completely close the facility briefly to complete the project or a critical phase of the project. In some cases, this alternative has reduced the overall project duration significantly.

Concrete Overlay Staging

A common misconception is that constructing a concrete overlay on a two-lane roadway requires closing the roadway for the duration of the project. Many easy-to-use approaches exist for staging concrete overlay projects in almost any situation.

For example, concrete overlays can be constructed on four-lane divided roadways without crossovers and head-to-head traffic. Traffic can be allowed on the new pavement within 24 hours of construction by protecting the concrete as described under Accelerated Construction beginning on page 54.

A system approach that considers work zone safety, traffic requirements, and key elements of construction should be used in staging concrete overlay projects for fast, cost-effective construction projects. Some common scenarios are described below.

Two-Lane Highway under Traffic

When staging a two-lane concrete overlay project under traffic, the widths of the vehicle lane and of the construction lane must be considered.

Typically, the minimum desirable width for the vehicle lane is 11 ft (3.4 m). Some jurisdictions may allow as little as 10 ft (3.1 m) under certain circumstances, for example, in very short segments (less than 100 ft [30.5 m]).

Figure 40. Controlling paving profile using a moveable stringline on the adjacent lane (Photo courtesy of Kevin Klein, Gomaco)

Figure 41. Controlling paving profile using a paver ski on the adjacent lane (Photo courtesy of Wouter Gulden, P.E., Southeast Chapter ACPA)

The width of the construction lane depends on several factors, including thickness of overlay, maximum allowable centerline or edge fillet, slope of fillet, type of traffic control device, type of paving machine, and automobile and truck traffic.

Concrete overlays can be successfully constructed under traffic with conventional paving machines; in some cases where minimum clearances are required, minor adjustments may be necessary.

The length of the temporary traffic control zone is another important factor. Typically, the length of traffic control zones is limited to 0.25 mi (0.40 km), and a pilot car is not used. In rural areas, however, it may be more feasible to pave longer sections. In such situations, a pilot car and flaggers are often used and the maximum length of the traffic control zone is established by the jurisdiction.

Other traffic control measures, including flaggers and traffic control signals, may be warranted according to jurisdictional requirements.

When granular shoulders of adequate widths are available to accommodate a conventional paver, it is recommended that the shoulders be treated with 3 ft (0.9 m) of calcium chloride before opening the road to vehicular traffic. The calcium chloride treatment is a successful way of stabilizing the shoulder in case errant vehicles leave the pavement. Also, vertical traffic control panels may be used to designate the pavement edge (figure 42).

If shoulder paving is part of the project, the trenching of paved shoulder base widening should be completed in the first stage along with surface preparation of the initial lane to be overlaid. Once this is completed, this lane can be opened to traffic and the adjacent lane can be prepared for paving.

During the second stage, the second lane is paved. A thickened edge may be paved if pavement widening is part of the project.

The third stage includes opening the newly placed overlay to traffic and shifting traffic control for work on the opposite lane. The final stage includes placing pavement markings, rumble strips if shoulders are paved, and final shouldering.

Some possible two-lane staging options are presented in figures 44 through 46.

Fillets

If two-way traffic is desired on the roadway after the first lane is cured, and the overlay thickness is greater than 2 in. (50 mm), construction of centerline and outside edge fillets may be an option (figure 43). Outside edge fillet should be considered if shouldering will not be completed before opening the roadway to traffic.

Continuous Production

Pilot cars can be used to keep one lane of traffic adjacent to the paving operation open at all times. To minimize traveler delays, many jurisdictions limit the length of such work zones. Contractors must balance those limitations with their need for continuous production so that crews do not stand idle at any time. This requires detailed planning and staging.

Following are some considerations for staging a project using pilot cars cost-effectively:

- Typically, a contractor can prepare and pave 4,000 to 5,000 ft (1,219 to 1,525 m) in one lane per working day, roughly one short lane mile.
- Constructing an edge fillet may make it possible to open the lane to traffic before the shoulder backfill is completed.
- A new overlay can be opened in 24 hours or less.
- Leaving gaps in or staggering construction areas (that is, leap-frogging over a section of pavement) can allow the contractor to stage work in ways that use crews and machinery more efficiently. This may require two separate traffic control systems.
- Using multiple paving machines may make it possible to stagger work zones more efficiently.
- The direction of the initial pour is important to make sure the paver ends each pour in the optimum position to begin the next.

Two-Lane Highway Expanded to Three Lanes under Traffic

When constructing a concrete overlay and widening a pavement from two lanes to three lanes, some states require that the remaining shoulder after pavement widening be at least 4 ft (1.2 m) wide. Therefore, using both existing shoulders for staging and widening has distinct advantages.

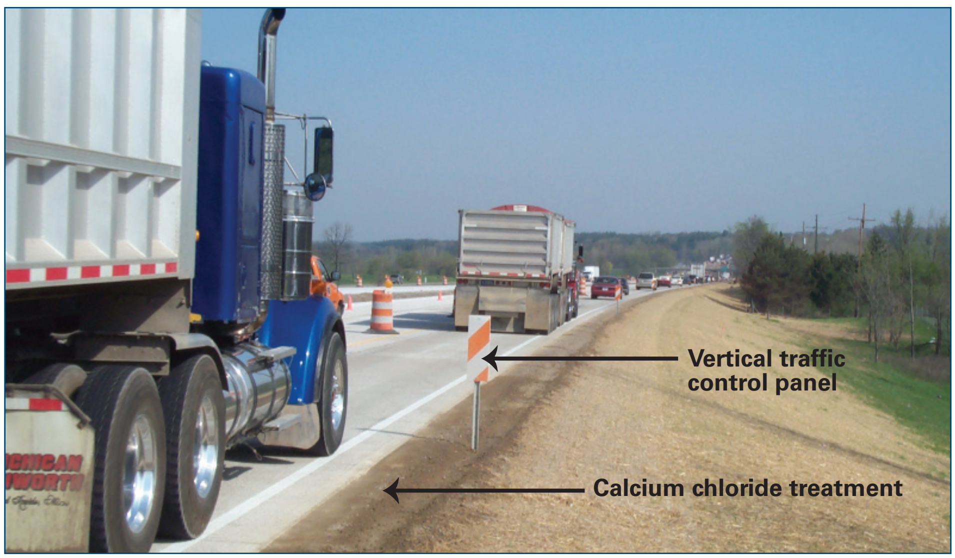


Figure 42. Vertical traffic control panels may be used to mark pavement edge dropoff (Photo courtesy of Dan DeGraaf, P.E., Michigan Concrete Paving Association)

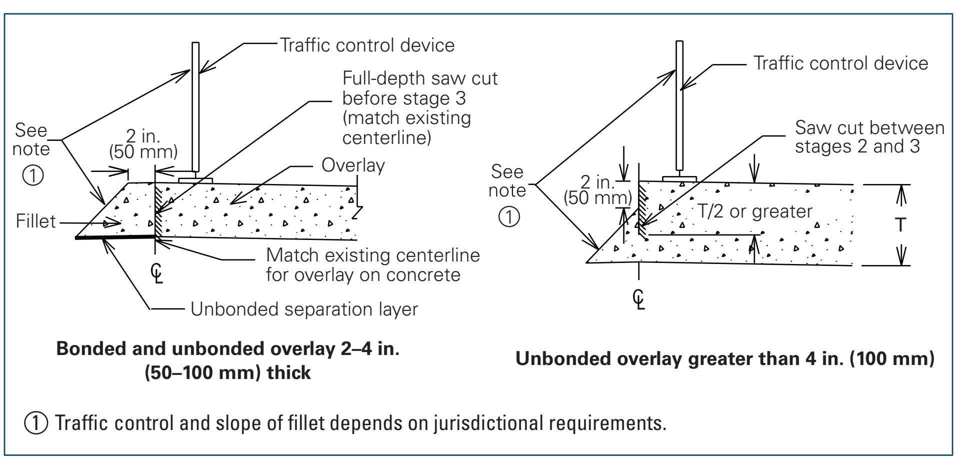


Figure 43. Centerline fillets for overlays 2 in. (50 mm) or greater

First, base shoulder widening on one half of the road is accomplished. The overlay is constructed in halves similar to the two-lane staging example. The existing shoulder is trimmed and properly compacted. The first concrete overlay section is then placed with a thickened edge. The other half of the overlay can be placed directly on top of the base shoulder constructed first.

A possible staging sequence for this type of construction management is shown in figure 47.

Four-Lane Divided Highway without Crossovers and under Traffic

Staging a concrete overlay on a four-lane divided highway is similar to that on a two-lane highway. Both two-lane sides may be under construction at the same time, and crossovers are eliminated. By eliminating crossovers, project costs are reduced and safety is increased. The existing shoulders usually provide adequate room for the paver track, stringline, and workers between the paver and traffic.

A possible staging sequence for this type of construction is shown in figure 48. Because each half of the four-lane divided highway is treated like a two-lane section, any of the staging sequences from figures 44 through 46 may be used on either half of the section.

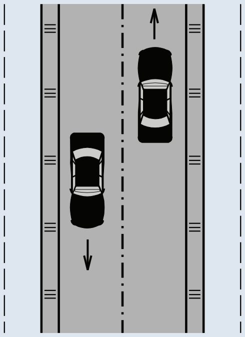
Key Resources

FHWA (2003b)

COMPLETED OVERLAY (Two-Lane Roadway with Paved Shoulders, Conventional Paver)

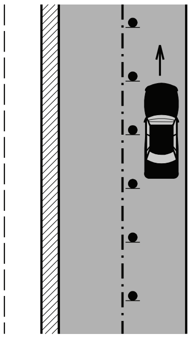
Applied to:

- ☑ **Bonded concrete overlay of concrete pavements**
- ☑ **Bonded concrete overlay of asphalt pavements**
- ☑ **Bonded concrete overlay of composite pavements**
- ☑ **Unbonded concrete overlay of concrete pavements**
- ☑ **Unbonded concrete overlay of asphalt pavements**
- ☑ **Unbonded concrete overlay of composite pavements**



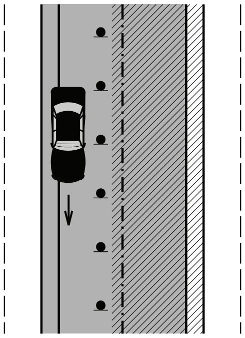
STAGE 1. Repair surface, prepare for overlay, and construct base shoulder widening and separation layer

- Install traffic control and close the left lane. Follow jurisdictional requirements for traffic control. Check with jurisdiction regarding allowable lane closure length. If surface repair and preparation for the overlay are minimal, then slow-moving traffic control may be appropriate. Closing the lane may require additional traffic control (e.g., signals, flaggers, and/or pilot cars).
- Repair the surface as appropriate. Prepare the surface for the overlay (or, in the case of concrete overlay on concrete, the separation layer) as described in the contract document.
- Prepare for shoulder widening by trenching the existing shoulder and trimming to the specified width. The trench should be rolled and compacted as necessary to obtain a firm and stable platform as specified in the contract documents. A continuous progression approach with the shoulder trencher and placement of the base shoulder widening material is encouraged.
- Construct separation layer (only for unbonded overlay on concrete).



STAGE 2. Construct right shoulder and concrete overlay

- Shift the traffic control to the left lane and close the right lane to traffic. The length of the closure will depend on the jurisdiction's maximum closure length with pilot car. Traffic controls and traffic control signals will be based on jurisdictional requirements.
- Repair and prepare the surface for the overlay or the separation layer and subsequent overlay as described in the contract documents. Construct separation layer (for unbonded overlay).
- Normal space for the paver stringline is 1–1.50 ft (0.30–0.46 m) and the paver track is a minimum of 2.50–3 ft (0.76–0.91 m). 1 ft (0.3 m) incremental encroachment reduction (up to 2 ft (0.6 m) total) is common through typical machine adjustment. Speeds should be additionally restricted adjacent to paver when clearance between the paver and vehicle traffic is tight.
- Construct concrete overlay on the existing pavement. Complete right PCC shoulder widening with the overlay. Bull float work shall operate from the outside shoulder only.
- Early entry saws are encouraged and should follow the depth as described in this manual.
- The "X" dimension between the roadway centerline and vertical panel is for the paving machine track and stringline.



STAGE 3. Construct left lane concrete overlay

- Close the opposite lane to traffic and place the concrete overlay according to contract documents, using the same procedures as described in stage 2. Note that stringline may not be necessary for the right edge of the paving when the paved overlay constructed in stage 2 is used as the paver control in this stage. If the right stringline is not used, the "X" dimension could possibly be reduced to 3 ft (0.9 m).
- If the outside edge dropoffs at the shoulder exceeds the jurisdictional allowance for a 1:1 fillet, then construct the granular shoulders in this stage.
- Complete shouldering. Install (mill) rumble strips in the paved shoulders and complete pavement marking and regulatory signing in accordance with contract documents.

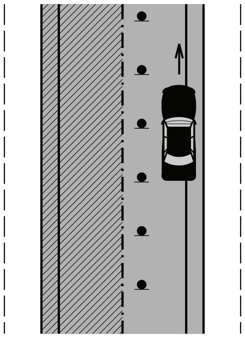
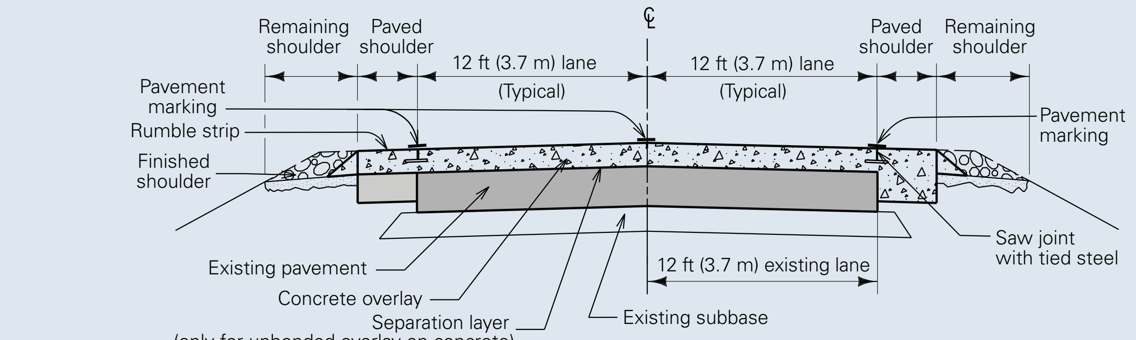
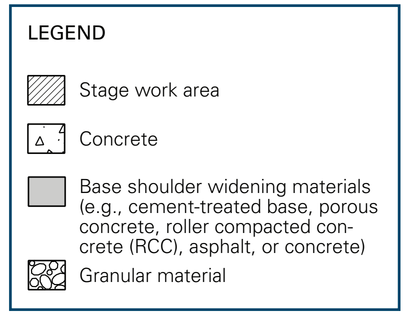
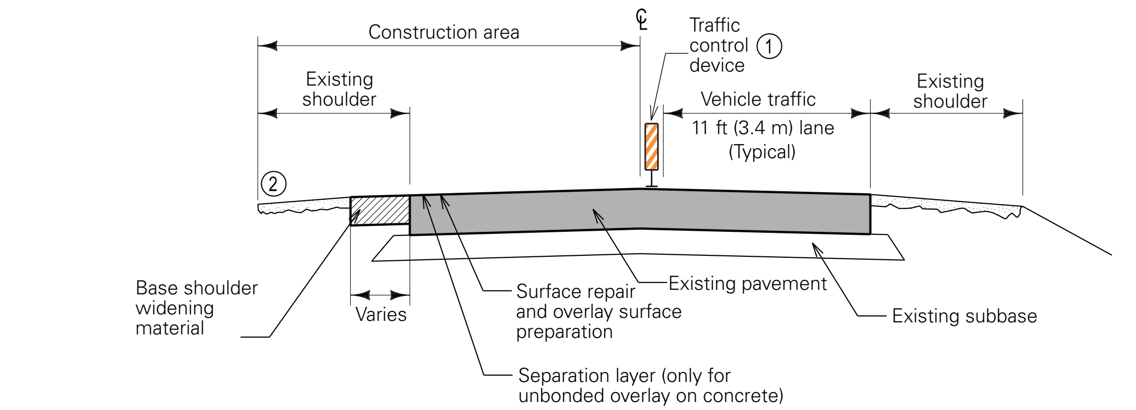


Figure 44. Overlay of two-lane roadway with paved shoulders (conventional paver)

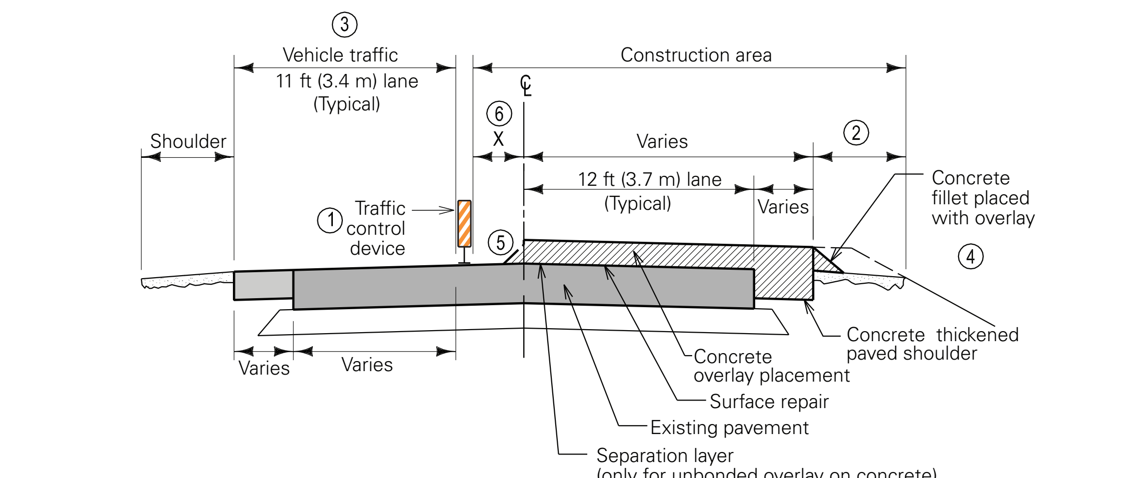


COMPLETED OVERLAY

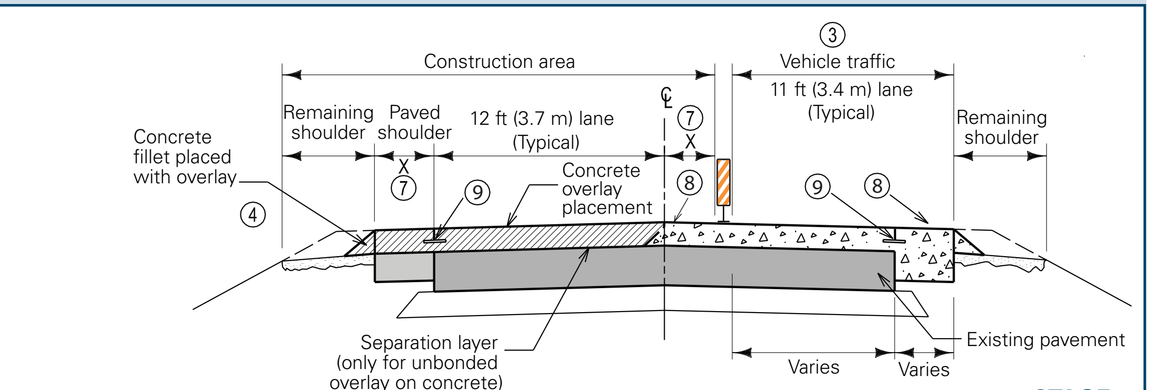




STAGE 1



STAGE 2



STAGE 3

NOTES:

① Follow jurisdictional requirements for traffic control devices.

② Treat 3 ft (0.9 m) area outside of proposed paved shoulder with calcium chloride. If the existing shoulder outside the proposed paved shoulder is less than 3 ft (0.9 m), it may be necessary to adjust the slipform paver and/or paver control to accommodate the reduced space.

③ Minimum lane width next to the paver may be reduced for short-term, stationary work on low-volume, low-speed roadways when vehicular traffic does not include longer and wider heavy commercial vehicles.

④ If the overlay is opened to traffic in this stage, and final shoulder backfill is delayed, place fillet as shown or (if overlay creates a dropoff greater than jurisdictional allowance) place granular shoulder.

⑤ See centerline fillet illustration and subsequent removal on figure 43.

⑥ For “X” less than 4 ft (1.2 m), adjustments to paver may be necessary to accommodate paver control and paver track.

⑦ The “X” dimension can be reduced to 3 ft (0.9 m) minimum when the right lane is used as paver control.

⑧ Mark edgelines and centerlines per MUTCD (FHWA 2003b) section 6F.71 (mark both lanes).

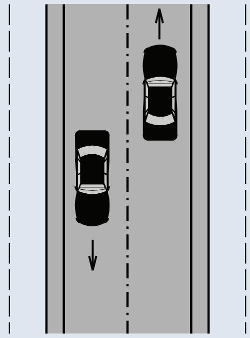
⑨ Construct longitudinal joint.

Overlay of Two-Lane Roadway with Paved Shoulders (Conventional Paver)

COMPLETED OVERLAY (Two-Lane Roadway with Granular Shoulders, Conventional Paver)

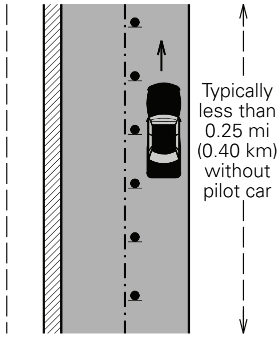
Applied to:

☑ **Bonded concrete overlay of concrete pavements**
☑ **Bonded concrete overlay of asphalt pavements**
☑ **Bonded concrete overlay of composite pavements**
☑ **Unbonded concrete overlay of concrete pavements**
☑ **Unbonded concrete overlay of asphalt pavements**
☑ **Unbonded concrete overlay of composite pavements**



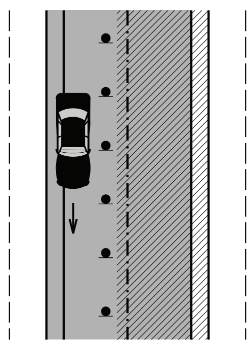
STAGE 1. Repair surface, prepare for overlay, and construct left shoulder and separation layer

- Install traffic control and close the left lane. Follow jurisdictional requirements for traffic control. Check with jurisdiction regarding allowable lane closure length. If surface repair and preparation for the overlay are minimal, then slow-moving traffic control may be appropriate. Closing the lane may require additional traffic control (e.g., signals, flaggers, and/or pilot cars).
- Repair the surface as appropriate. Prepare the surface for the overlay (or, in the case of concrete overlay on concrete, the separation layer) as described in the contract document.
- Prepare shoulder widening by trenching the existing shoulder and trimming to the specified width. The trench should be rolled and compacted as necessary to obtain a firm and stable platform. Compact shoulder material as specified in the contract documents. A continuous progression approach with the shoulder trencher and placement of the base shoulder widening is encouraged.
- Construct calcium chloride treated granular shoulder as outlined in contract documents. The treated shoulder shall be firm and stable to support vehicular traffic at low speeds.
- Construct separation layer (only for unbonded overlay on concrete).



STAGE 2. Construct right shoulder and concrete overlay

- Shift the traffic control to the left lane and close the right lane to traffic. The length of the closure will depend on the jurisdiction's maximum closure length with pilot car. Traffic controls and traffic control signals will be based on jurisdictional requirements.
- Repair and prepare the surface for the overlay or the separation layer and subsequent overlay as described in the contract documents. Construct separation layer (for unbonded overlay on concrete).
- Normal space for the paver stringline is 1–1.5 ft (0.3–0.5 m) and the paver track is a minimum of 2.5–3 ft (0.8–0.9 m). 1 ft (0.3 m) incremental encroachment reduction (up to 2 ft [0.6 m] total) is common through typical machine adjustment. Speeds should be restricted adjacent to paver when clearance between the paver and vehicle traffic is limited.
- Construct concrete overlay on the existing pavement. Construct right shoulder base with 6 in. (150 mm) thick granular shoulder. Bull float work shall operate from the outside shoulder only.
- Place 6 in. (150 mm) minimum thickness calcium chloride treated granular shoulder to help stabilize shoulder and minimize heavy dust that can impair vision.
- Early entry saws are encouraged and should follow the depth as described in this manual.
- The "X" dimension between the roadway centerline and vertical panel is for the paving machine track and stringline.



STAGE 3. Construct left lane concrete overlay

- Close the opposite lane to traffic and place the concrete overlay according to contract documents, using the same procedures as described in stage 2. Stringline may not be necessary for the right edge of the paving when the paved overlay constructed in stage 2 is used as the paver control in this stage. If the right stringline is not used, the "X" dimension could possibly be reduced to 3 ft (0.9 m).
- If the outside edge dropoffs at the shoulder exceeds the jurisdictional allowance for a 1:1 fillet, then construct the granular shoulders in this stage.
- Complete shouldering. Complete pavement marking and regulatory signing in accordance with contract documents.

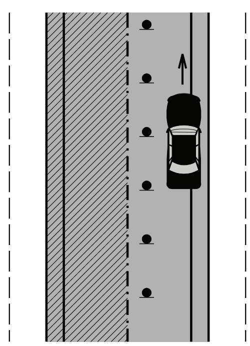
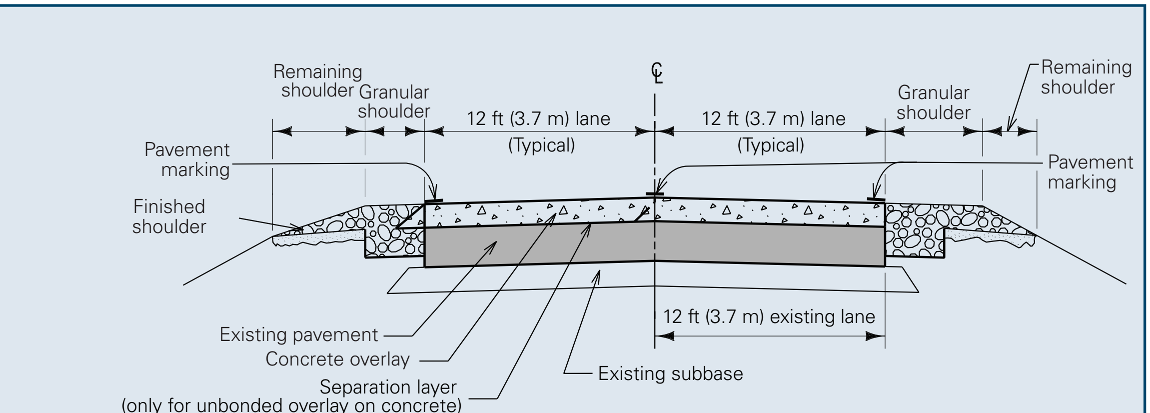
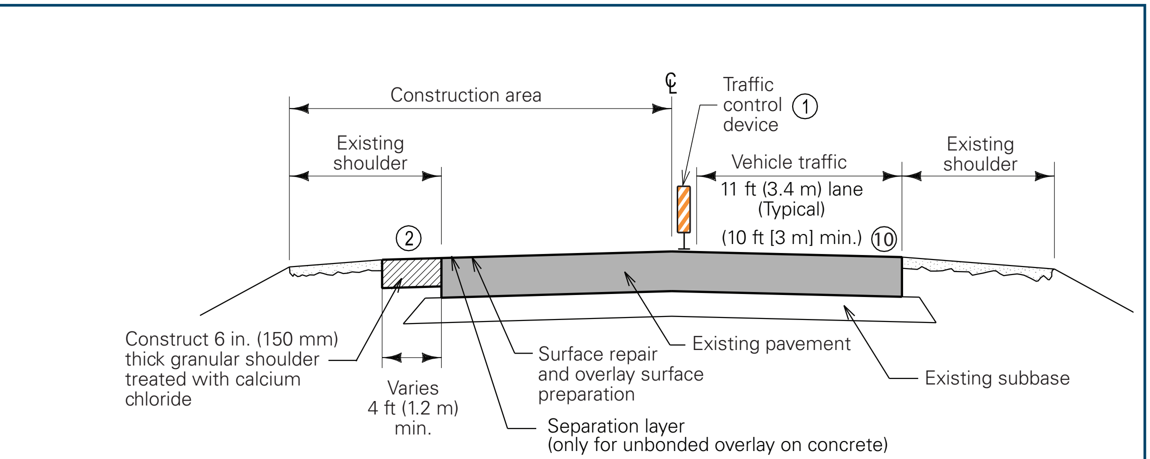


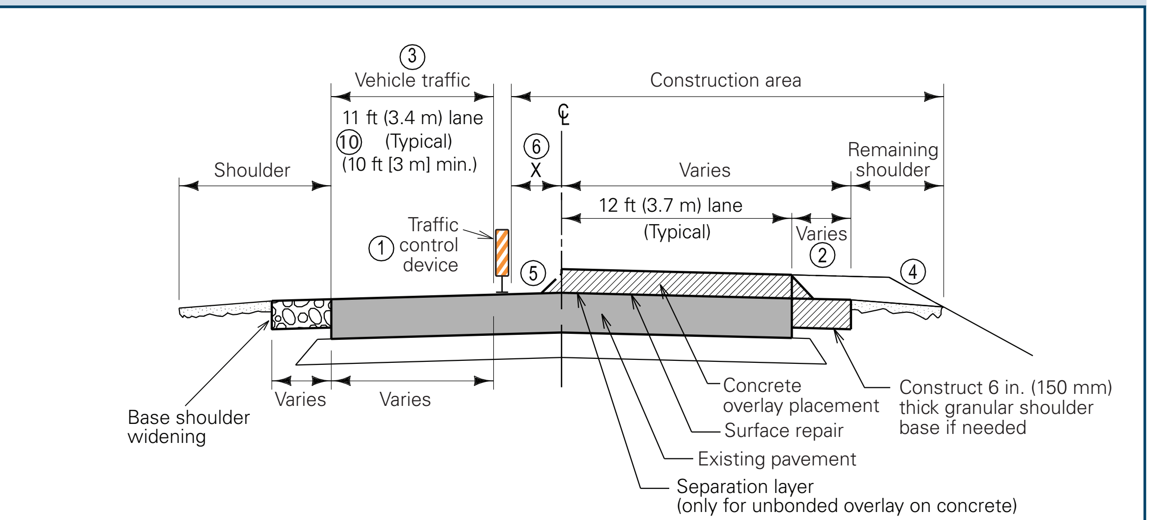
Figure 45. Overlay of two-lane roadway with granular shoulders (conventional paver)



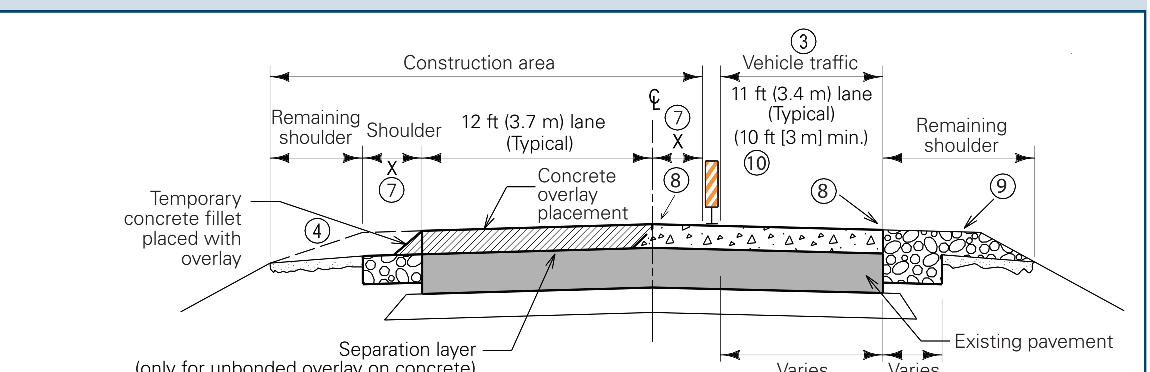
COMPLETED OVERLAY



STAGE 1



STAGE 2



STAGE 3

LEGEND

- Stage work area
- Concrete
- Granular material

NOTES:

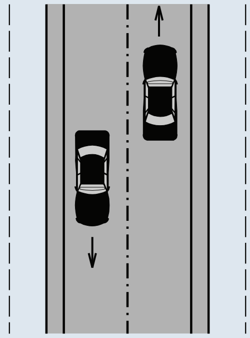
1. Follow jurisdictional requirements for traffic control devices.
2. When the existing shoulder is less than 4 ft (1.2 m), adjustment to the slipform paver and/or paver control may be necessary to accommodate the reduced space for paver control and paver track.
3. Minimum lane width next to the paver may be reduced for short-term, stationary work on low-volume, low-speed roadways when vehicular traffic does not include longer and wider heavy commercial vehicles.
4. If the completed overlay in this stage opens to traffic and the final shoulder backfill is delayed, place fillet as shown. If overlay creates a dropoff greater than jurisdictional allowance, place granular shoulder in lieu of concrete fillet.
5. See centerline fillet illustration and subsequent removal on figure 43.
6. For “X” less than 4 ft (1.2 m), adjustments to paver may be necessary to accommodate paver control and paver track.
7. The “X” dimension can be reduced to 3 ft (0.9 m) minimum when the right lane is used as paver control.
8. Mark edgelines and centerlines per MUTCD (FHWA 2003b) section 6F.71 (mark both lanes).
9. Use calcium chloride for dust control.
10. For low-volume roads only

Overlay of Two-Lane Roadway with Granular Shoulders (Conventional Paver)

COMPLETED OVERLAY (Two-Lane Roadway with Minimum Granular Shoulders, Zero-Clearance Paver)

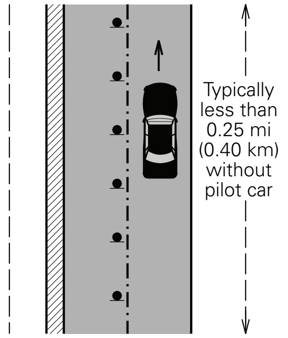
Applied to:

- ☑ **Bonded concrete overlay of concrete pavements**
- ☑ **Bonded concrete overlay of asphalt pavements**
- ☑ **Bonded concrete overlay of composite pavements**
- ☑ **Unbonded concrete overlay of concrete pavements**
- ☑ **Unbonded concrete overlay of asphalt pavements**
- ☑ **Unbonded concrete overlay of composite pavements**



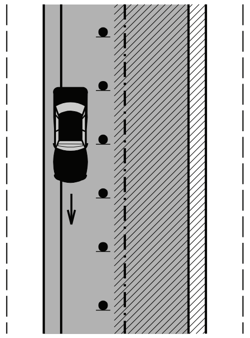
STAGE 1. Repair surface, prepare for overlay, and construct left shoulder

- In order to construct an overlay on a roadway with a minimum of 2 ft (0.6 m) wide existing shoulders, adjustments to typical slipform pavers are necessary in order to meet existing clearances adjacent to the paver. The width of the clearance zone is dependent on traffic control, paver track, and paver control (stringline). When there is not enough clearance for the paver track, paving molds may be installed on typical two-track pavers to provide zero clearances. The outside edges of the mold are brought out behind the rear tracks and then the material from the front of the paver is moved to the back by an auger to be spread and paved.
- Install traffic control and close the left lane. Follow jurisdictional requirements for traffic control. Check with jurisdiction regarding allowable lane closure length. If surface repair and preparation for the overlay are minimal, then slow-moving traffic control may be appropriate. Closing the lane may require additional traffic control (e.g., signals, flaggers, and/or pilot cars).
- Repair the surface as appropriate. Prepare the surface for the overlay (or, in the case of concrete overlay on concrete, the separation layer) as described in the contract document.
- Construct calcium chloride treated granular shoulder as outlined in contract documents. The treated shoulder shall be firm and stable to support vehicular traffic at low speeds.
- Construct separation layer (only for unbonded overlay on concrete).



STAGE 2. Construct right shoulder and concrete overlay

- Shift the traffic control to the left lane and close the right lane to traffic. The length of the closure will depend on the jurisdiction's maximum closure length with pilot car. Traffic controls and traffic control signals will be based on jurisdictional requirements.
- Repair and prepare the surface for the overlay or the separation layer and subsequent overlay as described in the contract documents. Construct separation layer (for unbonded overlay).
- Normal space for the paver stringline is 1–1.5 ft (0.3–0.5 m) and the paver track is a minimum of 2.5–3 ft (0.8–0.9 m). 1 ft (0.3 m)incremental encroachment reduction (up to 2 ft [0.6 m] total) is common through typical machine adjustment. Modification to a conventional paver is necessary to achieve these dimensions. Speeds should be restricted adjacent to paver when clearance between the paver and vehicle traffic is limited.
- Construct concrete overlay on the existing pavement. Bull float work shall operate from the outside shoulder only.
- Place 6 in. (150 mm) minimum thickness calcium chloride treated granular shoulder to help stabilize shoulder and minimize heavy dust that can impair vision.
- Early entry saws are encouraged and should follow the depth as described in this manual.
- The 1.5 ft (0.5 m) dimension between the roadway centerline and vertical panel is for the stringline and fillet.



STAGE 3. Construct left lane concrete overlay

- Close the opposite lane to traffic and place the concrete overlay according to contract documents, using the same procedures as described in stage 2.
- Complete shouldering. Complete pavement marking and regulatory signing in accordance with contract documents.

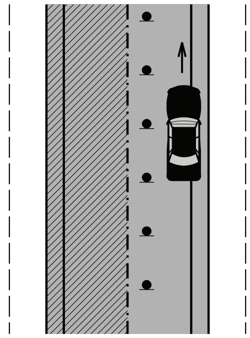
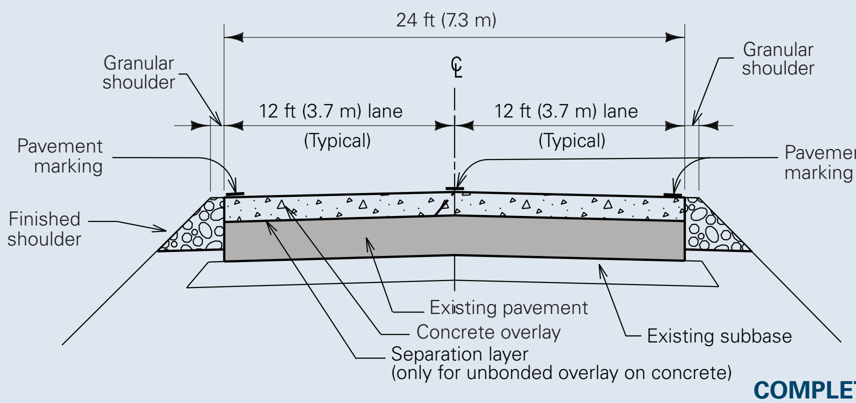


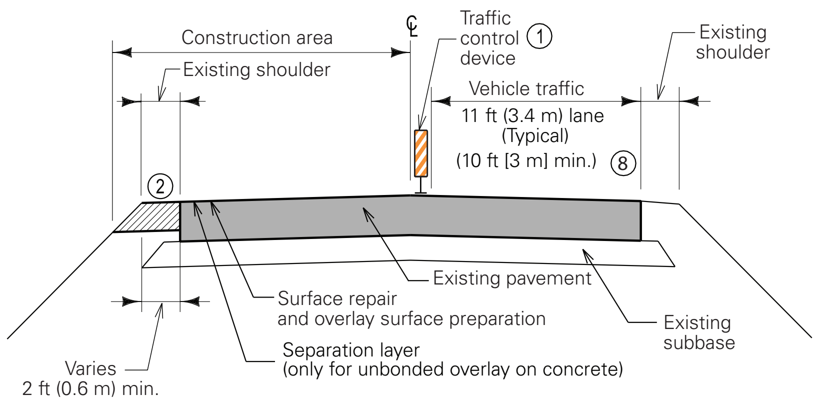
Figure 46. Overlay of two-lane roadway with minimum granular shoulders (zero-clearance paver)



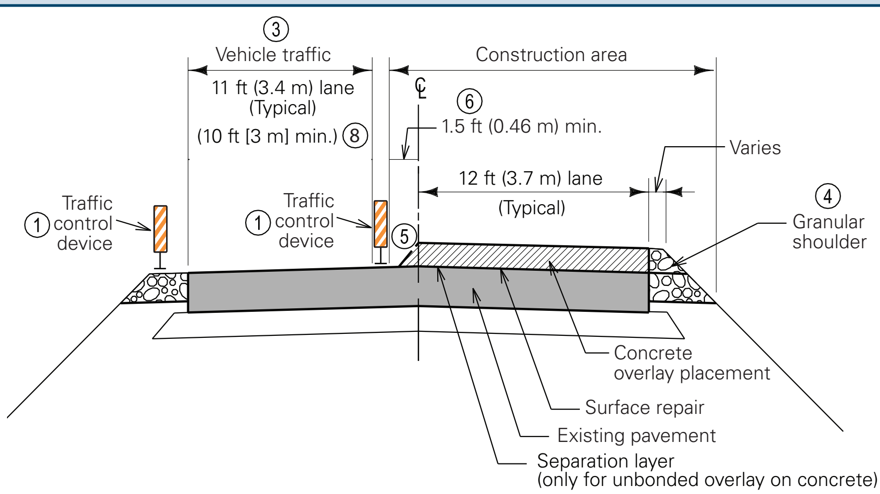
COMPLETED OVERLAY

LEGEND

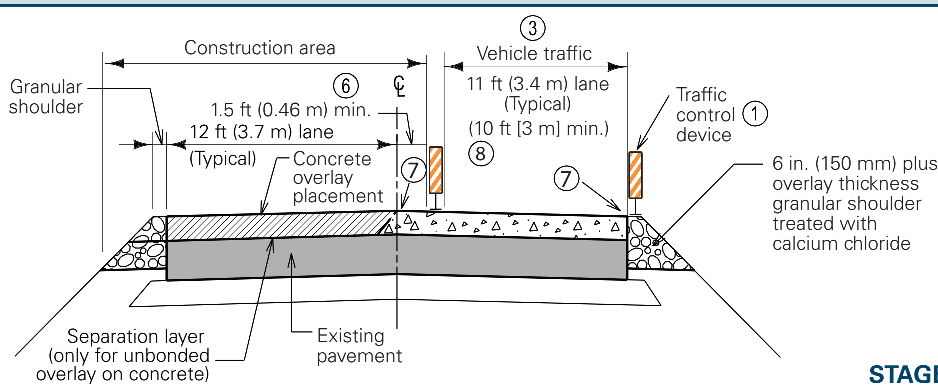
- Stage work area
- Concrete
- Granular material



STAGE 1



STAGE 2



STAGE 3

NOTES:

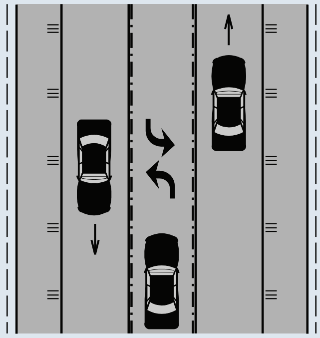
1. Follow jurisdictional requirements for traffic control devices. Outside shoulder traffic control may depend on width of shoulder.
2. Existing shoulder should have minimum 6 in. (150 mm) of granular material and should be treated with calcium chloride.
3. Minimum lane width next to the paver may be reduced for short-term, stationary work on low-volume, low-speed roadways when vehicular traffic does not include longer and wider heavy commercial vehicles.
4. Place granular shoulder with calcium chloride in two lifts. The first lift is for the paver track. The second lift is for final shoulder. If the completed overlay in this stage opens to traffic and the final lift is delayed, place concrete fillet as shown. If overlay creates a dropoff greater than jurisdictional allowance, place second lift before opening overlay to traffic.
5. See centerline fillet illustration and subsequent removal on figure 43.
6. Requires minimum to zero clearance paver. 1.5 ft (0.5 m) dimension is for the paver ski or stringline.
7. Mark edgelines and centerlines per MUTCD (FHWA 2003b) section 6F.71 (mark both lanes).
8. For low-volume roads only

Overlay of Two-Lane Roadway with Minimum Granular Shoulders (Zero-Clearance Paver)

COMPLETED OVERLAY (Two-Lane Roadway Widened to Three Lanes with Paved Shoulders, Conventional Paver)

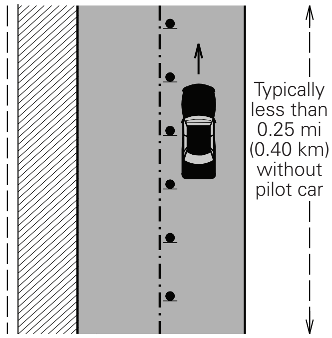
Applied to:

- ☑ **Bonded concrete overlay of concrete pavements**
- ☑ **Bonded concrete overlay of asphalt pavements**
- ☑ **Bonded concrete overlay of composite pavements**
- ☑ **Unbonded concrete overlay of concrete pavements**
- ☑ **Unbonded concrete overlay of asphalt pavements**
- ☑ **Unbonded concrete overlay of composite pavements**



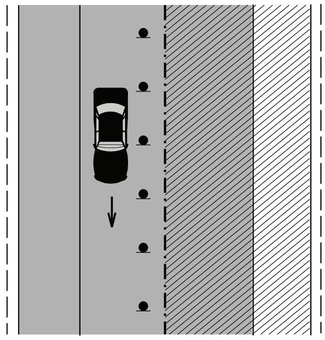
STAGE 1. Repair surface, prepare for overlay, and construct base shoulder widening and separation layer

- Install traffic control and close the left lane. Follow jurisdictional requirements for traffic control. Check with jurisdiction regarding allowable lane closure length. If surface repair and preparation for the overlay are minimal, then slow-moving traffic control may be appropriate. Closing the lane may require additional traffic control (e.g., signals, flaggers, and/or pilot cars).
- Repair the surface as appropriate. Prepare the surface for the overlay (or, in the case of concrete overlay on concrete, the separation layer) as described in the contract document.
- Prepare shoulder widening by trenching the existing shoulder and trimming to the specified width. The trench should be rolled and compacted as necessary to obtain a firm and stable platform. Compact shoulder material as specified in the contract documents. A continuous progression approach with the shoulder trencher and placement of the base shoulder widening is encouraged.
- Pave the existing shoulder a minimum of 6 ft (1.8 m) with concrete.
- Use excavated granular material to widen existing shoulder. Treat 3 ft (0.9 m) area of shoulder with calcium chloride.
- Construct separation layer (only for unbonded overlay on concrete).



STAGE 2. Construct thickened shoulder and concrete overlay

- Shift the traffic control to the left lane and close the right lane to traffic. The length of the closure will depend on the jurisdiction's maximum closure length with pilot car. Traffic controls and traffic control signals will be based on jurisdictional requirements.
- Repair and prepare the surface for the overlay or the separation layer and subsequent overlay as described in the contract documents. Construct separation layer (for unbonded overlay).
- Construct concrete overlay on the existing pavement. Complete right PCC shoulder widening with the overlay.
- Early entry saws are encouraged and should follow the depth as described in this manual.
- The "X" dimension between the roadway centerline and vertical panel is for the paving machine track and stringline.



STAGE 3. Construct left lane concrete overlay

- Close the opposite lane to traffic and place the concrete overlay according to contract documents, using the same procedures as described in stage 2. Stringline may not be necessary for the right edge of the paving when the paved overlay constructed in stage 2 is used as the paver control in this stage.
- If the outside edge dropoffs at the shoulder exceeds the jurisdictional allowance for a 1:1 fillet, then construct the granular shoulders in this stage.
- Complete shoulders. Install (mill) rumble strips in the paved shoulders and complete pavement marking and regulatory signing in accordance with contract documents.

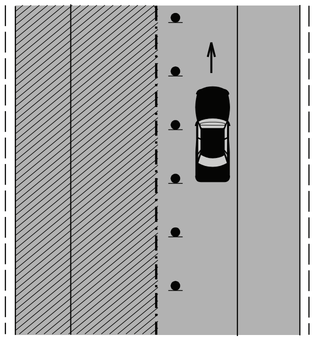
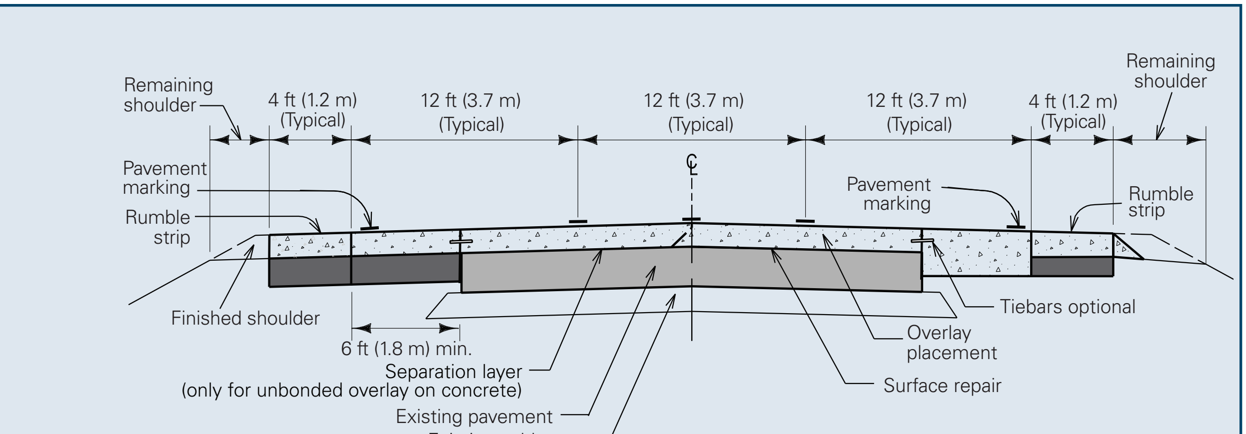


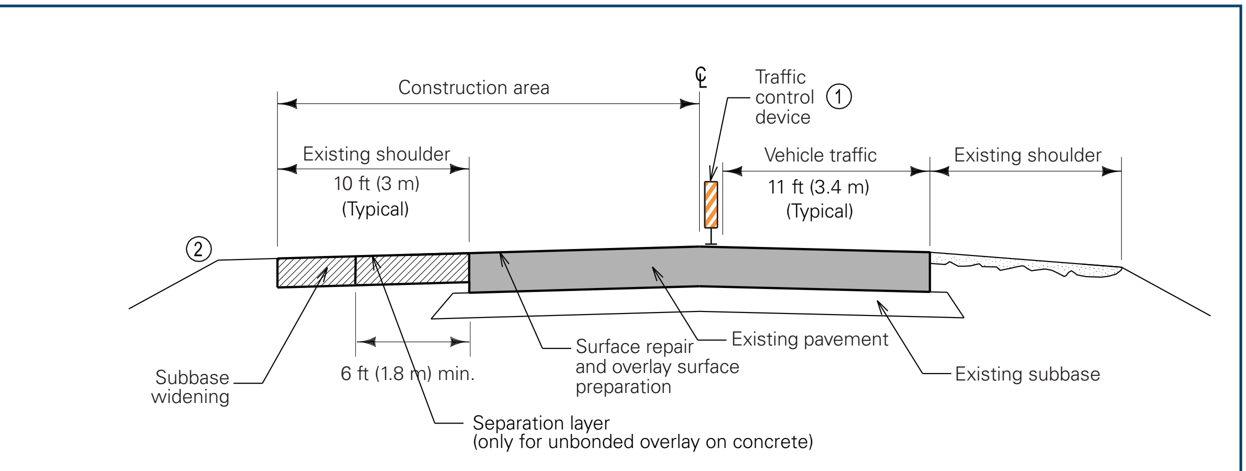
Figure 47. Overlay of two-lane roadway widening to three lanes with paved shoulder (conventional paver)



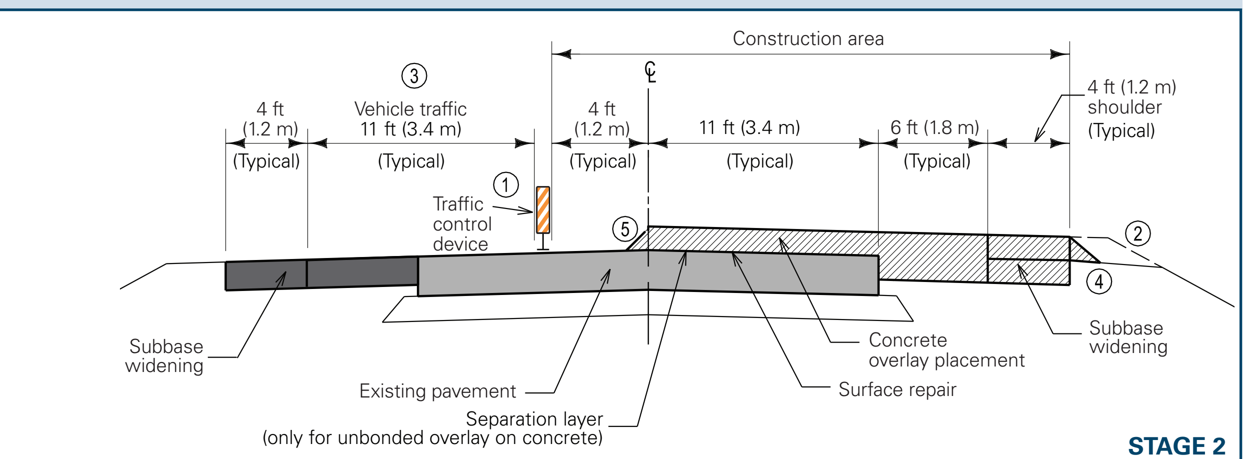
COMPLETED OVERLAY

LEGEND

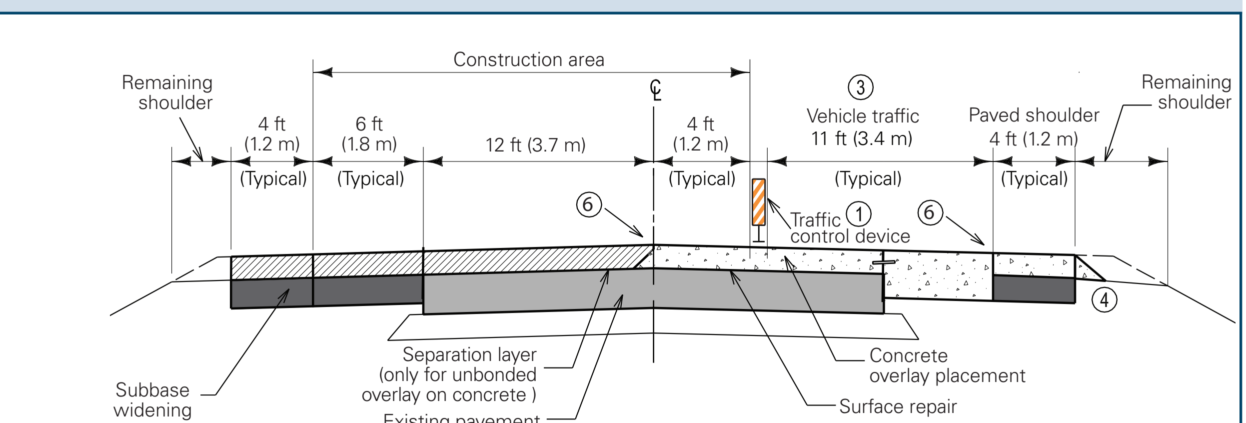
- Stage work area
- Concrete
- Base shoulder widening materials (e.g., cement-treated base, porous concrete, roller compacted concrete (RCC), asphalt, or concrete)
- Granular material



STAGE 1



STAGE 2



STAGE 3

NOTES:

1. Follow jurisdictional requirements for traffic control devices.
2. Use excavated granular material to widen existing shoulder. Treat 3 ft (0.9 m) area of shoulder with calcium chloride.
3. Minimum lane width next to the paver may be reduced for short-term, stationary work on low-volume, low-speed roadways when vehicular traffic does not include longer and wider heavy commercial vehicles.
4. If the completed overlay in this stage opens to traffic and the final shoulder back fill is delayed, place fillet as shown. If overlay creates a dropoff greater than jurisdictional allowance, place second lift before opening overlay to traffic.
5. See centerline fillet illustration and subsequent removal on figure 43.
6. Mark edgelines and centerlines per MUTCD (FHWA 2003b) section 6F.71 (mark both lanes).

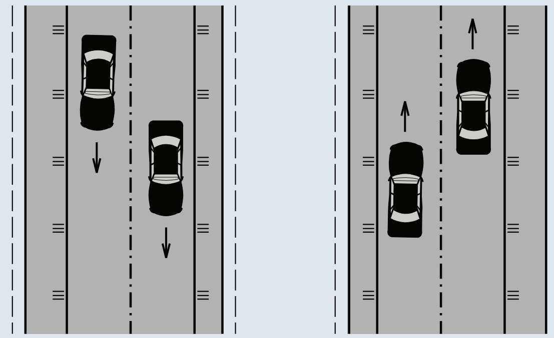
Overlay of Two-Lane Roadway Widened to Three Lanes with Paved Shoulders (Conventional Paver)

COMPLETED OVERLAY (Four-Lane Roadway with Paved Shoulders, Conventional Paver)

Applied to:

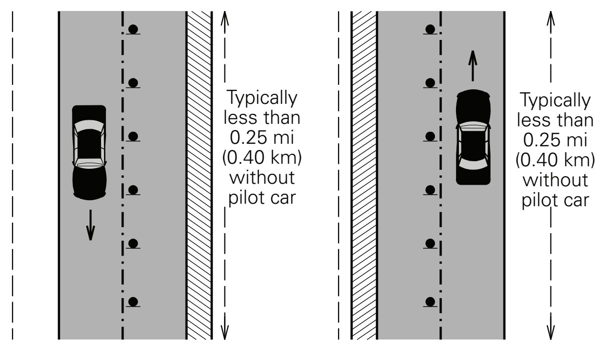
☑ **Bonded concrete overlay of concrete pavements**
☑ **Unbonded concrete overlay of concrete pavements**
☑ **Bonded concrete overlay of asphalt pavements**

☑ **Unbonded concrete overlay of asphalt pavements**
☑ **Bonded concrete overlay of composite pavements**
☑ **Unbonded concrete overlay of composite pavements**



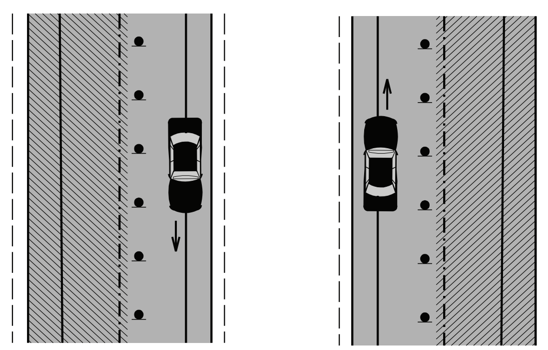
STAGE 1. *Repair surface and prepare for overlay*

- Install traffic control and close the inside lanes. Follow jurisdictional requirements for traffic control. Check with jurisdiction regarding allowable lane closure length. If surface repair and preparation for the overlay are minimal, then slow-moving traffic control may be appropriate. Closing the lanes may require additional traffic control (e.g., signals, flaggers, and/or pilot cars).
- Repair the surface as appropriate. Prepare the surface for the overlay (or, in the case of concrete overlay on concrete, the separation layer) as described in the contract document.
- Evaluate the structural condition of the existing shoulder. Mill existing shoulder or reconstruct shoulder to carry traffic load if necessary.
- Construct separation layer (only for unbonded overlay on concrete).



STAGE 2. *Construct concrete overlay on outside lane*

- Shift the traffic control to the inside lanes and close the outside lanes to traffic. The length of the closures will depend on the jurisdiction's maximum closure length with pilot car. Traffic controls and traffic control signals will be based on jurisdictional requirements.
- Repair and prepare the surface for the overlay or the separation layer and subsequent overlay as described in the contract documents. Construct separation layer (for unbonded overlay).
- Construct temporary shoulder for paver track.
- Construct concrete overlay on the existing pavement. Bull float work shall operate from the outside shoulder only.
- Early entry saws are encouraged and should follow the depth as described in this manual.



STAGE 3. *Construct concrete overlay on inside lane*

- Shift the traffic control to the outside lane and close the inside lane to traffic. Place the concrete overlay according to contract documents, using the same procedures as described in stage 2. Stringline may not be necessary for the right edge of the paving when the paved overlay constructed in stage 2 is used as the paver control in this stage. If the right stringline is not used, the "X" dimension could possibly be reduced to 3 ft (0.9 m).
- Complete shoulder finish grading. Install (mill) rumble strips in the paved shoulders and complete pavement marking and regulatory signing in accordance with contract documents.

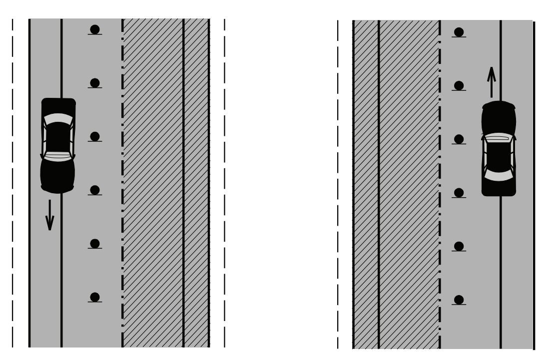
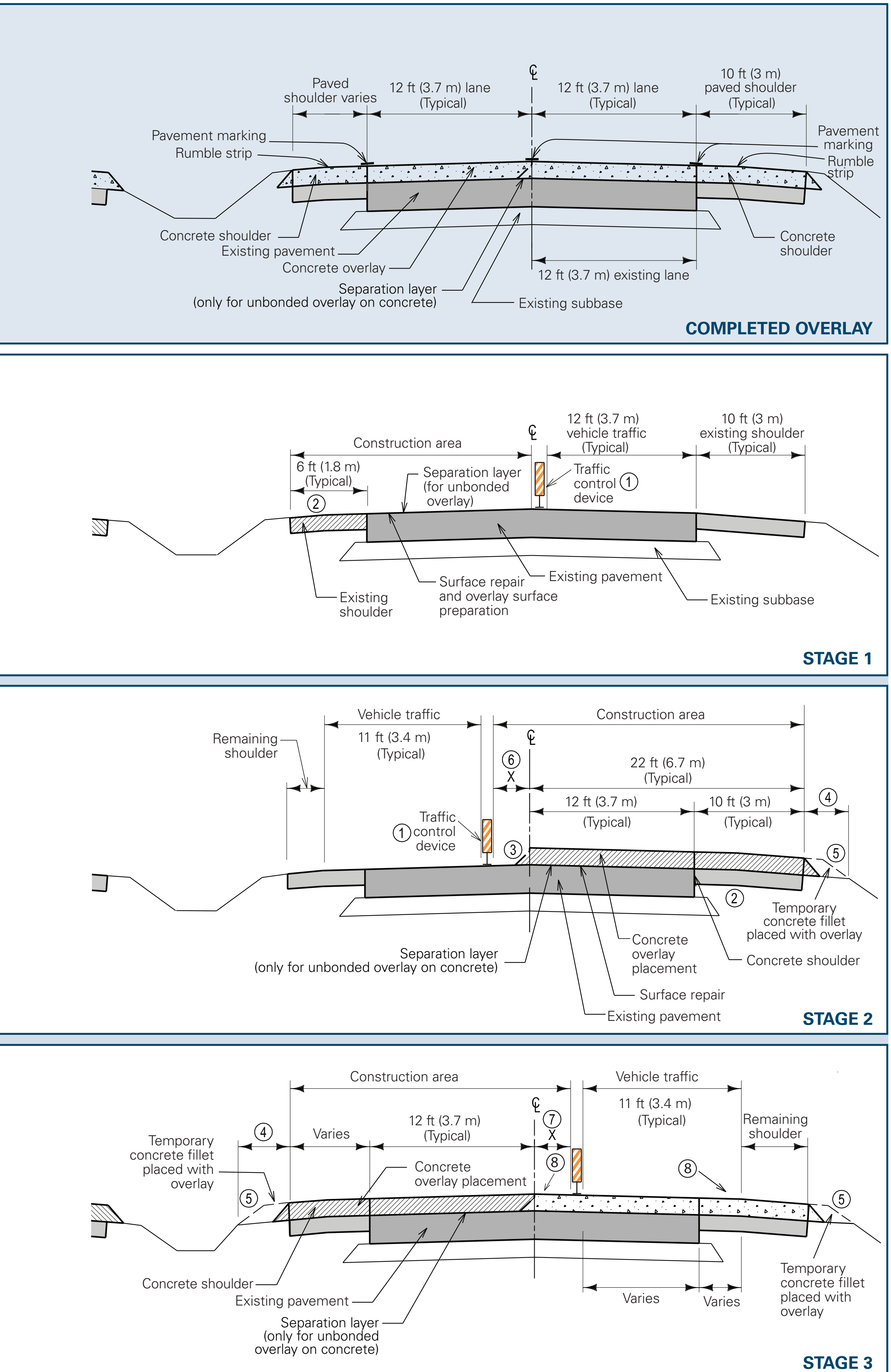


Figure 48. Overlay of four-lane roadway with paved shoulders (conventional paver)



LEGEND

- Stage work area
- Concrete
- Existing shoulder (Reconstructed if necessary)

NOTES:

1. Follow jurisdictional requirements for traffic control devices.
2. Evaluate the structural condition of the existing shoulder. If necessary, reconstruct shoulder with PCC or asphalt to carry the traffic load.
3. See centerline fillet and subsequent removal illustration on figure 43.
4. When the existing shoulder outside of the proposed paved shoulder is less than 3 ft (0.9 m), adjustment to the paver may be necessary to accommodate paver control and paver track.
5. If the completed overlay in this stage opens to traffic and the final shoulder backfill is delayed, place fillet as shown. If overlay creates a dropoff greater than jurisdictional allowance, place second lift before opening overlay to traffic.
6. For "X" less than 4 ft (1.2 m), adjustments to paver may be necessary to accommodate paver control and paver track.
7. The "X" dimension can be reduced to 3 ft (0.9 m) minimum when the right lane is used as paver control.
8. Mark edgelines and centerlines per MUTCD (FHWA 2003b) section 6F.71 (mark both lanes).

Overlay of Four-Lane Roadway with Paved Shoulders (Conventional Paver)

Key Points for Concrete Overlay Construction

Normal concrete paving construction practices can be used to complete concrete overlay projects as quickly and efficiently as any other paving method (table 10). Resurfaced streets and highways can be opened to traffic within short periods of time with adequate planning, expedited staging, and efficient operations.

HIPERPAV is a software tool available to predict stresses in concrete. It is especially useful when there is a need for more information in less-than-desirable conditions, such as inclement weather conditions, when an overlay is particularly thin, or when a project does not have much flexibility in scheduling.

Payment is typically based on two items: square yards and cubic yards. The surface is measured to account for the square-yard surface area, and batch tickets are collected to account for the cubic-yard concrete volume, including variable depths.

Table 10. Concrete paving construction practices for overlays

	Bonded Overlays		Unbonded Overlays	
Construction Consideration	**Bonded Overlays of Concrete**	**Bonded Overlays of Asphalt or Composite**	**Unbonded Overlays of Concrete**	**Unbonded Overlays of Asphalt or Composite**
1. Mixture Design				
• Aggregate:				
Physically and chemically stable and durable	X	X	X	X
Well-graded mix	X	X	X	X
Match aggregate thermal properties with existing pavement	X			
Maximum aggregate size should be D/2.5 in relation to the new overlay thickness	X	X		
• Use conventional mixtures with type I or II cement.	X	X	X	X
• If the project is to move forward as quickly as possible, all aspects of construction need to be treated with an expedited approach and not just a few elements of the project. For example, do not only use accelerators to expedite the set time and then not finish the shoulders in an efficient manner. Use fly ash and slag to reduce permeability with w/cm ratio of 0.45. Use water reducer to help maintain w/cm ratio, desired slump, and to increase strength.	X	X	X	X
• To improve bonding and expedite opening, use higher cementitious content (an example would be 660 lb/yd^3 [299 kg/m^3]).	X	X		
• Fibers may be used to increase the "toughness" of concrete (measure of its energy absorbing capacity), improve resistance to deformation, hold concrete together in case of cracking, and serve as an insurance policy that protects the surface from unseen base conditions.	X	X		
• Verification testing in the laboratory of nonstandard mixes (trial batches) and specifications of temperatures representative of site conditions is encouraged to flag any mix problems.	X	X	X	X
2. Grade Control				
• Centerline profile only (as-built) with uniform finished cross section.	X	Mill and fill		
• Three-line profile (edges and centerline) when cross slope varies or surface distortions exist.	X	Little or no milling	Inlays only	Inlays only
• Measure off existing pavement or top of milled surface to set stringline or form. Adjust individual points up to produce a smooth line.	X	X	X	X
• Survey 100–500 ft (30.5–152 m) cross sections when shouldering, foreslopes, and backslopes need adjusting. If the existing profile grade is irregular, additional centerline elevations may be necessary for grade corrections in certain locations for smoothness.			X	X
• Survey bridge tie-end or bridge clearance conditions and extreme superelevations.			X	X
• To prevent thicker asphalt separation layer and thus compaction, stability, and grade control issues, use concrete to make up any 3 in. (75 mm) or greater variances in grade and a nominal 1 in. (25 mm) asphalt separation layer.			X	
3. Preoverlay Repairs for Uniform Support				
• Minimal minor repairs of surface defects. Remove deteriorated area and replace with overlay.	X			
• An engineer should observe final condition of subbase pavement prior to overlay construction. For minimal isolated distress that causes some loss of structural integrity that cannot be overcome with milling, thicken the overlay in this area.		X		
• Replace isolated areas of subbase pavement when there is evidence of active movement.			X	X
• Joint deterioration with little or no faulting can be bridged with the overlay.			X	
• To widen the roadway, excavate the shoulder to allow for the widened thicker section to be placed with the overlay.	X	X	X	X
4. Surface Preparation				
• Surface roughness for bonding:				
Shot- or sandblasting	X			
Minimal milling to remove significant distortions or reduce high spots		X		X
• Surface cleaning:				
Sweeping followed by high pressure air blasting (waterblasting may be needed to remove dirt tracked onto surface)	X	X		
Surface sweeping only			X	X
• Maintain saturated surface dry (SSD) surface.	X	X		
• Place nominal 1 in. (25 mm) asphalt layer to separate concrete layers and prevent bonding. When heavy truck traffic is anticipated, it is advisable to consider a drainable asphalt layer and drainage system.			X	
• If the existing asphalt surface of a composite pavement section remains intact, it can serve as a separation layer.				X

Table 10. Concrete paving construction practices for overlays, continued

Construction Consideration	Bonded Overlays		Unbonded Overlays	
	Bonded Overlays of Concrete	**Bonded Overlays of Asphalt or Composite**	**Unbonded Overlays of Concrete**	**Unbonded Overlays of Asphalt or Composite**
5. Concrete Placement				
• When the surface temperature of the asphalt is at or above 120°F (49°C), surface watering can be used to reduce the temperature and minimize the potential for shrinkage cracking. No standing water should remain at the time the overlay is placed.		X	X	X
• The bonding of the overlay can be affected by the climatic conditions at the time of placement. Significant stresses that develop due to rapid changes in temperature, humidity, and wind speed may cause debonding under severe conditions. HIPERPAV can predict interface bond stress based on numerous factors.	X	X		
• Feeding concrete consistently into the paver requires an adequate number of batch delivery trucks. The number of trucks will often dictate the slipform or placement speed. The entire cycle of mixing, discharging, traveling, and depositing concrete must be coordinated for the mixing plan capacity, hauling distance, and spreader and paving machine capabilities. Extra trucks may be needed as the haul time increases.	X	X	X	X
• Do not track paste or dirt onto the existing surface ahead of the paver because it can cause debonding.	X	X		
• The manner in which the crew deposits concrete in front of the paving operation is an important factor for creating a smooth pavement surface in overlay projects. Placement in front of slipform paver should be done in small overlapping piles so as to minimize lateral movements.	X	X	X	X
• Properly established, secure, and maintained stringline is very important to smoothness; constant and continuous paving prevents interruptions that lead to bumps.	X	X	X	X
• Tiebars may be appropriate in an open-ditch situation when constructing 3–6 ft (0.9–1.8 m) widening units and overlay thickness is 5 in. (125 mm) or greater. Normally, tiebars are not used for lane widening to prevent cracking from stresses due to differential expansion and contraction between lanes.	X	X		
• Dowel bar use should follow full-depth pavement requirements. When used, they should be located approximately in the mid-third of the overlay. Isolated thicker sections should not dictate a change in basket height or dowel bar insertion depth.			X	X
• Texturing needs to be performed at the right time so as not to disturb setting of the concrete. Shallow longitudinal tining or burlap/turf are two effective textures. Burlap/turf drag have shown adequate friction with a quiet surface when hard sands are used in the mix.	X	X	X	X
6. Curing to Prevent Rapid Loss of Water from the Concrete				
• HIPERPAV is a useful tool for predicting the effect of various curing techniques. It can model the design, materials, construction, and environmental conditions affecting the concrete during early age.	X	X	X	X
• Proper curing of bonded and thin unbonded overlays is particularly important because they are thin with large surface compared with the volume of concrete. The curing rate may be increased from the normal rate to provide additional protection. Standard curing compound rates may be used for thicker unbonded overlays.	2 times normal	1.5–2 times normal	1.5–2 times normal	1.5–2 times normal
• During hot weather, steps should be taken to reduce the evaporation rate from the concrete. For significant evaporation, provide a more effective curing application, such as fog spraying, or apply an approved evaporation reducer.	X	X	X	X
• Adequate curing of overlays on a stiff support system (especially on underlying concrete pavement) is important to minimize curling and warping stresses.	X	X	X	X
7. Joints				
• Joint spacing for concrete overlays requires special consideration for each type:				
Joints are to be matched with underlying concrete to prevent reflective cracking.	X			
Joints are typically mismatched to maximize load transfer from the underlying pavement. However, some states that have not intentionally mismatched joints have not experienced any adverse effects.			X	
Joint panel spacings are very short (1.5 times overlay thickness) to reduce shear stress and reduce curling and warping stress.		X		
Because of the potential for higher curling and warping stress from a rigid underlying pavement, shorter than normal spacing is typical (see pages 19, 20, and 22).			X	X
• Joint sawing:				
The timing of sawing is critical. Sawing joints too early can cause excess raveling. HIPERPAV may be useful in helping to predict the appropriate time window for joint sawing, based on the concrete mix design, construction times, and environmental conditions.	X	X	X	X
Sawing must be completed before curl stresses exceed the bond strength developed.	X	X		
Sawing too late can cause excess stresses, leading to uncontrolled random cracking.	X	X	X	X
Transverse joint saw-cut depth for conventional saws.	Full depth + 0.50 in. (13 mm)	T/4	T/4 min.–T/3 max.	
Transverse joint saw-cut depth for early-entry saws.	Full depth + 0.50 in. (13 mm)	Not < 1.25 in. (31 mm)	Not < 1.25 in. (32 mm)	
Longitudinal joint saw-cut depth.	T/2 (at least)	T/4–T/3	T/4–T/3	
Transverse joint width must be equal to or greater than the underlying crack width at the bottom of the existing transverse joint.	X			
• Sealing:				
Seal joint using low-modulus hot-pour sealant with narrow joint.	X	**	*	*

* Some states have experienced problems with asphalt stripping of the separation layer, particularly under heavy truck traffic and high speeds. Therefore, sealing is important in these conditions. On lower speed roads without a heavy traffic loading, some states successfully do not seal.

** Joint between overlay and curb and gutter

Accelerated Construction

Road improvements not only have direct construction costs, but they also have indirect time-related costs. Construction delays and road closings are generally not well accepted by the road users.

One of the significant benefits of accelerated concrete overlay construction (typically unbonded overlays) is decreasing total construction time which in turn reduces road user costs and increases driver safety. In addition, concrete overlays offer confidence that the improvements will provide a long-life pavement.

One of the main goals during accelerated overlay construction is to maintain successful traffic management throughout the duration of the project. The techniques used for accelerated construction often have more benefit when the overlay operation is open to traffic.

Approach and Considerations

Accelerated construction often uses conventional concrete pavement materials and procedures, but key changes can significantly expedite projects (appendix C). These changes add flexibility for the contractor. They often involve contract incentives, modifying pavement equipment for minimum zero clearance, materials proportioning modifications, accelerated curing methods, construction staging, changes to pavement joint construction, and revisions to opening criteria.

Life-cycle user costs should be evaluated when determining the type of rehabilitation that is to be implemented. When determining if accelerated construction is to be implemented, it is important that there is a benefit to be gained such as reducing road user costs and delays.

The implementation of accelerated construction techniques on concrete overlays is based on project and user needs. The techniques may be used on critical parts of a project, such as intersections and crossovers, the final segment, or for the entire project.

Typically, standard mixtures used in conjunction with mixture additives and accelerated construction techniques meet project accelerated opening requirements. In some critical areas, accelerated concrete mixtures are used for unbonded concrete overlays and at times on bonded overlays, particularly over asphalt.

Table 11, beginning on page 57, outlines a variety of details for planning, designing, and constructing concrete overlays in an accelerated process. Not all items listed are needed for every accelerated overlay project. However, the following topics should be considered for most projects:

- Evaluation of existing pavement
- Staging
- Concrete mixture
  (type III cement is not necessary)
- Surface preparation
  (depending on type of overlay)
- Grade control (too much or too little)
- Bonding where required
- Separation layer where required
- Jointing widths and depths
- Maturity methods for early opening
- Curing

Early Opening of Overlays to Traffic

A common question is, "When can I open a bonded overlay to traffic so that the loading will not compromise the bond?" The answer is related to minimum concrete strength and not an arbitrarily selected time from placement. Concrete opening strength (compressive or flexural) directly relates to concrete's load-carrying capacity and provides an indication of the bond strength.

Quality of Bond for Bonded Overlays of Existing Concrete Surfaces

When bonding a concrete overlay to an existing concrete surface, the necessity for a sound bond cannot be overstated. Both theory and practice show that without this bond, the overlay will develop secondary distress quickly, thus significantly compromising the life of the pavement system.

Research has attempted to measure and characterize bond strength during early ages of the concrete overlay. However, to date no simple and reliable test has been developed. As a result, bond strength is typically characterized using a surrogate test, namely strength (compressive or flexural) of the overlay. The strength of the bond between the overlay and the existing concrete pavement can be correlated with the flexural/compressive strength of the overlay. If the early opening strength criteria has been met, then the bond strength should also be adequate to allow the pavement to be open without bond failure, provided that care has been taken to prepare the existing pavement surface properly and the overlay has been adequately cured.

Several elements (beyond those common to a typical concrete pavement) are particularly important in ensuring a good bond between the concrete overlay and the underlying concrete pavement. There are issues related to the concrete mixture, surface preparation and cleaning, curing, sawing, and strength measurement. While several of these factors are currently considered in conventional concrete paving, specific emphasis should be placed on certain key factors of these elements, since bonded concrete overlays are particularly sensitive to volumetric changes.

Concrete mixtures used in bonded concrete overlays should shrink as little as possible and behave thermally as close to the existing concrete pavement as possible. This typically means optimizing the cement content to minimize shrinkage while maintaining an adequate strength. Another mixture-related consideration is aggregate gradation (which helps in reducing cement factors without sacrificing strength), as well as aggregate type. To help minimize the thermal strains and stresses experienced at the bond line of bonded overlays over concrete, the overlay should have aggregate thermal properties similar to the aggregate in the underlying concrete pavement. If local aggregate sources make matching the thermal coefficient difficult, an effort should be made to use only aggregates with a thermal coefficient lower than that of the aggregates in the existing pavement.

Surface preparation of the existing concrete pavement is accomplished to produce a roughened surface that will promote bonding between the two layers (figure 49). A variety of surface preparation procedures may be used, including shotblasting, milling, and high water pressure blasting. A bonding grout or epoxy is not required. The most commonly used and most effective surface preparation procedure is shotblasting. Although milling will roughen the concrete pavement surface, milling should not be used solely for that purpose because of its potential for causing surface microcracking and fracturing the exposed aggregate. If milling is used to lower the pavement elevation, any resulting microcracking should be removed by shotblasting or high water pressure blasting.

In some cases, a surface roughness or mean texture depth is specified. The sand patch test (ASTM C 965) is often used to measure and verify the mean texture depth. Typically, a mean texture depth in the range of 0.04 to 0.08 in. (0.9 to 2.0 mm) is deemed adequate for proper bond development.

Following surface preparation, the surface should be thoroughly cleaned to remove all loose material to ensure adequate bonding. Cleaning may be accomplished by sweeping the concrete surface, followed by cleaning in front of the paver with compressed air. Airblasting and waterblasting should be used only as supplementary cleaning procedures to remove loose material from the surface after shotblasting or milling. In no case should standing water or moisture remain on the pavement surface when the overlay is placed. Paving should commence soon after cleaning to minimize the chance of contamination.

Vehicles should be limited on the existing surface after it is prepared. If it is absolutely necessary to have vehicles on the existing concrete, care should be taken that they do not drip oil or other contaminants that could compromise the bond.

When the surface temperature of the concrete is at or above 120°F (49°C), surface watering can be used to reduce the temperature and minimize the chance of shrinkage cracking. Water standing on the surface should be blown off with compressed air.

Curing also can have a pronounced impact on concrete overlay bond. The diligent and thorough application of curing compound (sometimes at twice the normal application rate) is an effective method to control moisture loss and thus lower shrinkage and early-age cracking potentials. This is particularly true for thin bonded overlays. More "extreme" measures, such as wet or blanket curing, can help to minimize the risks of poor performance when proper curing compound application is either difficult or doubtful. These types of more "extreme" curing regimes are typically only applicable for short paving sections such as intersection rehabilitation.

Good construction sawing practices can also greatly reduce early pavement stresses and help accommodate early opening to traffic. As mentioned elsewhere in this document, sawing the transverse joints in the new overlay full depth exactly over the joints in the existing pavement is absolutely critical for proper bonding. There have been examples of early bonded concrete overlay failures due to debonding as a result of not sawing the joints all the way through the depth of the overlay. The width of the transverse joints in the overlay should be equal to or greater than the width of the cracks under transverse joints in the existing pavement.

When all of these factors have been properly considered and executed during construction, the overlay strength can be used to characterize the bond with some confidence. Strength monitoring of the overlay concrete can be done in a fashion similar to that of conventional concrete paving. Maturity methods for early-age strength prediction (ASTM C 1074) can be particularly helpful. Knowing that bond strength correlates reasonably well with concrete strength under these conditions means that early opening to traffic decisions can be made relatively reliably, in-place, and in a timely fashion.

In some cases, given the critical importance of proper bond development to good bonded overlay performance, states are relying on actual bond measurement to increase their confidence level in the quality of the bond. Several bond tests have been used for this purpose, most notably the Iowa Shear Test (Iowa Test Method 406C) (figure 50) and the Pennsylvania Shear Test (PTM 610). These tests involve coring the overlaid pavement and placing the core in a shear testing jig, where a shear load is applied along the bond interface on the core. Early work (research and evaluation) with this kind of testing suggests that a shear bond strength of 200 psi is enough to ensure that the "composite pavement" (i.e., the bonded concrete overlay and the underlying pavement) behaves like a truly monolithic slab. The direct pull-off test (ASTM C 1583) (figure 51) has also been used for this purpose, although most commonly with bridge deck overlays. As with most tests of this nature that are sensitive to core orientation, asymmetry in testing, and specimen handling, results tend to be variable. However, when these factors are carefully controlled and tests are performed by experienced personnel, shear bond testing can be a useful way to develop confidence that the desired quality of bond has been achieved.

Figure 49. Compare the surface texture of the non-shotblasted area (upper left half of image) to the roughened surface texture on the shotblasted section of pavement (under the pen) (Photo courtesy of Leif Wathne, P.E., American Concrete Pavement Association)

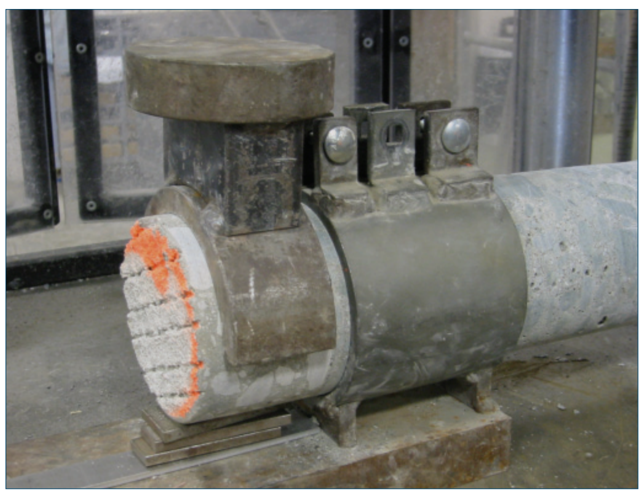


Figure 50. Shear test (Photo courtesy of Leif Wathne, P.E., American Concrete Pavement Association)

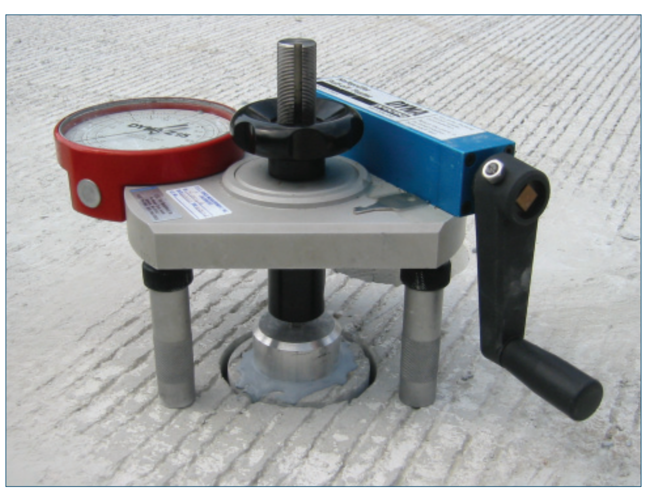


Figure 51. Pull-off test (Photo courtesy of Leif Wathne, P.E., American Concrete Pavement Association)

Strength Conversions for Opening to Traffic

Guidance on concrete strength requirements for opening concrete roadways to traffic is readily available. For example, the *Flexural Strength Criteria for Opening Concrete Roadways to Traffic,* as published by TRB (Cole and Okamoto 1995), bases its opening flexural strengths on thickness, *k*-values, and estimated ESALs, whereas FHWA and ACPA's *Traffic Management Handbook* (2000a) is based on thickness, foundation support, and the number of ESALs between the time of opening and the time concrete reaches strength. Other methods are available (FHWA 1994) and depend on the type of traffic, early loading locations on the slab, pavement thickness, and subbase support.

Conversions

The modulus of rupture, or flexural strength, is an important parameter in the estimate of fatigue damage. Many states use flexural strength (modulus of rupture) for concrete opening strength criteria and others use compressive strength. The following equation is sometimes used to convert compressive strength to third-point flexural strength, although it is widely recognized that this relationship is mixture dependent:

$$*f_r = 2.3\, f_c^{\,0.667} \text{ (psi)}$$

where
- f_r = flexural strength (MR or modulus of rupture, psi)
- f_c = concrete compressive strength, psi

Note: This empirical equation was developed using data from four different studies, conducted between 1928 and 1965 (Raphael 1984). Also the equation is contained in reports from ACI Committee 330 (2008).

Since early-age strength can change rapidly in a short time and since some agencies use a variation of the above referenced equation, it is recommended that each agency develop its own relationship between the compressive strength and flexural strength (modulus of rupture) for the mixture they intend to use. As described earlier, non-destructive tests such as maturity can be used to determine opening strength since it provides real-time results.

Strength Criteria for Opening Bonded Systems to Traffic

Existing Concrete Pavement

If proper surface treatment, curing, and sawing are employed in the construction of concrete overlays, the bond strength at the time of opening should be adequate if 540 psi (3.7 MPa) flexural or 3,600 psi (24.8 MPa) compressive strength is achieved. As a rule of thumb for bonded concrete overlays, the bond tensile strength may be on the order of 2 to 10 percent of the compressive strength, and the bond shear strength approximately 4 to 20 percent of the compressive strength. It is advisable to verify the relationship between compressive, flexural, and bond strength for the mixture intended for use.

Existing Asphalt Pavements

Bonded concrete overlays on asphalt have one distinct advantage over bonded concrete overlays on concrete. The concrete panels can be cut into small squares or rectangles in order to reduce the curling and warping stresses and the expansion and contraction of concrete at the bond interface because there are no joints that need to be matched in the underlying pavement. The result is a reduction in shear at the bond interface. This technique has been successfully used for a number of years. However, overlays over asphalt are typically relatively thin and are therefore susceptible to excessive temperature-related stresses, particularly when the existing asphalt is hot from solar heating. If accelerated methods are used, extreme care must be taken to minimize shrinkage cracking through diligent and thorough curing (sometimes at double the ordinary rate of curing compound, or, in short sections, wet curing and/or blankets may be necessary). Some states have incorporated fibers to increase the toughness of the concrete as well as to improve its resistance to cracking.

Determining a reasonable value for opening bond strengths for these types of overlays may prove difficult, as described above, since there is not a simple field test available to measure the bond strength. Instead, a value for opening strength of the concrete of 420 psi (2.9 MPa) flexural (2,500 psi [17.2 MPa] compressive) to 480 psi (3.3 MPa) flexural (3,000 psi [20.7 MPa] compressive) seems to be reasonable. An additional consideration for accelerated construction is to encourage bond via milling of the existing asphalt surface. If shear failures do occur, they will likely occur in the asphalt since concrete shear strength is greater than asphalt shear strength.

Strength Criteria for Opening Unbonded Systems to Traffic

It is common for unbonded overlays plus the existing pavement to have a total thickness in excess of new full depth pavements. Therefore, it is appropriate to use opening strength criteria that are commonly used for conventional paving. For example, a minimum flexural strength (3rd point) of approximately 340 psi (2.3 MPa) or 1,800 psi (12.4 MPa) compressive strength can be used for non-interstate traffic. The state of Georgia for example, uses a concrete opening strength criteria of 1,400 psi (9.7 MPa) as long as the mixture reaches 2,500 psi (17.2 MPa) in 24 hours and 3,500 psi (24.1 MPa) in 3 days. Georgia typically uses a special mixture for these accelerated construction projects.

Minimizing Early Loading Fatigue Damage

The fatigue life of concrete pavements are sensitive to early wheel loading. A fatigue-consumption approach (FHWA 1994) theorizes that concrete pavement has a finite life and can withstand some maximum number of load repetitions, N, of a given traffic loading before fracture. Every individual traffic loading applied decreases the life of pavement by an infinitesimal amount. This damage value provides the percentage of life that is consumed by the actual number of traffic loads up to a given point in time. During the early stages of strength development, it is important that decreases in pavement fatigue life are not caused by heavy early loadings, until the concrete strength has reached a certain point. Certain techniques can be employed to control early loading that reduces fatigue damage until the concrete strength can accommodate normal traffic loadings.

One of the most important techniques is restricting wheel loads to within 3 to 4 ft (0.9 to 1.2 m) from the edge of the pavement (and ideally 6 ft [1.8 m]) to minimize stress. Research has shown that allowing only interior early slab loadings greatly reduces fatigue damage (FHWA 1994). Traffic cones are an effective way of restricting construction traffic along the pavement edges until the pavement reaches the desired full opening strength. In addition to restricting early edge loadings, the use of higher modulus of subgrade reaction, *k*, can help minimize early-age stress. With concrete unbonded overlays this is a particular plus, since the underlying pavement provides a high level of base support.

Differential temperature and moisture values throughout the slab can result in early-age curling and warping stress. When these stresses are added under certain conditions to early-age loading stress, cracking can occur. This can be controlled through proper curing and sawing techniques.

Table 11. Accelerated construction under traffic for concrete overlays

Factors to Consider	Objectives / Expectations	Considerations / Limitations
Incentives/Disincentives	An effective way of managing successful accelerated construction is to offer its incentives for the contractor. If the schedule is very critical, the contractor may likely consider innovative pavement techniques to complete the project on time or even ahead of schedule. The use of incentives also allows for a better competitive bidding environment for the owner.	Incentives and disincentives should be considered for the project to encourage the contractor to perform within the given schedule when a competitive bidding environment is expected. Use of disincentives should not deter potential bidders when the schedule is critical.
Grade Control	Grade control for the project should be considered early. In the planning of the project, the type of overlay and existing pavement conditions will often dictate the level of survey required for the design and stakeout of the project. Resurfacing projects historically have required little in the way of surveying. A vast number of them are even constructed without detailed construction plans; they are referred to in many states as log jobs. When concrete is used as the resurfacing material, there is no need to increase the level of surveying required on a project. With all resurfacing projects, it is advisable to visit the project site during a rain event and verify that there is no drainage issue. A drive through the project at the posted speed limit will alert you to adverse cross-slope issues. For rural areas, surveying is only required when you determine that there is some type of a drainage, cross-slope, or profile issue that needs to be corrected. The elevation of the concrete paver can be controlled by either a traveling ski or by a stringline that is referenced from the existing pavement. When stringline control is used, establish grades at each stringline pin by projecting the existing cross-slope, sight the string longitudinally, and adjust individual grades up to produce a smooth profile.	If payment is based on the plan area, then the contractor may want a more detailed survey and additional cross sections to ensure proper thickness and yield. If the payment is based on the volume of concrete supplied and the area paved, less survey is required. When milling machines are used to remove existing pavement, it is advisable to have them either follow the same control as the concrete paver or wait to establish the paving control until the milling has been completed. One point of caution for multi-lane construction is that on many pavements, the cross-slope of each existing lane may differ, and the paver should have crowning adjustment capability located at the intermediate lane lines or actively remove any cross-slope differences between the lanes with the milling operation.
Materials / Mixtures		
Reliability of Material Supply	All materials that are required on the project need to be available or scheduled or properly stored for use prior to constructing the overlay project.	Materials that are prone to delivery delays need to be stockpiled.
Material Schedule	Under an accelerated schedule, there is little time for deviation from the intended plan. As such, representative samples from all material supplies should be made with proper certification.	Contingency plans need to be developed to address potential changes in critical material properties.
Concrete Mixture	Normal concrete paving mixtures are typically used for concrete overlay projects. Rapid strength gain to meet accelerated construction schedules does not require special blended cements or sophisticated material. It is possible to proportion a mixture using locally available aggregates, type I and type II cements, SCMs, and certain admixtures. Some initial adjustments will probably be required by the paving crew as they become accustomed to the mixture characteristics.	The mixture needs to match the opening requirements and construction methods to obtain opening requirements. However, the mixture should not be accelerated to a point where there is a high probability of early-age cracking from shrinkage and curling and warping. Each crew member will have to be accustomed to the accelerated duties that accompany expedited construction.
Cementitious Materials	Hydraulic cements include portland cement and blended cements which contain SCMs. Other types of hydraulic cements are rapid-setting calcium sulfo-alumina cements used for repair materials or for pavements where fast turnaround times are critical. Cements and SCMs play a major role in both heat and strength development, and these properties depend on the interaction of the individual compounds that constitute the mixture.	High levels of Tricalcium Silicate C_3S (Alite) and finely ground cement particles will usually generate strength quickly for accelerated mixes. Tricalcuim Aluminate (C_3A) can be a catalyst to enhance the rate of hydration of Alite by releasing heat early during the cement hydration. The Integrated Materials and Construction Practices for Concrete Pavement Manual (IMCP Manual) is a very good reference in order to understand the importance of the proper blend of cementitious materials.
Type I/II cements	Type I/II cements can reach opening strength without increasing the risk of shrinkage cracks.	More cement does not necessarily mean higher strength.
Slag Cement	Slag cement can effectively reduce ASR expansion, increase long-term strength, reduce permeability, reduce concrete temperature, and slow hydration.	Slag cement may reduce rate of strength gain and hydration rate.

Table 11. Accelerated construction under traffic for concrete overlays, continued

Factors to Consider	Objectives / Expectations	Considerations / Limitations
Fly ash	Fly ash will increase long-term strength, reduce permeability, and reduce set temperature. Some fly ash can slow hydration on accelerated construction projects.	Some states impose restrictions on the use of fly ash in cold weather and may restrict the use of fly ash to 10% on accelerated construction projects even in warm weather months.
Type C	Type C fly ash will increase long-term strength and reduce water demand and permeability. This may or may not slow hydration or reduce ASR expansion.	Type C fly ash can affect strength gain. Mixtures must be tested to determine how much class C fly ash is required to reduce ASR-related expansion. Too high a dosage may increase the risk of rapid stiffening and/or damage due to salt scaling.
Type F	Type F fly ash will increase long-term strength and reduce permeability. It will also slow hydration and help reduce ASR expansion.	Type F fly ash delays setting and reduces rate of strength gain. High loss-on-ignition affects air entrainment. Type F is generally effective at reducing ASR-related expansion. Availability may be a limitation.
Chemical Admixtures	Chemical admixtures are added to the concrete mixtures to modify certain concrete properties such as strength. Adding chemical admixtures can achieve these properties more efficiently than adjusting other mixture ingredients such as the type of cement. Admixtures that are combined and contain both water reducers and accelerators are available.	The effects of set-modifying admixtures on other properties of concrete, like shrinkage, may not be predictable. Therefore, acceptance tests of set modifiers should be made with job materials under anticipated job conditions. Compatibility of the admixtures with other ingredients should be tested as it relates to potential constructibility problems.
Water reducers	Water reducers reduce water demand in order to reduce paste content (lowers w/cm) to help minimize shrinkage, temperature, and cracking without sacrificing workability. Water reducing admixtures can also increase early strength gain by lowering the quantity of water necessary for cement hydration (by as much as 10% in 28 days). The w/cm ratio typically are at or lower than 0.43 for accelerated construction.	Confirm that water reducers are compatible with other chemical admixtures and cements, particularly under harsh environmental conditions. Confirmed laboratory testing is essential to determine if the admixtures will develop the desirable properties. Type F and G water reducers (superplasticizers) are not normally used in pavements because of their high cost and because it is difficult to control the slump range required for slipform paving with their use. Overdoses of water reducers, particularly normal-range products, may severely retard or prevent setting.
Accelerators	Accelerating admixtures are used to increase the rate of strength development of concrete at an early age, including in cold weather. It is important to test both fresh and hardened concrete properties before using accelerators in overlays, particularly bonded overlays.	Long-term strength may be lower. Excess acceleration may result in cracking before finishing and/or saw cutting can be completed. Care must be exercised in using accelerators in thin overlays so as not to cause early shrinkage, cracking, and high curling and warping.
Air entrainment	Air entrainment will dramatically improve the durability of concrete exposed to moisture during cycles of freezing and thawing. It improves concrete resistance to surface scaling caused by chemical deicers. It also tends to improve the workability of concrete mixtures, reduce water demand, and decrease mixture segregation and bleeding.	Need to check compatibility with other admixtures. For about every 1% of air entrained, about 5% of concrete compressive strength is lost. Loss of air through the paver is acceptable up to 1.50% to 1.75%. However, when the loss of air through the paver approaches 3%, the air system (quantity and distribution) is not acceptable.
Retarders	Retarders are useful in extending set times. They increase the bleeding rate and capacity and may be accompanied by some reduction in early-age strength gain (one to three days) but higher later strengths.	Retarders are sometimes used to try to decrease slump loss and extend workability. This application is incorrect because, under certain conditions, the opposite results can occur.
Aggregates	It is critical that aggregate be well graded (that is, there should be a wide range of aggregate sizes). Well-graded aggregate has less space between aggregate particles, therefore reducing paste demand without loss of workability. Reduced paste content reduces shrinkage and early-age cracking, particularly with accelerated mixes. With accelerated construction, aggregate moisture content needs to be constantly monitored since it can change significantly during the course of construction. Physical properties of the aggregate such as absorption may be one source of change.	An aggregate's CTE is a measure of how much the material changes in length (or volume) for a given change in temperature. For bonded overlays over concrete, use aggregates that match the underlying pavement CTE. The material is subject to varying conditions in storage and handling. At the very least, these changes should be anticipated, and accommodations made to adjust the water content in the mixture as necessary. Ideally, real-time monitoring of the aggregate moisture content would allow for "on the fly" changes. In most circumstances, a well-regulated sampling program using rapid evaluation equipment will improve this component of the process considerably.
Separation Layer	A separation layer provides a necessary separation plane between overlay and underlying pavement. For asphalt separation layer under heavy truck traffic, decrease sand content and increase 0.13 in. (3.3 mm) aggregate in order to reduce stripping the asphalt due to pore pressure.	A separation layer does not provide structural support. Heavy truck traffic may decrease stability and strip the asphalt due to pore pressure. Consider drainable asphalt layer and drainage system under heavy truck traffic.

Table 11. Accelerated construction under traffic for concrete overlays, continued

Factors to Consider	Objectives / Expectations	Considerations / Limitations
Fibers	Although not typically required for concrete overlays, consideration needs to be given to the use of fibers under accelerated conditions. Fibers improve the toughness of the concrete overlay and resistance to plastic and dry shrinkage cracking, particularly with bonded overlays. Fibers also can increase the flexural strength of the concrete.	Placement of fibers in the mixture must be accomplished so as to prevent balling of the fibers into clumps. In some cases, water-soluble bags are added to the final batch. A staging area may be needed with adequate capacity to avoid a queue. In other cases, individual (bulk) fibers may be introduced into the mixture, where a blower appropriate to the application should then be considered.
Batching	Batching of concrete used in concrete overlays is usually no different from conventional concrete paving, or even other ready-mix applications.	Depending on the size of the job, a dedicated mobile batch plant is a benefit to the project under accelerated construction. In fact, this is recommended when at all possible due to the potential for increased control of quality and reliability.
Capacity	Having adequate batching capacity is a critical link in the process of constructing concrete overlays under an expedited schedule. Both mixing time and the availability of transport equipment should be balanced along with cost.	Contingency plans should include preparation for rapid responses (repairs) of the more common equipment malfunctions.
Consistency	During batching, consistency and uniformity are critical. Adequate mixing time should be balanced with the need for increased production rates. If possible, a continuous type or high-speed twin-shaft mixer could be used to accommodate both objectives.	Overlays are particularly vulnerable to changes in material properties due to their commonly thin sections.
Concrete Transportation		
Traffic Separation	In an ideal situation, a separation of the transit vehicles from both the traveling public and other construction vehicles is helpful.	In most situations, however, circumstances deviate from the ideal, which warrants appropriate measures to ensure an accelerated schedule.
Transit Time	Transit time is one variable that must be known. If a mobile batch plant is used, transport of the concrete from the batch plant to the paver may be quick. As a result, deviations from a conventional concrete mixture (including the admixtures that are used) may not be necessary. However, if there is a potential for delay (e.g., due to traffic congestion), or if a ready-mix plant is used for supply with a longer travel time, a modified mixture may be necessary.	Caution must be exercised if a retarder is used as it may also effect the strength gain of the mixture, thus affecting the time of opening to traffic. Curing may also become more critical in these situations as fresh concrete will be exposed for longer.
Protection	Protection of the mixture from environmental factors may also be a consideration, particularly in long transit times.	Dry and windy conditions can lead to rapid moisture loss from any exposed concrete. Conditions that are marginal for the risk of freezing or rain must also be addressed. In each case, protection of the concrete in transit may be warranted, and can often be done by use of tarps. If ready-mix trucks are used, protection is often less critical as the concrete is provided by the drum.
Haul Roads	The condition of the haul roads is another consideration when constructing under expedited conditions.	Care must be taken to ensure that the repeated heavy axles of the trucks will not excessively rut the haul road. Evaluation of a haul road in questionable areas should be done prior to the first batching.
Preoverlay Repairs	Prior to the construction of overlays, there may be a need for a variety of spot repairs on the existing pavement to be overlaid. The timing of these repairs will effect the schedule of the overlay construction.	If the preoverlay repairs dictate the accelerated overlay schedule, the repairs should be considered under a separate project or completed in off-peak hours.
Dowel Bar Retrofit	Typically, dowel bar retrofit is not done in conjunction with unbonded overlays since both can serve many of the same functions. Dowel bars have been used in conjunction with thin bonded overlays when you want to significantly increase load-carrying capacity. Good candidate projects for dowel bar retrofits have the following characteristics: pavements with adequate slab thickness, but showing significant loss of load transfer due to lack of dowels, poor aggregate interlock, or subbase/subgrade erosion. Relatively young pavements, because of insufficient slab thickness, excessive joint spacing, inadequate steel reinforcement at transverse cracks, and/or inadequate joint load transfer, are at risk of developing faulting, working cracks, and corner cracks unless the load transfer is improved. Typically, 3 to 5 smooth round steel dowel bars are used in each wheel path.	Slots should be cut by special diamond slot cutters that are capable of making multiple cuts at a time. Modified milling machines are not recommended due to associated spalling and variable cut widths that effect chair width requirements. Slots should be cut parallel with the direction of traffic. To properly prepare the slots, material should be removed with a lightweight jackhammer, and the slot should be sandblasted and cleaned. When choosing a repair material, select a material with the following characteristics: little or no shrinkage, good ultimate strength, thermal compatibility, freeze-thaw durability, and good bond to existing concrete.

Table 11. Accelerated construction under traffic for concrete overlays, continued

Factors to Consider	Objectives / Expectations	Considerations / Limitations
Drainage	Drainage improvements are sometimes warranted to complement the construction of a concrete overlay. These improvements may include cleaning adjacent ditches, increasing their capacity, or even retrofitting subdrains.	Since the equipment used for drainage improvements often works on or near the pavement edge, their operation before the overlay is complete would decrease the likelihood of premature damage to the young concrete. In addition, if retrofit subdrains are to stabilize the subbase, they should ideally be installed prior to the overlay in order to reduce movement of the existing pavement. However, be careful not to damage the subdrains during overlay construction.
Utilities	Utility work is also sometimes done prior to overlay construction. This may include relocation of utilities from beneath the pavement to off of the pavement edge. If trenching or other disturbance of the existing pavement is required, care should be taken to ensure proper construction of patches.	New patches can be particularly troublesome as they may not have adequate time to “settle” prior to the overlay construction. As with drainage improvements, all utility work should be completed prior to the overlay in order to minimize interference or early-age damage.
Spot Repairs	Some concrete overlays will require spot preoverlay repair to the existing concrete or asphalt pavement structure. If there are extensive repairs, the roadway may not be a good candidate for an overlay.	In all cases, quality of the spot repairs will often be critical to the success of the performance of the pavement.
Partial-depth repairs	Good candidates are sections where slab deterioration is contained to the upper one-third of the slab and where the existing load transfer devices (if any) are still effective.	Poor candidates for partial depth repairs are those with distress caused by compressive stress buildup in long-jointed pavements, spalling caused by dowel bar misalignment or lockup, transverse or longitudinal cracking caused by improper joint construction techniques, working transverse or longitudinal cracks, and spalls caused by D-cracking or reactive aggregate. It is important to verify that all delaminated concrete is removed, and that no concrete around the repair boundaries has been damaged during the process.
Full-depth repairs	Full-depth repairs of existing concrete or asphalt pavements are effective at correcting many different types of localized distress. However, there are a few cases that limit the effectiveness of a full-depth repair.	The effectiveness of a repair is dependent on the proper sizing of the repair. Most agencies specify a repair with a minimum length of 4 to 6 ft (1.2 to 1.8 m). Salvaging the existing dowel system is not recommended. It is also important to verify that all delaminated concrete is removed, and that no concrete around the repair boundaries has been damaged during the process.
Retrofitted edge drains	A good candidate project for retrofitted edge drains is a pavement that is showing early signs of moisture damage, is relatively young (i.e., less than 10 years old), and is only exhibiting a minimal amount of cracking (less than 5% cracked slabs) (Mathis 1990; FHWA 1992). Many studies have concluded that retrofitted edge drains are not effective at prolonging the service life of pavements that have already experienced significant moisture-related deterioration (Wells and Wiley 1987; Young 1990; VDOT 1990).	Retrofitted edge drains are not recommended on pavements where base contains more than 15% to 20% fines. When placing corrugated polyethylene pipes, extra care is also required to prevent overstretching of the pipes during installation. To avoid damage to the pipes during compaction, a minimum of 6 in. (150 mm) of cover over the drainage pipe is recommended before compacting.
Slab stabilization	Slab stabilization restores support beneath concrete slabs, thereby reducing progression of support-related distresses such as pumping, joint faulting, and corner breaks. Slab stabilization is not intended to raise depressed or settled slabs to the desired elevation. Cement grout mixtures and polyurethane are the most commonly used materials.	Watch the maximum pressure to make sure it does not exceed 100 psi (0.69 MPa). Monitor slab lift closely. Lift is typically limited to $\leq$ 0.13 in. (3.3 mm). Stop grout injection when the grout is seen flowing from holes, cracks, or joints. Stop injection if one minute has elapsed, regardless of pressure or lift changes.
Surface Preparation/Cleaning	Surface preparation and cleaning are required to prepare the existing surface for the concrete overlay.	The techniques used will vary depending on the surface type. The equipment used for repair should be sized to provide not only adequate production rates but also to minimize the disruption to the traveling public and to assist with the accelerated schedule.
Traffic on Prepared Surface	Phasing of the surface preparation operation can allow for intermediate trafficking of the surface prior to the overlay placement.	If trafficking is allowed on the prepared surface prior to the paving of the overlay, subsequent cleaning of the surface, particularly for bonded overlays, is required in order to remove any potential contamination.

Table 11. Accelerated construction under traffic for concrete overlays, continued

Factors to Consider	Objectives / Expectations	Considerations / Limitations
Bond on Concrete	Existing pavement surface preparation typically consists of shotblasting followed by sweeping the concrete surface. Cleaning consists of compressed air.	Paving should commence soon after cleaning to minimize the chance of contamination of the surface. Milling is used to lower the concrete elevation where required and is not used as a concrete surface preparation since it can cause surface microcracking and fracturing of the exposed aggregate.
Bond on Asphalt	Existing pavement milling may be used where surface distortions are 2 in. (50 mm) or greater to remove soft asphaltic material that would result in inadequate bond surface or to roughen the surface to enhance bond development. Cleaning consists of sweeping the asphalt surface then cleaning with compressed air.	Water or moisture cannot be allowed to stand on the asphalt surface prior to the bonding resurfacing. In order to prevent contamination of the surface, it is important to avoid a large lag time between the final surface cleaning and paving.
Unbonded on Concrete	Only the distresses that cause a major loss of structural capacity require repair.	The existing pavement needs to be stable and not shifting or moving, particularly at the subbase level.
Unbonded on Asphalt	Milling may be used where surface distortions are 2 in. (50 mm) or greater to remove distortions that contain soft or fractured asphalt. Before concrete placement, the asphalt surface should be swept. Remaining small particles are not considered a problem.	Spot milling of only parts of the projects with significant distortions or structural problems is often adequate.
Traffic Considerations		
Vehicle Access	Meet needs of user. May want to open pavement to cars earlier and open to trucks later.	Opening strength of pavement is the typical limit and may be increased through mixture material, protective curing, and heating.
Pedestrian Access in Intersections/Urban Areas	Channel pedestrian movements around construction zone.	In areas where heavy pedestrian traffic must be accommodated, looping the pedestrian path may be necessary.
Traffic Control Devices	Traffic can be accommodated during construction. Fit traffic control to user needs and follow the MUTCD (FHWA 2003b).	Too many times concrete overlays are eliminated as rehabilitation options when the project is to be built under traffic. The limitation of clearance requirements for paver tracks and stringline are no longer valid since many options are now available.
Lighting	Lighting allows night work. Lighting must be movable with construction.	Number of lights and control of light patterns within work zone must be considered.
Nighttime Construction	Nighttime construction for accelerated projects is increasing. It provides an off-peak construction period that lessens disruption to the traffic.	Nighttime visual limits must be utilized. They include shorter spacing of channelizing devices, longer transitions, changing colors nearing off-ramps, missing devices the same as no devices, widening pavement markings, using glare screens, using more truck-mounted attenuators, using real-time information on signs and changeable message signs, and covering signs when work is not being done.
Lane Capacity	Examine lane capacity of construction zone speed and not design speed of roadway.	Must deal with existing traffic flows in a safe manner for the driver and construction worker.
Large Trucks	Limited data show that tractor-trailer crash involvement in work zones is higher than the national average for these vehicles, particularly on the interstate system.	Special attention should be given to accommodate tractor-trailer combinations, both in work zones and their transitions, especially where there are large truck volumes. Items to consider are lane widths in curves with runs of barrier on both sides and stopping distance where congestion is expected.
Detours	Must be conveniently located and have effective signage.	May have negative impact on users. Always minimize the out-of-distance travel where possible.
Events		
School	Coordinate schedule with bus routes and events.	The schedule may be difficult to control because of limit changes.
Commuter	Plan project to minimize disruption.	Normally limits can be relied upon.
Holidays	Normally work stops during holidays.	Holidays present an uncontrollable increase of traffic.
Visibility	Provide adequate stopping distance, which increases overall safety.	Equipment and traffic control must be considered in regard to visibility.

Table 11. Accelerated construction under traffic for concrete overlays, continued

Factors to Consider	Objectives / Expectations	Considerations / Limitations
Construction Staging		
Staging Area	The project limits should be evaluated to determine adequate staging areas. The staging areas are necessary for ready mix truck washouts, storage of equipment and materials, construction trailers, and possibly a portable concrete mixing plant.	A dedicated ready mixture plant or mobile batch plant located near the project site will also cut down on the haul times to the site, and the quality of the mixture will be more easily controlled.
Incremental Lane Closure (Leap Frog)	Allows for continuous single lane paving in one direction, leaving opened areas for traffic recovery.	Requires multiple traffic control setups and pilot cars.
Mobilization	It is important that the project is planned to minimize staging operations. Every time a stage comes to an end, there are mobilizations necessary to regroup and prepare for the next step in the paving process.	Remobilizing of the paving crew on the project site takes time, and time not paving increases costs. A paradigm approach to paving is recommended to minimize the staging operations and mobilizations.
Work Production	To keep paving crews busy and provide cost-effective work, it is important to keep construction crews effectively utilized in accelerated construction projects involving overlays. That requires the crews to utilize effective work schedules that provide continuous and uninterrupted results.	Length based on curing time and production rates and acceptable traffic delays when under traffic.
Number and Type of Lane Closure	Traffic control must meet acceptable standards. Methods and materials used must meet project restriction.	Number and type of closures will depend on traffic demands, lane capacity, adjacent access requirements, and number of available traffic lanes.
Paver Encroachment	All encroachment restrictions can be met.	Normal stringline and track paver widths per side is typically 4 ft (1.2 m). One foot incremental encroachment reduction (up to 3 ft [0.9 m] reduction total) is common through typical machine adjustment. These do not require specialized pavers, but may require adjustment or modifications to an existing paver.
Construction Under Traffic Versus Lane Closure	The user costs of constructing the roadway under traffic typically are less than the costs of closing the road. However, closing the roadway is less in construction costs since it eliminates staging expense and improves the speed of construction.	Additional construction cost and delays to users when construction is under traffic must be compared to travel delay and out-of-distance travel for detours.
Construction		
Thickness of Overlay	Thinner overlays cure quicker, causing stresses to form earlier. Therefore, early sawing is important.	Thin overlays are subject to higher risk of cracking (shrinkage, curling, and warping stresses).
Weather		
Cold weather (below 40°F [4.4°C])	Consider covering pavement to help achieve opening strength.	Do not place overlays less than 4 in. (100 mm) thick; there is a higher risk of debonding and overlays require insulation.
Normal weather 40°F to 85°F (4.4°C to 29°C)	Overlays have fast strength gain and high production rates with reduced early-age cracking potential.	There should only be project restrictions and not normal material or equipment limits.
Hot weather > 85°F (29°C)	Faster strength gain exists during hot weather.	There is a higher risk of surface cracking during hot weather. Proper curing is important. Also, bottom up cracking needs to be considered when the underlying pavement is too hot.
Construction Equipment	One of the most important aspects of accelerated construction that is often overlooked is the availability and performance of the equipment on the site. All equipment should be in working condition and properly maintained. The contractor should present a back up plan in the event of equipment failure during construction. Proper parts, hydraulic fluids, oil, and fuel should be readily available. Concrete saws should be abundant and readily available on the job site.	In the event of failure to the concrete paver, a plan should be available to continue operations. The plan could be simple, such as keeping a mechanic on call, or it may be more complex, such as having a backup paver in the vicinity. A staging plan should be part of the back up plan to properly rout traffic in the event of scheduling disruptions. If the pavement is to be open in a matter of hours after paving, the critical stage is often the sawing. It is important to have the adequate manpower and saws on the job site when constructing a concrete overlay on an accelerated schedule.

Table 11. Accelerated construction under traffic for concrete overlays, continued

Factors to Consider	Objectives / Expectations	Considerations / Limitations
Curing	Curing is arguably more critical for overlays than for most other paving. The relatively thin nature of concrete overlays increases their surface area with respect to the volume of concrete. The result is more susceptibility to excess moisture loss and the distresses that can result from this. To avoid problems including plastic shrinkage cracking, full-depth shrinkage cracking, wide joints, and surface distresses, a rapid and effective curing program should be adopted that includes using twice the recommended compound rate for bonded overlays and 1.50 to 2 times the application rate for unbonded overlays.	While cost should be a consideration, the incremental quality improvements, such as high production curing from an effective curing program, will often far outweigh the additional cost.
Special curing	For overlays that require a very short opening to traffic and are relatively short in length, special curing in addition to curing compound is used. It normally consist of insulating blankets that provide a uniform temperature environment for the concrete.	Special curing is normally not required in summer months for accelerated construction, but it does have an effect on strength gain when air temperatures are less than 65°F (19°C), and it has a pronounced effect when temperatures are less than 55°F (13°C) in colder months.
Jointing	Jointing concrete overlays is also typically a more critical operation as compared to more conventional concrete paving. The thin section will often gain stresses rapidly, and thus require accelerated sawing. Sometimes the need for accelerated sawing is underestimated and the sawing operations fall too far behind the paver. To respond to this, the contractor should be prepared with the proper type and number of saws. In the case of jointing, redundancy in equipment is also important.	The timing of the saw cutting should be done to balance the potential for uncontrolled cracking with the potential for excessive joint spalling during sawing. Bonded concrete overlays over concrete require the most effective sawing operations to prevent overlay failures. Not only does the transverse joint require full depth saw cut plus 0.50 in. (13 mm) over the existing joint, the width of the cut should not be less than the existing transverse crack below the existing saw cut. This allows the two monolithic pavements (overlay and existing pavement) to contract the same way. For overlays on asphalt, particularly when there is wheel rutting in the asphalt, the depth of the saw should be increased to account for the extra depth in the wheel rut areas.
Fillets	Provide fillets a level of safety precaution at dropoffs.	Placement of form fillets may require sawing.
Opening Pavement Considerations		
Public Relations	Where construction will affect adjacent homeowners and businesses along with the traveling public, an effective public relations campaign should be implemented. Flyers, media coverage, and public meetings regarding the project schedule and the reason for the schedule timeline need to be developed and implemented. Preconstruction meetings between the government and the citizens, with the contractor in attendance, help keep the public well informed and allow the contractor to understand any concerns.	Construction needs to follow the schedule and, during construction, signing to business access is very important, along with daily communication between the contractor and the impacted business. Informed local drivers can avoid the area when possible, thus reducing delays.
Schedule	The project schedule must be reachable and realistic. The schedule affects public acceptance, contractors methods, payment and incentives, quality of work, and safety. Most accelerated construction projects are moving more to calendar days and days when work is not usually done in order to address critical completion dates where a large volume of traffic is affected. It also allows for the counting of weekends when necessary and eliminates working day issues of whether a contractor could or could not work.	Proper equipment and staffing, mixture, construction methods, curing, and sawing are all considerations. There is a need to understand the impact of traffic controls and openings, staging, material requirements, and isolated restricted spot locations on the construction schedule.
Maturity Method	Utilizing maturity testing for accelerated construction provides a reliable technique for estimating in-place strength and thus the time of opening. The temperatures measured as part of maturity testing have shown to be effective in identifying potential changes to the concrete mixture. Maturity testing provides a reliable technique for continuous monitoring of concrete strength gain. Most importantly, maturity testing enables any pavement to be opened to traffic as soon as it meets strength criteria. Concrete maturity concepts are being applied by 32 states.	Development of a maturity curve is an important element of maturity testing. As construction proceeds on a project, validation of the maturity curve may be necessary when changes occur in mixture constituents, material sources, mixture operations, and the water–cementitious materials ratios. Also some states set an automatic validation criterion based on a time period. Most states that use a maturity curve have validation criteria established which allows some flexibility in mixture changes without the development of a new maturity curve.
Opening Strength	See “Early Opening of Overlays to Traffic” section.	See “Early Opening of Overlays to Traffic” section.

Note: Adapted from multiple sources.

Considerations for Developing Project and Supplemental Specifications

Every jurisdiction has its own project development process and concrete pavement specifications. The following guidelines can be used in overlay project development and in developing supplemental specifications or special provisions. They apply to bonded and unbonded concrete overlay projects on existing concrete, asphalt, and composite pavements.

The guidelines are specific only to concrete overlay projects and do not represent every item that needs to be considered in a concrete paving project.

General

Contractor Submittal Considerations

- Maturity method for strength determination prior to opening to traffic.
- Paving mixture design for each source of aggregate to be used for review and approval by the engineer.
- Provide material certifications to the engineer.
- Where required, submit a plan for construction sequence and schedule prior to commencing construction. If the plans show a specific sequence/schedule, the contractor may need to verify compliance with the schedule or submit an alternate plan to the engineer for approval. A detailed staging and sequencing plan is recommended for concrete overlay projects when using an expedited construction process and schedule of opening.

Scheduling and Conflicts

- Construction sequence: A preconstruction meeting is recommended to discuss critical items such as staging, opening strengths, time of placement, and overall schedule.
- Typically, a concrete overlay schedule is much shorter than a standard concrete paving project.
- Conflict avoidance: Expose possible conflicts in advance of construction. Verify elevations and locations of each and verify clearance for proposed construction.
- Complete elements of the work that can affect line and grade in advance of construction unless noted on plans.
- Traffic control plan: The contractor should develop a traffic control plan where required based on the MUTCD (FHWA 2003b) and approved by the engineer.

Limitations of Operations

In addition to the limitations of operations for the placement of standard concrete pavement, the following limitations for concrete overlays apply:

- At air temperatures below 55°F (13°C), the opening of the pavement should be established using in-place strength measurement devices, such as the maturity method (ASTM C-1074). In order to place concrete in cold weather, air temperature requirements for the jurisdiction should apply.
- The engineer may impose a restriction on edge loading of construction equipment on the finished slab until opening strength is reached.
- Bonded concrete overlays should be placed according to the local jurisdiction's schedule, based on seasonal temperatures.
- Unbonded overlays should not be placed when the asphalt or concrete pavement surface temperature exceeds the maximum temperature allowed by the engineer. Typically, this temperature is around 120°F (49°C). Water may be added to cool the pavement ahead of the paver. The surface should be dry and free of standing water prior to paving.

Method of Measurement and Basis of Payment

The quantity of the various items of work involved in the construction of concrete overlay will be measured by the engineer in accordance with the following provisions:

- Surface preparation may include milling, air, water, and sand- or shotblasting; these should be measured and paid in square yards. Sweeping and cleaning with compressed air is a surface preparation task but is most often incidental to paving.
- Concrete overlay, furnish only: The quantity of concrete furnished will be measured in cubic yards. This quantity should include concrete placed in widening sections and partial depth patches. The contractor can be paid the contract unit price per cubic yards. This payment should be full compensation for furnishing all raw materials, and for proportioning, mixing, and delivery of concrete to the paving machine.
- Concrete overlay, placement only: The quantity of concrete overlay, placement only, should be measured and paid for in square yards. This will be the quantity shown in the contract documents. The area of concrete overlay placement can be determined from the length and pavement width, including widening sections. Payment should be full compensation for labor and equipment necessary to place, finish, texture, protect and cure the pavement, including sawing and sealing (if required) joints, furnishing, and installing reinforcement (if required).
- Separation layer: Hot mix asphalt or other approved separation layer material should be measured and paid by area or weight.
- If the contract documents require accelerating curing, such as wet or blanket curing, the curing area should be measured and the contractor should be paid per square yard.

Materials

- The CTE of the bonded overlays over concrete need to be similar to that of the existing concrete pavement. This is typically accomplished by using similar aggregates in the concrete mixture. If it is not possible, a coarse aggregate should be used in the overlay that has a lower CTE than in the existing pavement.
- The largest particle size of the coarse aggregate should be less than or equal to one-third of the overlay thickness.
- Refer to contract requirements for concrete mixture parameters.

Separation Layer for Unbonded Overlays

- If asphalt is used as the separation layer material, it should be designed with the intention of preventing asphalt stripping from the build up of pore pressure from heavy traffic. Special consideration should be given to pavements where high speeds and heavy trucks are expected. These variables are known to contribute to stripping.
- Fabric: Technology is evolving rapidly on the use of geotextile fabric for the separation layer. Care should be exercised in selecting geotextile fabric, however, because not all products perform equally well for this application.

Construction

Preoverlay Repairs

- Preoverlay repairs include: slab stabilization and slab jacking, partial depth repairs, full-depth repairs, retrofitted edge drains, load transfer restoration, and milling. If milling is part of the repairs, it should be completed prior to other repairs.

- Materials removed in the preparation operation may be temporarily placed in the shoulder area unless otherwise specified in the contract documents. The removal of materials must take place prior to the removal of approved construction signage.

- Surface preparation equipment used should be subject to approval of the engineer. Milling, air, water, sandblasting, and shotblasting equipment should be power operated and capable of preparing and cleaning of the existing surface in accordance with the contract documents.

Bonded Concrete Overlays Over Concrete

- The surface of the existing pavement should be prepared by shotblasting, sandblasting and/or milling. Milling, if used, should be followed by shotblasting or high pressure water blasting to remove concrete damaged during milling (evidenced by microcracking).

- Preparation should be adequate to remove all dirt, oil, and other foreign materials, as well as any laitance or loose material from the surface and edges against which new concrete is to be placed.

- Airblast surface to remove loose debris and prevent resettlement of debris into cleaned area. The surface should be free of oil or other automobile fluids. The pavement surface should not be moist or damp or have standing water prior to placement of the overlay.

Bonded Concrete Overlays Over Asphalt

- A guideline to determine whether milling is required is if asphalt surface distortions are 2 in. (5.08 cm) or greater. If milling is specified, it is important that there is at least 3 to 4 in. (7.62 to 10.16 cm) of asphalt remaining prior to the overlay. Milling should remove the asphalt to the nearest tack line.

- After milling, the surface should be inspected for further preoverlay repairs. The milling operation may expose wide thermal cracks. If the cracks are wider than the maximum overlay aggregate size, they may be filled with fly ash slurry, sand, or other appropriate material.

- Following any milling, partial or full depth repairs should be completed with concrete to ensure bonding with the overlay.

- All concrete patches plus the overlay should be isolated from the rest of the overlay using normal joint patterns (see page 15).

Unbonded Overlays Over Concrete

- For uniform support of the overlay, all partial and full-depth repairs should be completed with concrete.

- The concrete surface should be cleaned prior to the placement of the separation layer. If a leveling course is required, it should be completed with the concrete overlay and not with the asphalt separation layer.

Unbonded Concrete Overlays Over Asphalt

All partial and full-depth patching should be completed with asphalt. Existing concrete patches in the existing asphalt pavement should be isolated to prevent bonding to the concrete overlay. A debonding agent, fabric, or other bond-breaking material should be applied to the patch before the overlay is placed (see page 21).

Surface Cleaning

Bonded Concrete Overlays Over Concrete or Asphalt

- The surface of the existing pavement should be cleaned by sweeping and followed by compressed air in front of the paver. Paving should commence soon after cleaning to minimize contamination.

- Pressure washing should only be considered when surface contaminants are hard to remove or when mud or other debris is tracked on the surface. If pressure washed, no standing water should be allowed prior to paving. Paving should commence soon after cleaning to minimize contamination.

Unbonded Concrete Overlays Over Concrete or Asphalt

Surface cleaning is provided by sweeping of the existing asphalt surface with a mechanical sweeper or air blower. Paving should commence soon after cleaning to minimize contamination.

Concrete Placement

Grade Control

- The engineer will review and approve the control system. Information detailing the pavement thickness at the various survey points and material quantities should also be provided.

- Concrete paver should place in single lane width or be capable of adjusting the crown at each plan lane line when placing multiple lanes.

- When appropriate, grade control for the paving operation should be referenced off the milled surface, unless the milling machine is controlled by a previously established paver control line.

Overlay Placement

- Surface watering may be allowed by the engineer to help cool the pavement in extremely warm conditions and when the existing pavement surface condition is at or exceeds 120°F (48.89°C). The pavement surface should not be moist or wet prior to placement of the overlay.

- Conventional concrete paving procedures should be followed for placing, spreading, consolidating, and finishing the unbonded overlay when required. When dowels are specified, anchoring dowel baskets to the underlying pavement must be done according to the jurisdictions requirements. Alternatively, paving machines equipped with dowel bar inserters can be used.

- A quality control plan should dictate the time of placement with consideration given to air and pavement temperatures. For bonded overlays on concrete, it is not desirable to have the overlay pavement contracting, due to shrinkage, at the same time as the existing underlying concrete is expanding due to the heat of the day. The best time to place a bonded overlay over concrete is when the temperature differential between the existing pavement and new overlay is minimal.

Liquid Membrane Curing

- Apply curing compound immediately after surface moisture has disappeared but typically no later than 30 minutes after finishing/texturing. Apply liquid curing compound in a fine spray to form a continuous, uniform film on the horizontal surface and vertical edges of pavement, curbs, and back of curbs.

- Use a white pigment liquid curing compound for concrete.

- For overlays with a thickness of 6 in. (150 mm) or less, apply curing compound at 2 times the manufacturer's recommended application rate for a standard concrete pavement. Do not dilute the compound.

- For overlays with a thickness greater than 6 in. (150 mm), curing compound should be applied at 1.5 times the manufacturer's recommended rate for a standard concrete pavement.

- When white pigment curing compound is employed correctly, the surface of the concrete pavement should be solid white with no visible grey.

- If forms are used, apply to pavement edges and back of curbs within 30 minutes after forms are removed.

- Protect concrete pavement during cold weather for at least 5 days, or protect for a minimum of 24 hours and until flexural strength of 340 psi (2.3 MPa) is achieved for unbonded concrete overlays, 420 to 480 psi (2.9 to 3.3 MPa) for bonded concrete overlays over asphalt, and 540 psi (3.7 MPa) for bonded concrete overlays over concrete.

Joint Sawing

General

- The contractor should provide a joint sawing plan that demonstrates how all saw cuts will be accomplished within a shortened sawing window. Details should include the number of saws and anticipated sawing production rates, as well as estimated starting and finishing times. All sawing must be completed within the first one-half of the sawing window.

  The contractor should exercise care in placing, consolidating, and finishing the concrete at and around all joints.

- Wet sawing should be used when required by the contract documents for dust control.

Joint Width

- All conventional sawing widths are normally 0.19 in. (4.8 mm) +/- 0.06 in. (1.5 mm).
- All early entry sawing are normally 0.13 in. (3.3 mm) +/- 0.06 in. (1.5 mm) in width and a minimum T/4 inches in depth.

Joint Seal

- Joint sealing should follow the jurisdictional requirements. When narrow (.13 in. [3.3 mm]) saw cuts are used and sealing is required, follow jurisdictional requirements for low modules hot-pour sealant.

Timing

- Timely sawing is necessary to prevent random cracking due to shrinkage. This is particularly important for overlays less than 6 in. (150 mm).

Bonded Overlays Over Concrete

- Prior to construction of a concrete bonded overlay, the exact location of each contraction and expansion joint in the existing pavement, including joints created by full-depth patches, should be identified and marked on both sides of the pavement by a reliable method.
- Transverse joints should be placed in the overlay pavement directly over existing transverse joints.
- Transverse joint width must be equal to or greater than the underlying crack width at the bottom of the existing transverse joint to prevent debonding due to movement.
- Saw all transverse joints to full depth of overlay plus 0.50 in. (13 mm).
- Saw longitudinal joints to T/2.

Bonded Overlays Over Asphalt

- Saw transverse joints to a minimum depth of T/4.
- Saw longitudinal joints to a depth of T/3.
- Early entry saws may be required unless otherwise specified in contract documents.
- When 0.13 in. (3.3 mm) wide saw cuts are used and sealing is required, follow the jurisdictional requirement for low modulus hot-pour sealant.

Unbonded Overlays

- Saw transverse joints to a depth of T/4 (minimum) or T/3 (maximum). For early entry, saw depth will be 1.25 in. (31 mm) or greater.
- Saw all longitudinal joints to a depth of T/3.
- Sealing will follow jurisdictional requirements.
- For unbonded overlays over asphalt, the saw cut depth may need adjustment over rutted asphalt location in order to maintain a depth of T/4 to T/3 requirements.
- When 0.13 in. (3.3 mm) saw cuts are used and sealing is required, follow jurisdictional requirement for low modulus hot-pour sealant.

Repairs of Concrete Overlays

Concrete overlays can be expected to provide excellent performance and long life. Their performance is directly related to the uniformity and quality of the existing pavement base. Isolated weak or thin spots in the existing pavement may not be uncovered during the pavement evaluation, overlay design, or overlay construction phases and, like all pavement systems, some repairs may be necessary during its service life. If a bonded or unbonded overlay panel becomes distressed, overlay repairs are relatively straightforward and, in many cases, easier to perform than repairs of conventional concrete pavements.

Figure 52. Removing overlay panels (Photo courtesy of Randell Riley, P.E., Illinois Chapter ACPA)

Repairs of Bonded or Thin Unbonded Concrete Overlays

Full-depth panel replacement rather than partial-depth panel replacement is typical for bonded and thin unbonded overlays, because the panels are small and relatively thin. After full-depth sawing of the panel perimeter, the panel can be removed easily by jack hammers or a backhoe (figure 52).

Figure 53. Finish and cure of concrete overlay repair (Photo courtesy of Dan DeGraaf, P.E., Michigan Concrete Paving Association)

When the overlay has been removed, the existing base should be examined. If the old existing pavement is determined to be deficient, it should be removed and replaced with concrete; the pavement replacement may be placed in a separate layer or poured monolithically with the overlay. Asphalt should not be used as a patching material since concrete does not bond well with new asphalt. Replacing an overlay panel(s) is easily accomplished using typical overlay procedures and materials (figure 53).

Figure 54. Typical concrete pavement milling operation (Photo courtesy of Randell Riley, P.E., Illinois Chapter ACPA)

Thin concrete overlays at the end of their service life can be milled and refilled easily (figures 54 and 55). Removal by milling (also referred to as carbide milling, cold planning, and roto-milling) is a good option for concrete overlays, because they rely on the existing pavement base for load transfer and therefore do not typically require steel reinforcement.

Figure 55. Typical concrete pavement milling operation (Photo courtesy of Dan DeGraaf, P.E., Michigan Concrete Paving Association)

Generally, the productivity of milling concrete is very good, depending on aggregate hardness, bit configuration, and removal depth. For example, removal of a concrete overlay at 2 in. (50 mm) depth has been reported as high as 8,000 ft^2/hr (720 m^2/hr) and for 4 in. (100 mm) depth as low as 2,700 ft^2/hr (243m^2/hr).

The method of removal is similar to that used for asphalt layers, particularly when there are no steel tiebars in the overlay.

Milling can be performed under wet or dry conditions.

The milling depth can be feathered into adjacent pavements. Milling can be completed on specific selected sections. The coarseness of the surface after milling and the fineness of the millings can vary based on the type and spacing of milling teeth on the drum (figure 56).

Repairs of Full-Depth Unbonded Concrete Overlays

Full-depth unbonded overlays typically are constructed with dowel basket and lane ties, so common concrete pavement repair techniques are used. These include partial or full-depth repairs, diamond grinding, and joint resealing. With thicker overlays (8 in. [200 mm]) subject to heavy traffic, load transfer restoration can also be applied to restore load transfer and mitigate joint problems.

When a uniform separation course is used, overlay thickness will likely vary, especially where super-elevation changes are encountered; repairs made in these areas may require provisions to account for additional saw-cut depth.

Standard full-depth concrete removal techniques are used on thicker overlays. However, 8 to 9 in. (200 to 250 mm) concrete overlays have been successfully removed by milling.

Figure 56. Typical concrete pavement millings from milling operation (Photo courtesy of Dan DeGraaf, P.E., Michigan Concrete Paving Association)

Appendix A. Evaluation and Selection Tables

Table 12. Distress types and severity levels recommended for assessing concrete pavement structural adequacy

Load-Related Distress	Highway Classification	Current Distress Level		
		Adequate	Marginal	Inadequate
Jointed plain concrete medium- and high-severity transverse and longitudinal cracks and corner breaks (% slabs)	Interstate/Freeway	<5	5 to 10	>10
	Primary	<8	8 to 15	>15
	Secondary	<10	10 to 20	>20
Jointed reinforced concrete medium- and high- severity transverse cracks and corner breaks (#/lane-miles)	Interstate/Freeway	<15	15 to 40	>40
	Primary	<20	20 to 50	>50
	Secondary	<25	25 to 60	>60
Jointed plain concrete mean transverse joint/crack faulting (in.)	Interstate/Freeway	<0.10 (2.5 mm)	0.10 to 0.15 (2.5 to 3.8 mm)	>0.15 (3.8 mm)
	Primary	<0.125 (3.2 mm)	0.13 to 0.20 (3.3 to 5.1 mm)	>0.20 (5.1 mm)
	Secondary	<0.15 (3.8 mm)	0.15 to 0.30 (3.8 to 7.6 mm)	>0.30 (7.6 mm)
Jointed reinforced concrete mean transverse joint/crack faulting (in.)	Interstate/Freeway	<0.15 (3.8 mm)	0.15 to 0.30 (3.8 to 7.6 mm)	>0.30 (7.6 mm)
	Primary	<0.175 (4.5 mm)	0.18 to 0.35 (4.6 to 8.9 mm)	>0.35 (8.9 mm)
	Secondary	<0.20 (5.1 mm)	0.20 to 0.40 (5.1 to 10.2 mm)	>0.40 (10.2 mm)
Continuously reinforced concrete medium- and high-severity punchouts (#/lane-miles)	Interstate/Freeway	<5	5 to 10	>10
	Primary	<8	8 to 15	>15
	Secondary	<10	10 to 20	>20
Applicability of Bonded Concrete Overlays				
Applicability of Unbonded Concrete Overlays				

Table 13. Distress types and levels recommended for assessing asphalt and composite pavement structural adequacy

Distress Type	Highway Classification	Distress Level		
		Adequate	Marginal	Inadequate
Fatigue cracking (% of wheel path area)	Interstate/Freeway	<5	5 to 20	>20
	Primary	<10	10 to 45	>45
	Secondary	<10	10 to 45	>45
Longitudinal cracking in wheel path (ft/mi)	Interstate/Freeway	<265 (50.2 m/km)	265 to 1060 (50.2 to 200.8 m/km)	>1060 (200.8 m/km)
	Primary	<530 (100.4 m/km)	530 to 2650 (100.4 to 501.9 m/km)	>2650 (501.9 m/km)
	Secondary	<530 (100.4 m/km)	530 to 2650 (100.4 to 501.9 m/km)	>2650 (501.9 m/km)
Composite pavement reflection cracking crack width (in.)	Interstate/Freeway	<0.50 (12.7 mm)	0.25 to 0.50 (6.4 to 12.7 mm)	>0.50 (12.7 mm)
	Primary	<0.50 (12.7 mm)	0.50 to 0.75 (12.7 to 19.1 mm)	>0.75 (19.1 mm)
	Secondary	<0.50 (12.7 mm)	0.50 to 0.75 (12.7 to 19.1 mm)	>0.75 (19.1 mm)
Transverse crack spacing (ft)	Interstate/Freeway	>200 (61.0 m)	100 to 200 (30.5 to 61.0 m)	<100 (30.5 m)
	Primary	>120 (36.6 m)	60 to 120 (18.3 to 36.6 m)	<60 (18.3 m)
	Secondary	>120 (36.6 m)	60 to 120 (18.3 to 36.6 m)	<60 (18.3 m)
Mean depth of rutting in both wheel paths (in.)	Interstate/Freeway	<0.25 (6.4 mm)	0.25 to 0.40 (6.4 to 10.2 mm)	>0.40 (10.2 mm)
	Primary	<0.35 (8.9 mm)	0.35 to 0.60 (8.9 to 15.2 mm)	>0.60 (15.2 mm)
	Secondary	<0.40 (10.2 mm)	0.40 to 0.80 (10.2 to 20.3 mm)	>0.80 (20.3 mm)
Shoving (% of wheel path area)	Interstate/Freeway	None	1 to 10	>10
	Primary	<10	10 to 20	>20
	Secondary	<20	20 to 45	>45
Applicability of Bonded Concrete Overlays				
Applicability of Unbonded Concrete Overlays				

Appendix B. Sample Geotextile Specifications (Germany)

The following specifications for geotextile interlayers in Germany are taken from Rasmussen (2008).

Design Specifications

Property	Requirement*
Fabric Type	• Non-woven Geotextile • Uniform color
Mass per unit area	≥ 13.3 oz/yd² (450 g/m²) ≤ 16.2 oz/yd² (550 g/m²)
Thickness under load (pressure)	0.29 psi (2 kN/m²): ≥ 0.12 in. (3.0 mm) 2.9 psi (20 kN/m²): ≥ 0.10 in. (2.5 mm) 29 psi (200 kN/m²): ≥ 0.04 in. (1.0 mm)
Tensile strength	≥ 685 lb/ft (10 kN/m)
Maximum elongation	≤ 130% †
Water permeability in normal direction under load (pressure)	≥ 3.3×10-4 ft/s (1×10-4 m/s) [under pressure of 2.9 psi (20 kN/m²)]
Water permeability in the plane direction of the fabric (transmittivity) under load (pressure)	≥ 1.6×10-3 ft/s (5×10-4 m/s) [under pressure of 2.9 psi (20 kN/m²)] ≥ 6.6×10-4 ft/s (2×10-4 m/s) [under pressure of 29 psi (200 kN/m²)]
Weather resistance	Resistance ≥ 60% (per EN 12,224)
Alkali resistance	≥ 96% Polypropylene/Polyethylene

* Specifications must be met for 95% of samples.
† 60% maximum is recommended as a better practice.

Quality Control

- The first sample of fabric is taken after placement of 1,200 yd² (1,000 m²)
- Second sample after 12,000 yd² (10,000 m²)
- One sample every 12,000 yd² (10,000 m²) thereafter.
- Samples are 1.20 yd² (1 m²) in size.
- Testing of samples to meet requirements is on a different schedule for each requirement.

Cost

- Material cost for the geotextile appears to be $1.50 to $2.00 per yd² (circa 2008)
- Installation cost is on the order of $0.50 per yd² (circa 2008)

Appendix C. Innovative Methods for Accelerated Concrete Overlay Construction

The following table provides a summary of innovative accelerated construction methods (adapted from Simon et al. 2003).

Table 14. Applicability, pros, and cons of various accelerated construction methods

Method	Applicability / Limitations	Pros(+) / Cons(-)
Formal partnering with design consultants, contractors, local authorities, and regulatory agencies	• This method has not been used very much with designers or other agencies. • Little training has been done and much skepticism is in place regarding this method.	+ Provides a faster and cheaper construction process due to reduction of conflicts, litigation, and claims (win-win situation) + Brings about continuous improvement in the quality of services and products + Utilizes resources more effectively + Implements easily because is already being used on an informal basis + Improves communications – Limits completive market strategy – Creates strong dependency on the partners
Methods for expediting utility relocation work	• In highway construction, the need for the relocation of utilities often arises, particularly in urban areas. • Relocation is handled primarily by utility companies. • Currently, there is little recourse that can be taken against utilities for delays. • Utilities have to pay for relocations.	+ Encourages project managers to develop more economical means and methods + Shortens project execution by using less formal documentation and improving communication + Reduces executive personnel + Produces more continuity during the project – Brings about need for independent engineers to check PMs' work – Encourages overcoming the "specialist mindset" of the organization
Intelligent Transportation Systems (ITS) and work-zone traffic control	• Applicable areas include but are not limited to traffic control, route guidance, automated highway systems, collision avoidance, en-route driver information, transportation demand management, etc.	+ Increases safety + Reduces congestion + Enhances mobility + Minimizes environmental impact + Increases energy efficiency + Promotes economic productivity for healthier economy – Requires additional training of employees – Includes costs to implement
Public input on phasing of construction	• This method is applicable on construction projects where there is a significant impact on the public.	+ Allows for more expeditious construction methods to be employed – Requires more public relations effort earlier
Multiple approaches to Traffic Control Plans (TCPs)	• TCP solutions for small simple jobs are often apparent, but otherwise they should be thoroughly investigated earlier in the process.	+ Reduces both construction costs and user costs through optimal TCPs – Requires larger consultant fees for development because of more thorough TCP analysis
Descriptive catalog of construction technologies	• Applicability of new technologies could be widespread, but specifications may be affected.	+ Provides an online catalog that could easily be accessed and supported by FHWA and other states – Requires effort for maintenance and upkeep of the catalog
Contractor preparation of the TCP based on minimum requirements	• This approach will encourage contractor innovation, but may be possible only on smaller, simpler projects.	+ Reduces efforts + Provides incentive for construction innovation – Increases costs – Excludes impact on local businesses – Means that contractor compliance with safety standards may be challenging
Linear Scheduling Method (LSM) and accurate productivity to rate data and establish project target duration	• This method can be used for repetitive projects in which there are no strict dependencies/constraints between project activities. • Resurfacing overlays and shoulder improvement are good types of projects for the LSM.	+ Provides a better understanding of the project + Enables the planner to determine when and where a change in resources must take place to satisfy the goals set by the project + Helps identify existing relationships and encourages the project team to try different alternatives + Shortens schedule by overlapping activities instead of sequencing – Scheduling projects involving large cuts and fills might be more difficult to schedule with LSM

Table 14. Applicability, pros, and cons of various accelerated construction methods, continued

Method	Applicability / Limitations	Pros(+) / Cons(–)
A+B contracting (costs plus time)	• A+B bidding can be used to motivate the contractor to minimize the delivery time for high priority and highly trafficked roadways. • There must be a balance between the benefits of early completion and any increased cost of construction. • This approach requires incentives and disincentives to be effective.	+ Includes consideration of the time component of a construction contract + Includes favorable treatment of contractors with the most available resources to complete the project + Involves incentives for contractors to compress the construction schedule + Includes greater potential for early project completion – Requires that incentives and disincentives are carefully managed – Means that costs are defined whereas benefits are distributed to the public
Contractor milestone incentives	• Incentives must be relevant. • Goals must be reachable. • Incentives cannot be conflicting.	+ Encourages contractors to finish on time – Causes impacts to contractors to be highly scrutinized – Causes disagreements over compensable delays that may be problematic
Packaged multi-primes contracting	• This method can be used when a specific highway project is composed of several major segments or is very large.	+ Increases competition among construction bidders + Reduces pyramiding of costs, particularly overhead and profit + Reduces project time through overlap of design and construction or from multiple work forces + Requires more direct control by the project owner – Presents interface management challenges for the agency – Leads to physical interferences between contractors
Pre-qualified bidders based on past schedule performance	• Bidders qualify based on several key items, including specific project type experience, individual experience, past performance, capacity of the firm, and the primary firm location.	+ Provides a shorter and easier selection process + Provides possibly better contractors – Reduces the competition – Requires that schedule performance data are well kept – Requires that agency and other noncontractual schedule impacts are recognized and equitably settled
Incentives for TCP development with a contractor who values an engineering cost-savings sharing provision	• To use this method, seek involvement of local municipalities in funding the incentive (e.g., 5% of estimated user cost savings). • This method requires close scrutiny to determine actual time savings.	+ Leads to innovative ideas for successful TCPs – Means that savings are difficult to estimate
Incentives for contractor work progress with a lane-rental approach	• Incentives must be explicitly described in the bid package. • Rental rates have to be significant and should address high impact lanes.	+ Leads to innovative ideas for successful TCPs + Minimizes contractor impact on the traffic – Causes administration to be difficult
Increased amount of liquidated damages and routine enforcement	• Just as important as the damages happening in the contract are the claims made for damages. The time and effort involved in pursuing these claims is, however, a limitation. This should be weighed against potential benefits. • Possibly provide incentives to finish projects ahead of time.	+ Motivates better contractor performance – Requires rigorous documentation and quick request for information (RFI) response to enforce
"No excuse" incentives	• These incentives preclude delay claims by contractors, give contractors incentives to finish early, and require a realistic schedule.	+ Results in considerable improvements in schedule performance – Transfers risk to contractor and therefore may increase costs on the average over time
Tools and best practices for implementing multiple work shift and/or night work	• New technologies (such as intrusion alarms), modified traffic control plans, and new methods to monitor traffic provide improvements in night work-zone safety. • These improvements will lead to high nighttime productivity.	+ Increases safety for road users and workers + Reduces user costs + Provides faster completion time – Requires research and design costs

Table 14. Applicability, pros, and cons of various accelerated construction methods, continued

Method	Applicability / Limitations	Pros(+) / Cons(–)
Exploitation of web-based team collaboration system	• To be efficient, access to information is needed quickly and without hassle. A web-based system can be used to track project deliverables, track project tasks online, receive email alerts as items become due, share documents, and reduce administrative document production and delivery cost by uploading documents. This is handy for CAD drawings or anything else that needs to be shared with the project team.	+ Enhances project communication + Eases collaboration with project managers, designers, contractors, vendors, and the public + Keeps everyone in the loop + Allows tracking of project online which minimizes time taken and enhances performance – Requires high installation and learning costs – Lacks standards
Encouragement of the use of automated construction technologies	• Numerous research and implementation efforts are currently underway to automate conventional infrastructure construction, condition assessment, and maintenance actives such as earth moving, compaction, road construction, and maintenance. • Commercial systems are available	+ Results in possible savings + Presents opportunity for significant schedule compression – Requires some training – Requires contractor implementation
Employment of methods for continuous work zones	• These methods can be used where road geometry and weekend or night scheduling permit.	+ Decreases duration and unit costs + Increases safety – Results in possible higher user costs and traffic congestion
Use of windowed milestone	• This method can be used where milestone dates are not based on hard constraints. Milestones should be related to allow the contractor maximum flexibility in efficiently allocating project resources.	+ Lowers project costs + Lowers user costs – Reduces ability to "hold contractors' feet to the fire"
Schedule of calendar day projects	• Scheduling calendar day projects is applicable to projects where the completion is critical and a large volume of traffic is affected.	+ Produces better weather management + Provides a direct method of expediting – Requires strict adherence to the schedule for credibility with the public, even with breakdowns or weather problems
Construction time shortened by full closure of the roadway instead of partial closure	• Full closure could be used in areas where there is at least one alternative route for drivers and where volume is limited.	+ Shortens construction time – Causes possible traffic congestion on alterative routes
Duration and productivity effects tracked and associated with different technologies	• Data collected can be very useful in cost and time estimation for optimal plans. • Technology choices may be limited, however, by project conditions and logical equipment spreads.	+ Produces quicker and more dependable exploitation of new technologies – Requires personnel to devote time to properly monitor and record data – Can be perceived as costly
Optimal approaches to crew shifts and scheduling to eliminate long work hours	• The schedule can be shortened through use of additional crews on regular shift, multiple shifting, or selective overtime. • Scheduled overtime can be used where appropriate but effects should be evaluated carefully.	+ Provides possible cost savings + Increases productivity + Reduces cycle time of tasks which improves the schedule – Creates possible negative results if planning is done carelessly – Creates a necessity for contractor to implement
Selected field personnel trained in scheduling methods and claims	• Schedule flexibility may be minimal in practice, but for complex jobs a broad understanding of scheduling issues should help expedite progress.	+ Creates a flexible and quick-to-adapt project team + Leads to faster project completion – Leads to possibly too many people trying to manage
Lessons learned database on ways to expediate schedules	• This database would be broadly applicable but limited by legal and policy constraints.	+ Requires quick reference for implementation of expediting measures – Creates a need for the database to be maintained

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ACPA publication TB021.02P