CONCRETE OVERLAY REPAIR AND REPLACEMENT STRATEGIES

GUIDE | DECEMBER 2024

National Concrete Pavement Technology Center
CP Tech Center

Iowa State University
Institute for Transportation

About the CP Tech Center

The mission of the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, technology transfer, and technology implementation.

About This Guide

This guide presents preservation and repair solutions tailored to concrete overlay distresses and discusses end-of-life strategies that will enable agencies to preserve their investment for the longest possible time. These topics are applicable to each of the various types of concrete overlay solutions. The material in this guide is intended for engineers, contractors, and others interested in concrete overlay solutions.

This guide is a product of the CP Tech Center at Iowa State University's Institute for Transportation. For more detailed information about the topics covered in this guide, readers are encouraged to consult the CP Tech Center's concrete overlays website and complementary publications, including *Guide to Concrete Overlays*, Fourth Edition, *Concrete Overlays—A Proven Technology*, *Concrete Overlays—The Value Proposition*, and *Concrete Pavement Preservation Guide*, Third Edition.

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16. Abstract

Concrete overlays have become a vital technology in pavement maintenance, rehabilitation, and durability, offering a cost-effective and sustainable solution for extending the service life of existing pavements. This guide presents preservation and repair solutions tailored to concrete overlay distresses and discusses end-of-life strategies that will enable agencies to preserve their investment for the longest possible time. These topics are applicable to each of the various types of concrete overlay solutions.

Comprehensive details are provided on several concrete overlay repair and preservation methods, including pressure relief cuts, full-depth and partial-depth repairs, dowel bar retrofits, cross-stitching, and diamond grinding. End-of-life strategies such as overlay replacement, partial and full inlays, and reconstruction are discussed with an emphasis on the importance of condition monitoring, life-cycle cost analysis, and sustainable practices in deciding when an overlay reaches its end of life. Important details cover equipment considerations when milling concrete for partial or full removal of an existing overlay.

The material in this guide is intended for engineers, contractors, and others interested in concrete overlay solutions.

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Purpose

In the field of pavement technology, concrete overlays have witnessed significant growth and development. Over the years, the use of concrete overlays has evolved to address various challenges related to pavement maintenance, rehabilitation, and durability. This technology has proven to be a cost-effective and sustainable solution for extending the service life of existing pavements.

Numerous publications and guides have been written on the technology, helping engineers and contractors understand the requirements for success and improve upon their own applications. Concrete overlay technology is now a mature solution that has become a standard option among many departments of transportation, counties, and municipalities.

Two programs have had a significant influence on this growth. First, the Concrete Overlay Field Application Program, conducted by the National Concrete Pavement Technology Center (CP Tech Center) under a cooperative agreement with the Federal Highway Administration (FHWA), supported the construction of 37 new overlay projects. The program ran between 2013 and 2018. More recently, FHWA's Targeted Overlay Pavement Solutions (TOPS) program through the Every Day Counts (EDC) initiative has provided additional technology transfer to agencies interested in learning about and applying concrete overlay solutions. How to handle repair and replacement effectively as concrete overlays wear or fatigue is a final question stemming from these efforts.

This guide presents preservation and repair solutions tailored to concrete overlay distresses. It also discusses end-of-life strategies that will enable agencies to preserve their investment for the longest possible time. The guide covers these topics for each of the various types of concrete overlays and is intended for engineers, contractors and others interested in concrete overlay solutions.

Introduction

Concrete overlays have gained prominence due to their ability to enhance the structural and functional performance of existing pavements without the need for complete reconstruction. The growth of this technology can be attributed to factors such as increased awareness of sustainable practices, a focus on cost-effective solutions, and advancements in materials and construction techniques (ACPA 2024a).

As concrete overlay technology has matured, a strategic approach to overlay repair and end-of-life strategies has become imperative. Such an approach involves a holistic view of pavement management, including the consideration of economic, environmental, and performance factors to ensure the long-term sustainability and functionality of overlay systems.

Concrete overlays are not unlike most other pavement solutions in terms of repair and end-of-life strategies. Pavements generally deteriorate over time with traffic loading. The durability of concrete materials may also be a factor in deterioration, although with increased awareness of deterioration mechanisms like D-cracking and alkali-silica reactivity (ASR) and, as a result, more stringent materials selection and improved mixture design practices, encounters with these challenges should become less frequent.

As this guide will point out, there is no blanket solution to address concrete overlay repair. The circumstances of each project are unique and influence the specific deterioration mechanisms and the rate of deterioration leading to necessary repairs or upgrades. The prominence of certain pavement distresses may also directly depend upon the concrete overlay type. Therefore, it is important to factor the concrete overlay type into repair and end-of-life considerations.

Types of Concrete Overlays

The *Guide to Concrete Overlays*, Fourth Edition (Fick et al. 2021), describes the design and construction processes for concrete overlays on different types of existing pavement. Concrete can be placed on existing asphalt, composite, jointed plain concrete pavement (JPCP), jointed reinforced concrete pavement (JRCP), and continuously reinforced concrete pavement (CRCP) and can be used effectively on existing pavements in a variety of conditions.

Concrete overlays are grouped into four main types depending upon the type of existing pavement and the treatment of the interface between the overlay and existing pavement (Figure 1). In discussing repair and end-of-life strategies, this guide will refer to the overlay types using the nomenclature defined in Figure 1: concrete on asphalt–bonded (COA–B), concrete on asphalt–unbonded (COA–U), concrete on concrete–bonded (COC–B), and concrete on concrete–unbonded (COC–U).

Concrete on Asphalt

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

Concrete on Concrete

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

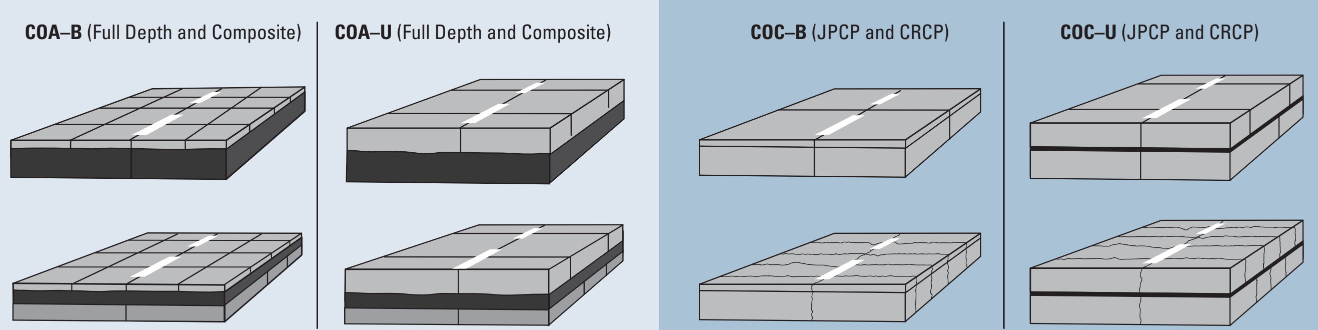

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Figure 1. Four main types of concrete overlays

As overlay usage has progressed, three of the four types, COA–U, COA–B, and COC–U, have emerged as the most frequently applied solutions. The COC–B overlay is a narrowly targeted solution intended for situations in which load capacity must be increased to meet an unexpected traffic demand on a pavement in otherwise relatively good condition. Such circumstances arise infrequently. As such, repair considerations for COC–B overlays are addressed in this guide to a lesser extent than repair considerations for the other, more frequently applied solutions.

Innovation Life Cycle

Concrete overlays have progressed through the innovation life cycle, moving from the initial stages of exploration and experimentation to widespread adoption and maturity. The technology has proven its effectiveness and gained acceptance in the pavement engineering community.

With the maturity of this solution, it is imperative to address how agencies can manage concrete overlays throughout their life cycle. Strategic priorities include the following:

1. **Condition monitoring.** Implement effective condition monitoring to assess the performance of existing concrete overlays and identify areas requiring repair or maintenance.
2. **Life-cycle cost analysis.** Conduct life-cycle cost analysis to evaluate the economic feasibility of overlay repair versus complete reconstruction, considering long-term performance and maintenance costs.
3. **Sustainability.** Consider sustainable practices in overlay repair strategies, including the use of materials and techniques that minimize environmental impacts over the overlay's life.
4. **Innovation in repair techniques.** Continuously explore and adopt innovative repair techniques to address specific issues such as cracking, spalling, or deterioration in concrete overlays.
5. **Research and development.** Invest in ongoing research and development to stay ahead of emerging challenges and to improve the performance and durability of concrete overlays.

Concrete Overlay Performance

Concrete overlays have demonstrated varying performance characteristics depending on factors such as construction techniques, materials used, and traffic and environmental conditions (Gross et al. 2017, Mahdi et al. 2020). The performance of concrete overlays can be broadly categorized into three stages: long-term service, repair/preservation cycle(s), and end of life (Figure 2).

Stage 1: Long-Term Service

Concrete overlays, when properly designed and constructed, have shown excellent long-term performance. Many studies indicate that well-executed concrete overlays can significantly extend the service life of existing asphalt or concrete pavements, with life expectancies ranging from 20 to 40 years or more. This is true regardless of overlay type.

Bonded overlays adhere directly to the existing pavement surface. These overlays are typically 6 in. thick or less and exhibit improved load distribution while working in conjunction with the existing pavement layers as a monolithic system. The bonding action enhances structural capacity using a relatively thin concrete layer.

Unbonded overlays are either placed without intentional effort to develop adherence to the existing surface or purposely separated from the existing pavement by a separation layer. These overlays have demonstrated long-term durability and, when designed and constructed with appropriate materials and methods, perform similarly to conventional concrete pavement.

Stage 2: Repair and Preservation Cycle(s)

Concrete overlays eventually enter a stage of repair and preservation cycles during their service life. These cycles are essential for maintaining the structural integrity and functionality of the overlay. The period over which an overlay pavement may be maintained depends upon the specific conditions of the project. Agencies may be able to extend the life of an overlay with multiple timely interventions, extending the overlay life for 20 years or longer after the initial intervention.

Key studies highlight the effectiveness of timely repairs and preservation treatments in addressing issues such as cracking, spalling, and surface distress. Routine maintenance activities, including proper surface rehabilitation, contribute to prolonging an overlay's functional life. Specific distresses associated with the different overlay types are discussed later in this guide.

Repair and preservation cycles involve strategic interventions to address specific distress mechanisms and ensure that the overlay continues to meet performance requirements.

Generally, a 6 in. thickness is the common threshold defining all concrete overlays as either thick (above 6 in.) or thin (6 in. or less). This convention is applied throughout this guide.

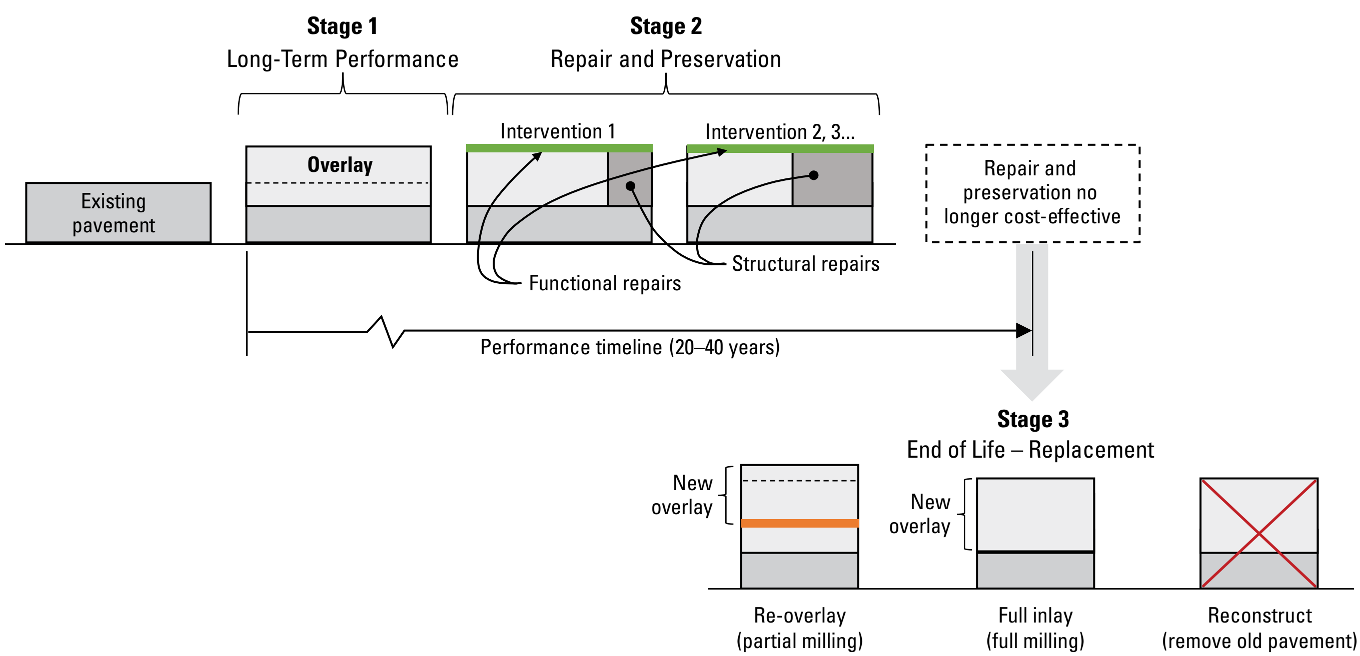

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Figure 2. Three stages of concrete overlay performance

Stage 3: End of Life

As concrete overlays approach the end of their service life, decisions must be made regarding rehabilitation or replacement strategies. End-of-life considerations involve evaluating the condition of the overlay and determining the most cost-effective and sustainable approach.

Best practices emphasize the importance of conducting thorough condition assessments and life-cycle cost analyses to inform decisions about rehabilitation or reconstruction. The goal is to maximize the value of the overlay while minimizing overall life-cycle costs. Sustainable practices, such as recycling materials into new construction or repurposing materials, are gaining attention as an important part of the end-of-life considerations.

Details regarding the addition of another overlay, use of an inlay, or reconstruction of the section are described later in this guide.

Key Performance Studies

An abundance of excellent publications are available that describe the performance of concrete overlays. Five notable studies are summarized here, as they underpin the foregoing discussion and the following discussion of overlay distresses.

In *Performance History of Concrete Overlays in the United States*, Gross (2023) states that concrete overlays are a cost-effective and long-lasting solution for pavement preservation, resurfacing, and rehabilitation. The document provides a brief history of the construction of concrete overlays in the United States and summarizes the details of 17 concrete overlay projects throughout the country. It concludes that concrete overlays offer several benefits that make them a key component of any agency's overall asset management program. The case histories presented in the document demonstrate the effectiveness and durability of concrete overlays and provide insight into the pavement distresses found on typical projects.

Izevbekhai et al. (2020) found that the number of years since the most recent intervention proved to be a significant predictor of the remaining service life (RSL) of Minnesota's COC–U projects. The study developed a simplified performance curve for COC–U, which predicted an RSL of 36 years. The study also suggested that COC–U overlays are a long-term solution with the potential for even higher service life if preventive maintenance is done within the first 7 years.

Gross et al. (2017) used pavement condition data (international roughness index [IRI], transverse cracking, longitudinal cracking, D-cracking, spalled joints, and faulting) collected on Iowa roadways since 2002 to evaluate concrete overlay performance in Iowa. A comparison of key concrete overlay parameters, such as overlay type, thickness, age, and joint spacing, with IRI and pavement condition index (PCI) performance data showed that Iowa's overlays performed very well, with service life trends exceeding previously defined expectations. Investigation of outlying data from poorly performing projects showed that pavement distress tended to be based on a combination of project-specific material- and construction-related issues rather than inherent overlay design issues.

Vandenbossche and Fagerness (2002) reported on a controlled study of the performance of COA-B overlays at the MnROAD pavement test facility. The study was among the first controlled studies of COA-B overlays. It concluded that COA-B overlays are a viable rehabilitation alternative for asphalt pavements. The distresses observed in the overlay sections in the study included corner breaks, transverse cracks, and reflective cracks. The distresses were more prevalent in the driving lane, which experienced 79% of the traffic load. The overlay performance was also influenced by joint layout, panel size, and overlay thickness. Repairs were made to the distressed areas using techniques such as milling, removing distressed panels, and placing new concrete.

In the mid-1980s, the first nationwide study of COC–U overlays evaluated 14 projects of various ages from around the country (Voigt et al. 1989). The study reported the projects to be performing very well with little deterioration at the time. Performance curves indicated a significantly lower rate of faulting development in COC–U overlays compared to conventional pavement due to the presence of the non-erodible underlying pavement. More recent studies have also found lower rates of faulting, pumping, and other support-related distresses. Cracking was noted to be an issue on some of the projects, which was attributed to joint spacing and inadequate separation of the overlay. The study set standards used to this day, including (1) keeping COC–U transverse joint spacing shorter than conventional pavement to prevent cracking in the overlay (less than seven times the radius of relative stiffness) and (2) ensuring that the interlayer is of sufficient thickness or means to separate the overlay from the existing slab to prevent reflective cracking and/or keying between the layers.

Overlay Deterioration

In general, pavement deterioration observed in thicker concrete overlays is like that in traditional concrete pavements built on stabilized bases and can be repaired in a similar fashion. Thinner overlays and overlays intended to be bonded with an existing pavement may experience some additional, unique distresses (King and Taylor 2022).

The distresses and deterioration modes most observed in concrete overlays include typical crack formations (transverse, longitudinal, corner, fatigue, and reflective) and roughness from curling/warping or faulting. These problems are easily addressed with preservation techniques. Some concrete overlays have developed one or more less common problems now largely mitigated by improved practices, such as those outlined in the *Guide to Concrete Overlays*, Fourth Edition (Fick et al. 2021). These distresses, which include panel movement/migration, buckling, debonding, asphalt stripping, and longitudinal cracking over widening units or along joints in wheel paths, might still occur in an isolated project.

Distresses in any pavement may affect the functional or structural capacity of the pavement, and concrete overlays are no exception. However, not all overlay distresses lead to an eventual removal and replacement of the overlay or of the entire pavement structure (end of life). Some distresses may be effectively managed over time using pavement preservation techniques. Therefore, it is important to understand the nature of pavement distresses to optimally maintain the performance and serviceability of a concrete overlay over the long term.

Typical Distresses

The subsequent sections provide a high-level overview of relevant distresses. For more detailed information, refer to *Guide for Concrete Pavement Distress Assessments and Solutions: Identification, Causes, Prevention, and Repair*, Chapters 15 through 18, for COA–B, COC–B, COA–U, and COC–U overlays, respectively. These chapters provide detailed descriptions of the distress mechanisms in each of these overlay types, including how to measure and qualify their severity level (Harrington et al. 2018).

Durability Issues

Environmental factors such as freeze-thaw cycles, chemical exposure, and moisture infiltration can lead to deterioration in concrete. In pavements, such problems can manifest as surface scaling, spalling, or widespread map cracking. While advances in performance-engineered mixture (PEM) design practices have all but eliminated these problems, reports of the presence of durability-related distresses such as D-cracking, ASR, and freeze-thaw damage have been made on older overlay projects, mostly those built before agencies instituted more stringent controls on concrete aggregate selection and alkalis in the cementitious paste (Gross et al. 2023).

With effective controls in place and the adoption of PEM tools and techniques, overlay deterioration from poor concrete mixture durability is not considered to be a major factor in future concrete overlay performance (Fick et al. 2021). If an overlay is experiencing material-related durability distress, it is likely to become a candidate for removal and replacement. Figure 3 provides an example of ASR-induced distress that may develop in a concrete overlay with substandard materials.

Cracking

Cracks can form in concrete overlays due to a variety of factors, such as restrained shrinkage, thermal expansion and contraction, reflection from underlying layers, or fatigue from traffic loads (Figure 4). Both thick and thin overlays are susceptible to cracking, but the type and extent of cracking may vary. Thick overlays experience less cracking due to their more effective load distribution capability. However, they can still develop cracks from underlying movements or material properties. Thin overlays are more prone to fatigue and top-down cracking simply because of their reduced thickness, which provides less resistance to applied stresses.

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Figure 3. Map cracking from alkali-silica reactivity evident near a transverse overlay joint

Matt Zeller, Concrete Paving Association of Minnesota, used with permission (top and center); Wisconsin Concrete Pavement Association, used with permission (bottom)

Figure 4. Typical overlay crack formations: (a) transverse, (b) longitudinal, and (c) fatigue cracking in thin overlays

Steve Waalkes, Michigan Concrete Association, used with permission

Figure 5. Joint spalling and deterioration on a concrete overlay

Joint Deterioration

Distresses can initiate at joints due to tension or compression stresses, loss of support, or loss of bond integrity at the interface between the overlay and the underlying pavement. Common forms of deterioration include spalling and edge cracking (Figure 5). These issues are often exacerbated by inadequate edge support, poor joint construction, or differential settlement between the overlay and the existing pavement. While both thick and thin overlays can experience joint and edge deterioration, thin overlays may be more susceptible due to their reduced thickness and the potential for loss of bonding with the underlying pavement.

Distresses in Thin Overlays

The thickness of the overlay can play a role in determining the rate and severity of deterioration and the types of distresses observed. Thicker overlays provide more mass, more aggregate interlock at joints, and increased resistance to distresses, which can result in different deterioration patterns than might be experienced in thinner overlays. Thin overlays also may be more vulnerable to fatigue problems if they lose bonding with the underlying pavement.

Thin Overlay Durability

Durability-related distresses such as D-cracking, ASR, and freeze-thaw damage may lead to end of life sooner on thin overlays, since thin overlays have a higher surface area-to-volume ratio, making them more vulnerable to the effects of moisture and environmental factors. In contrast, thicker overlays have more mass and are better able to withstand these distresses (King and Taylor 2022).

Debonding

Debonding between layers is categorized as a distress in COA–B and COC–B overlays, which are designed to bond to the existing pavement and act monolithically under loading. COA–B and COC–B overlays can be susceptible to debonding if the existing pavement surface was not properly prepared to facilitate bonding before construction. Debonding may also develop over time due to cumulative traffic loads, intrusion of moisture at the interface between pavement layers, or curling and warping stresses. Debonding can lead to accelerated transverse, longitudinal, corner and fatigue cracking in thin overlays because the pavement system no longer acts monolithically and the concrete surface layer must absorb nearly all of the tensile forces under loading.

Asphalt Stripping/Shearing

Stripping, or the loss of bonding between the asphalt binder and aggregate particles within an asphalt pavement layer, is associated with either thin COC-U overlays placed on asphalt separation layers or thin COA-B overlays on an existing asphalt pavement that does not withstand hydraulic pressure under repeated dynamic traffic loads. Thin overlays with poor drainage characteristics are most susceptible to stripping/shearing, which manifests in loss of support and various types of cracking similar in formation to the cracking found with other causes of debonding.

Longitudinal Cracking at Widening Units

Thin overlays with integral widening units are more prone to longitudinal cracking in the region above the transition point, generally in the outer wheel path or within the paved shoulder. The cause is usually attributed to either differential deflection and support under loading or to a stress riser created at the transition point to the thicker widening section (Figure 6). Thicker overlays are less likely to experience this type of cracking if they are supported properly.

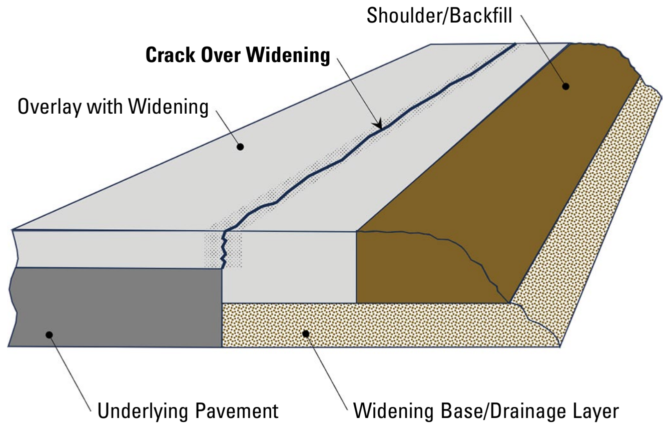

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Figure 6. Typical location of longitudinal crack that may form over a widening unit

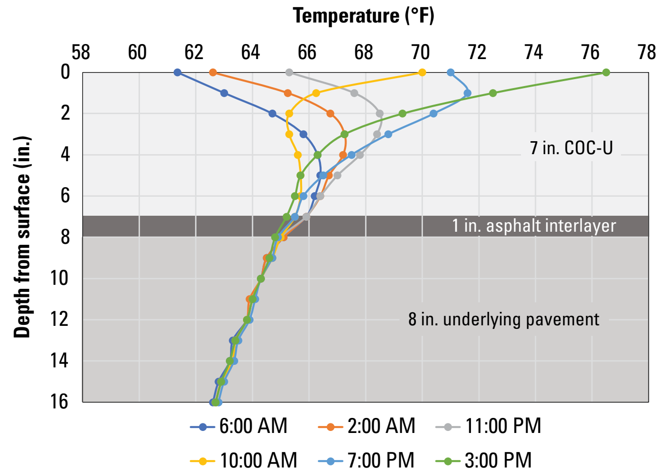
Panel Movement and Buckling

Panel movement, where portions of the overlay shift independently from the surrounding system, is more common in thin overlays (6 in. or less). This movement can result in visible panel or joint misalignment, where transverse joints no longer line up across the width of the pavement (Figure 7a). This movement occurs because thin overlays have less mass and may be more easily pushed under compression. Thin overlays also sometimes do not have tie bars to hold longitudinal joints together, contributing to the potential for joint misalignment. Panel movement can eventually lead to buckling, especially in conditions with high temperatures following significant rain events, which combine to induce significant concrete expansion and swelling (Rao et al. 2022). Figures 7b through 7d provide examples of buckling and other distresses in thin overlays resulting from panel movement.

Figure 8 illustrates the temperature differential through the depth of a 7 in. COC–U overlay at different times of the day/night (Voigt et al. 1989). The profile was created using pavement layer heat transfer modeling. The figure shows that the overlay and separation layer insulate the underlying pavement and undergo significantly more differential temperature change. This same effect applies to all overlay types and helps explain why thin overlays under certain extremes may experience slab migration/compression distresses. Overlay slabs can experience a higher temperature differential and may tend to expand to a higher degree than the underlying pavement layer(s).

Matt Zeller, Concrete Paving Association of Minnesota, used with permission (a, c and d); Gerald Voigt, Square One Pavement Consulting LLC, used with permission (b)

Figure 7. Slab movement distresses: (a) migration, (b) buckled/tented transverse joint, (c) migration with compression failure, and (d) longitudinal joint opening at buckle



Adapted from Voigt et al. 1989

Figure 8. Temperature profile through a COC–U overlay showing that the overlay undergoes larger daily temperature swings while insulating the underlying pavement

Determining End of Life

Table 1 summarizes the types of distresses associated with different types of concrete overlays depending on thickness and bonding condition and presents the implication of these distresses on the end of life.

If an existing overlay exhibits deterioration only in the surface layer, it may be a candidate for further preservation treatments, depending on the extent of the deterioration. If the surface layer deterioration extends consistently over the length of a project—roughly 30% or more of the project area—it may warrant an end-of-life consideration.

Deterioration associated with the underlying pavement or base layers will generally manifest into more extensive or severe distress conditions in the concrete overlay. The overlay may exhibit structural issues such as heaving, settlement, or the dislodging or erosion of materials due to poor drainage. Slab break-up due to loss of support for the overlay is also a condition associated with a compromised underlying structure. When present, these problems are likely to extend beyond the surface layer and may affect the structural integrity of the entire pavement structure. An extensive and significant loss of overlay structural integrity may necessitate end-of-life consideration (with a cost analysis required to make the final determination).

Table 1. Summary of concrete overlay pavement distresses, associated repair/preservation options, and end-of-life implications

Distress	Overlay Design Factor				Repair/Preservation Options	End-of-Life Implications
	≤6 in.	>6 in.	B	U		
Concrete Durability						
D-cracking	○	○	○	○	Full-depth repair	May drive end-of-life replacement if too severe
Alkali-silica reactivity	○	○	○	○	Do nothing, full-depth repair	
Freeze-thaw	○	○	○	○	Partial- or full-depth repair	
Cracking						
Plastic shrinkage	○	○	○	○	Do nothing, high molecular weight methacrylate (HMWM)	None
Transverse	●	●	●	●	Full-depth repair	None (unless progresses to shattered slab)
Longitudinal	●	●	●	●	Do nothing, cross-stitching	
Multiple (shattered slab)	●	●	●	●	Slab replacement	May drive end-of-life replacement if too severe or numerous
Corner	●	○	●	○	Full-depth repair, slab replacement	
Fatigue	●	○	●	○	Slab replacement	
Reflective – from a crack/joint	●	●	●	○	Cross-stitching, full-depth repair	None (unless spalling progresses)
Reflective – from widening	○	○	○	○	Cross-stitching	
Transition slab break-up	○	○	○	○	Full-depth repair	None
Roughness						
Bumps/Dips	●	●	●	●	Diamond grinding	None (may smooth by grinding multiple times)
Faulting	●	●	●	●	Diamond grinding, dowel bar retrofit	
Curling/Warping	○	○	○	○	Diamond grinding	
Rocking slabs	○	○	○	○	Do nothing	If cracks/shatters, may drive end of life
Loss of rideability (IRI)	●	●	●	●	Diamond grinding	May drive end-of-life replacement if too rough
Compression Problems						
Joint spalling	●	●	●	●	Partial-depth repair, full-depth repair	May drive end-of-life replacement if extensive
Slab migration	○	○	○	○	Do nothing, pressure relief joints	Discreet events managed with repairs
Tenting	○	○	○	○	Pressure relief joints, full-depth repair	
Buckling	○	○	○	○	Full-depth repair and pressure relief joints	
Punchouts (CRCP)	○	○	○	○	Full-depth repair	May drive end-of-life replacement if extensive
Interface Problems						
Loss of bond	○	○	○	—	Partial- or full-depth repair	Likely leads to cracking/fatigue driving end of life
Stripping asphalt separation layer	—	—	—	○	Do nothing, or pressure relief joints	

○ *Rarely occurring distress based on overlay performance studies*
● *Distress that develops over time based on overlay performance studies*
— *Distress not a factor*

Isolated substructure problems may be repaired by excavating below the overlay and existing pavement to address distresses caused by problems deeper in the pavement or roadbed. Associated repair strategies may entail comprehensive techniques, including patching, base stabilization, or localized reconstruction, depending on the severity of the damage. Bear in mind that even though an overlay may require an invasive excavation to address some underlying problems, a repair and preservation strategy may still be the most cost-effective and sustainable approach to extending the overlay's life. The determination hinges on the extent of the problem across the length of the project.

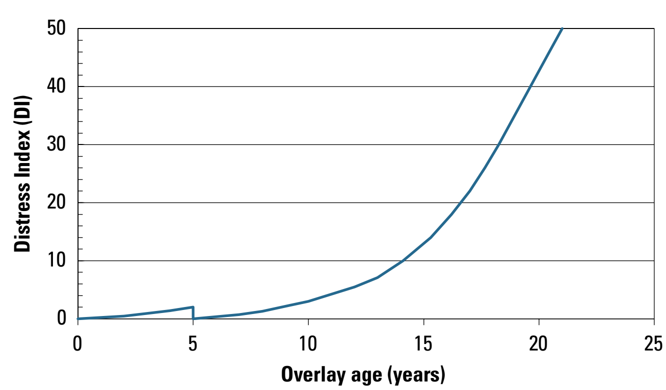
Determining whether a pavement is at the end-of-life stage can be challenging. Three methods can help inform the decision: structural capacity assessment, roughness evaluation, and economic feasibility analysis of continued repair. (The latter determines whether the cost of repairs is close to or exceeds the cost of replacement.)

Isolated substructure problems may be repaired by excavating the overlay and existing pavement to address the cause. In the interest of sustainable construction, the feasibility of less invasive repair strategies should always be fully investigated before declaring that an overlay has reached its useful life.

Structural Capacity Assessment

Determining the remaining structural life of a concrete overlay involves a comprehensive evaluation of the overlay's condition and integrity similar to the evaluation used for any pavement structural rehabilitation strategy. The following are recommended steps and considerations:

1. **Inspect visually.** Conduct a thorough visual inspection of the concrete overlay to identify and begin to quantify the deterioration. Document the extent and severity of the distresses present.
2. **Assess the concrete integrity.** Evaluate the overlay's surface layer using nondestructive testing (NDT) techniques to assess concrete strength and integrity.
3. **Core the pavement.** Core through the overlay and underlying pavement at various locations to measure the layer thickness and assess the interlayer condition and depth of surface distress. Variations in thickness can affect the overlay's performance and remaining service life.
4. **Assess subsurface layer(s).** Assess the condition of the underlying pavement layers, including the separation layer (if present) and base, to determine if there are any issues with bond loss, erosion, asphalt stripping, subgrade instability, or other moisture-related conditions that could affect the overlay's longevity.
5. **Review traffic projections.** Consider the anticipated traffic loading and whether this may accelerate deterioration and reduce the remaining life of the overlay.
6. **Performance history.** Review maintenance records, pavement performance data, and historical rehabilitation activities to understand the overlay's maintenance history and how this compares to the performance of similar overlays for the agency. Note any recurring issues that may be affecting the overlay's life in an unusual manner. Figure 9 from the Michigan Department of Transportation's (MDOT's) pavement management systems shows an excellent example of the prediction of remaining service life for its thin (<6 in.) overlays. The data show that the projected life of thin overlays in Michigan is 21 years on average and involves only one intervention of patching and joint resealing (MDOT 2021).
7. **Predictive modeling.** Use pavement design software or predictive modeling tools to estimate the remaining service life of the concrete overlay based on its current condition, anticipated traffic loading, and maintenance strategies. Refer to Appendix A (Table A.1) of the *Guide to Concrete Overlays*, Fourth Edition (Fick et al. 2021), which lists appropriate design methods by overlay type.



Recreated from MDOT 2021

Figure 9. MDOT thin overlay service life deterioration curve

Pavement Roughness Evaluation

Roughness is a core factor in the decision to rehabilitate, resurface, or reconstruct any pavement, including concrete overlays. Roughness, regardless of the cause, affects the pavement's functional capacity and overall user satisfaction. By quantifying concrete overlay roughness periodically, engineers can track an overlay's functional condition and project when it may require intervention.

All concrete overlays deteriorate due to traffic and long-term environmental exposure and will require more frequent interventions as they approach 20, 30, or 40 years of service. A pavement's IRI or other smoothness index value helps decision-makers program repair strategies and ultimately signals whether the overlay has reached the end of its useful life.

No special consideration is necessary to use IRI trigger values for determining concrete overlay interventions. Agencies can apply the same triggers that they use for other concrete pavements in their network.

Economic Feasibility Analysis of Continued Repair

The economic analysis for determining end of life is analogous to the determination used by insurance companies to decide whether to repair or "total" a damaged automobile. The analysis requires the information resulting from the structural capacity and roughness assessments, plus the following:

1. **Cost of repair.** Estimate the cost of repairing the existing pavement. This cost includes materials, labor, equipment, and any associated overhead costs. Different repair techniques may have varying costs, so it is essential to consider the most appropriate methods based on the pavement distresses present. (More details on overlay repair methods are found in subsequent chapters this guide.)
2. **Projected lifespan.** Evaluate the expected lifespan of the overlay after repair. This estimation is based on factors such as the quality of materials used, the effectiveness of repair techniques, and projected traffic loading. It is important to determine whether the repair will provide a sufficient extension of the overlay's service life to justify the cost. This determination may require engineering judgment along with any available predictive tools for pavement management.
3. **Cost of replacement.** Prepare an estimate of the cost of replacing the overlay and compare this cost with the cost of further repair. Replacement may involve any of the end-of-life strategies discussed in this guide.
4. **Long-term impacts.** Consider the long-term impacts associated with each option. While repair may be less expensive upfront, it is also essential to factor in potential future maintenance and repair costs and disruptions. If frequent maintenance is anticipated with continued overlay repair, the repair option may end up being more expensive in the long run than pursuing an end-of-life strategy.
5. **Traffic disruption.** Assess the impact of the construction activities on traffic flow and safety. Replacing an overlay or reconstructing a pavement typically requires more extensive work up front and longer road closures, which can result in greater disruptions to the area. The costs associated with maintenance of traffic are an important indirect cost associated with the economic feasibility of continued repair.
6. **Environmental impacts.** Consider the environmental impacts of both the repair and replacement options. This consideration includes factors such as greenhouse gas emissions, energy consumption, and use of natural resources. Choosing sustainable materials and construction techniques may be a consideration in some cases.

A life-cycle cost analysis may be a useful tool to combine all of these factors for an objective comparison of continued overlay repair versus replacement over the expected lifespan of the options. Walls and Smith (1998) and ACPA (2012) provide guidance on how to conduct such an analysis. Regardless of which tools are employed, a thorough economic analysis will help decision-makers identify the solution that optimizes the pavement's lifespan while balancing overall costs and disruptions.

Preservation/Repair Methods and Considerations

Most of the techniques used to repair and preserve concrete overlays are similar to the techniques used for conventional concrete pavements and are used for the same purposes. In both cases, the repairs are intended to address the causes as well as the symptoms of pavement distresses. The *Concrete Pavement Preservation Guide*, Third Edition, provides a comprehensive review of best practices for the repair/preservation of concrete pavements (Smith et al. 2022). The discussion herein does not repeat this information but rather presents important repair principles and establishes best practices for applying repair/preservation techniques to concrete overlays. Where differences exist, techniques unique to concrete overlays are also covered.

When multiple procedures are necessary to repair a single project, it is important to follow a progression sequence to ensure the integrity and effectiveness of each repair while protecting any previously performed repairs. Figure 10 introduces the recommended sequence for the repair of concrete overlays.

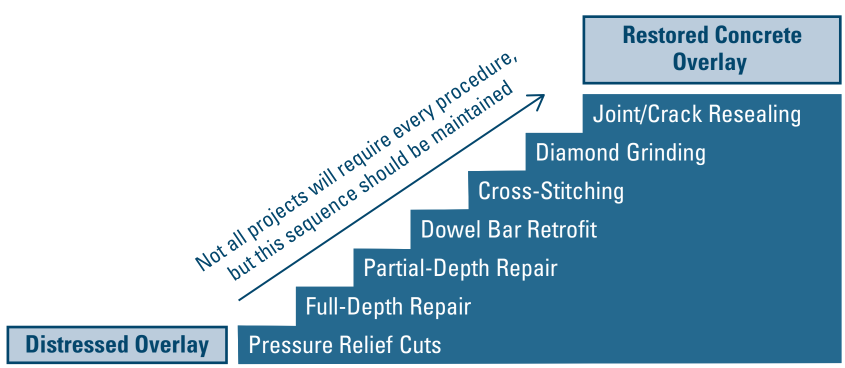
Not every project will require the full set of procedures, but for projects requiring more than one, the order should be maintained to prevent operations from working at odds with one another or causing costly damage to previous work. It is important to consider this sequencing in the planning and execution phases of an overlay preservation project or for standard maintenance work.

Prior to executing any technique, the engineer and contractor are advised to work together to do the following:

- Conduct a thorough assessment (walk-through) of the overlay to identify the areas that both parties agree require repair, noting any differences in distress levels that may warrant switching from one technique to another
- Ensure that the initial quantity of repairs (if included in bid documents) is still accurate and viable
- Agree on how the contractor should size repairs for typical distress conditions
- Intentionally mark or label areas for repair techniques, carefully considering the severity of the distresses and the functionality of each area

Pressure Relief Cuts

Pressure relief cuts refer to the introduction of wide, full-depth transverse sawcuts at specific locations within the overlay to mitigate the effects of compression forces due to thermal expansion (see Figure 11). This repair method is primarily a preventative technique to relieve pressure that builds up along the longitudinal axis of the pavement caused by the inability of transverse overlay joints to close during periods of very warm temperatures. The primary reason that transverse joints may be unable to close is due to the infiltration of incompressible materials, which can be exacerbated by a lack of complete transverse joint activation (i.e., when cracks do not develop beneath all transverse joints), leading to the development of dominant transverse joints that open and close to a greater magnitude than surrounding joints (Rao et al. 2022).



Adapted from ACPA 2018, ©ACPA 2008, used with permission

Figure 10. Sequence of techniques for proper repair/preservation of concrete overlays

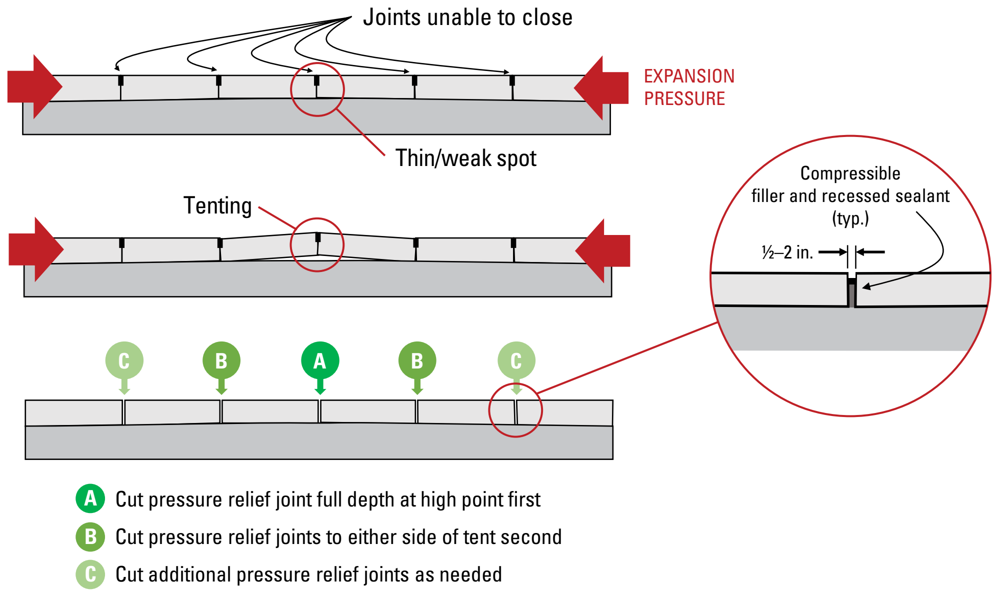


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Figure 11. Pressure relief cut procedure diagram

Purpose

In most cases, pressure relief cuts are used when an overlay has experienced a compression-related distress, such as slab migration, tenting, or buckling. As discussed previously, these distresses are rare but can occur in overlays less than 6 in. thick on both concrete and asphalt pavements under a certain sequence of extreme weather conditions. Agency engineers and maintenance personnel may apply this technique proactively to get ahead of a spalling or buckling event that might otherwise require a more extensive repair. The severity of distress from pavement pressures is characterized as minor (tenting), moderate (compression failure or spalling), and major (pavement buckling).

To apply pressure relief cuts as a preventative measure, determine whether the following sequence of conditions is present:

- Hot weather following a significant rain event
- A noticeable increase in the roughness of the pavement or overlay
- Visual signs of tenting at one or more joints

If pavement pressures are addressed early, any noticeable tenting in a thin overlay can subside once the cuts are in place, and the repair can help prevent compression failures or buckles. Experience shows that overlays that have experienced minor tenting have returned to their original position with the eventual reduction in ambient temperature, indicating that the vertical movement is not permanent.

The challenge with applying this procedure as a preventative measure without any physical evidence of tenting is determining where to place the relief cuts. Experience shows that thin overlay compression problems occur at weak points, such as the following:

- A thin spot in the pavement/overlay with less capability to withstand the internal bearing pressures (Note that thin spots have been eliminated in current overlay construction by the recommended use of three-dimensional [3D] modeling of the existing pavement surface prior to overlay construction, ensuring a minimum as-built thickness.)
- Near leave-outs that were part of the original overlay construction sequence
- At the crests or sags of vertical curves

Best Practice

For pressure relief, full-depth sawcuts are made through the transverse joint at the high point of the tent and then on both ends of the tent. A cut width of ½ to 2 in. is generally sufficient. Figure 11 shows the procedure starting with a cut at the high-point first and then proceeding outward until the pressure is fully relieved. This will usually require two joints to either side of the tent.

To minimize the potential of diamond blade binding, sawing can be done in the early morning when expansive pressures are lowest, or wedges may be used to hold the cut open to prevent blade binding. There are two options if blades bind and wedging is ineffective:

- Employ a more aggressive and wider carbide-tipped saw to avoid binding
- Break up the tented slab and use a full-depth repair at the location

Engineers and maintenance personnel are cautioned not to introduce pressure relief cuts regularly or indiscriminately into an overlay because the pressure relief cuts loosen up the slabs near the cuts, reducing load transfer. This specialty procedure is intended only for the rare case of overlays under extreme pressure.

It is always recommended to seal transverse pressure relief cuts afterward to prevent infiltration of incompressible material in a widened, open cut. Inserting a compressible filler into the sawcut and topping with hot-pour sealant is recommended for wider (1 in. or more) sawcuts. Narrow sawcuts can simply be filled with hot-pour sealant.

Full-Depth Repair

Full-depth repairs are the most common and useful repair method for all overlay types. The techniques used for full-depth repairs of conventional pavements also apply to concrete overlays. For a more detailed discussion of full-depth repairs, see *Concrete Pavement Preservation Guide*, Third Edition (Smith et al. 2022).

Purpose

The purpose of full-depth repairs of concrete overlays is to restore structural integrity, improve durability, create a smooth surface, and ensure the cost-effective long-term performance of the overlay system. Full-depth repairs in concrete overlays are used for the following:

- To address areas of significant damage or deterioration that evidence suggests extends below the overlay
- To replace cracked or shattered slabs to restore structural integrity
- To replace damaged transition slabs between the overlay and adjacent pavement that were not built properly
- As an optional component of a larger solution, to mitigate damage from excessive overlay expansion conditions
- To execute utility cut repairs in urban areas (see the Utility Considerations chapter in this guide)

While full-depth repairs require more invasive work compared to partial-depth surface repairs, addressing underlying issues comprehensively can ultimately be more cost-effective. One of the main benefits of this procedure is addressing the root causes of more extensive pavement distresses.

Best Practices

Materials

Concrete overlays are best repaired using concrete rather than asphalt patching materials. Experience from several overlays that were repaired using asphalt patches as slab replacements found that the asphalt repairs accelerated rather than slowed the deterioration of the overlay (King and Taylor 2022). Asphalt patching materials are not recommended for full-depth replacements for the following reasons:

1. Asphalt materials have different structural properties than concrete and may be difficult to compact properly in the repair area, leading to mismatched performance and potential structural issues.
2. The use of asphalt materials can result in differential movement between the patch and the surrounding concrete, leading to cracking and delamination in bonded overlay systems.
3. The use of asphalt materials allows for significantly more slab migration and overlay deterioration by allowing extensive loosening of transverse joints.
4. The use of asphalt materials results in a mismatched appearance and texture, detracting from the overall aesthetics of the overlay.

Using concrete for full-depth patching maintains closer uniformity in structural and thermal characteristics, such as stiffness, load bearing capacity, and coefficient of thermal expansion.

The type of concrete used in full-depth repairs should be based on the available lane closure time (Smith et al. 2022). A good rule of thumb is to start with conventional mixture materials and only adjust the mixture using chemical admixtures or switch to a specialty cementitious material if needed to meet the opening requirements. It is important to understand that the strength required for opening full-depth repairs (typically 2,000 to 3,000 lb/in.^{2} per Smith et al. [2022]) is less than historically believed, and faster-setting mixtures are generally more expensive and may require special handling, such as with volumetric mobile mixers.

If an accelerated mixture is deemed necessary, avoid using a higher cement content or Type III cement as the simplified approach. Mixtures with a high cement factor often provide high early strength but typically at the cost of increased shrinkage and poor durability (Smith et al. 2022). A properly designed accelerated patching mixture can achieve the desired early-age strength development without compromises. The slightly higher cost associated with using accelerated mixtures, chemical admixtures, or specialty cementitious materials over slower conventional mixtures or nondurable mixtures with a high cement factor pays off in savings related to scheduling, traffic control, and long-term durability.

The presence of fibers in an existing concrete overlay does not impact the full-depth repair method or material selection. The concrete repair material does not require fibers simply because material is being used to repair an overlay that contains fibers. The need for fibers should be based purely on structural or performance reasons.

Refer to Smith et al. (2022) for further information on material selection. For considerations on the use of fibers in a given mixture, review *Fiber-Reinforced Concrete for Pavement Overlays: Technical Overview* (Roesler et al. 2019).

Marking and Removal

After the initial evaluation and project walk-through, the deteriorated areas must be marked for removal. The recommended guidelines for sizing full-depth repairs for concrete overlays are summarized in Table 2.

Low-severity cracks do not warrant full-depth repairs, but replacement is recommended for panels with multiple cracks or evidence of movement, such as crack spalling and dislodging of material (ACPA 2024c). Overlays that are 6 in. thick or less often have a joint spacing of 6 ft or less, creating natural boundaries for the repairs. The entire panel containing the distress should be removed and replaced; partial panel replacement is not recommended. To avoid mistakes, it is advisable to mark panels for removal clearly with spray paint that is easy to see on the pavement surface (Figure 14).

Table 2. Size recommendations for full-depth repairs in concrete overlays

Overlay Joint Spacing ≤6 ft	Overlay Joint Spacing >6 ft
• Mark the removal area at joint lines just outside of the deteriorated concrete or cracked slabs. • Use straight-line perimeters, following both transverse and longitudinal joint lines. • Entire panels containing distresses should be removed and replaced, as shown in Figure 12; partial panel replacement is not recommended (ACPA 2024c).	• Mark the removal area 0.5 to 1.0 ft outside of deteriorated area; extend the boundary to the nearest transverse joint if the boundary is within 6 ft of an existing joint. • Use straight-line perimeters, forming rectangles in line with the jointing pattern. • To eliminate perimeter joints, connect repair areas that are within the given distances of each other depending on overlay thickness according to Figure 13. Connecting repair areas in this manner balances the cost of establishing perimeter joints against patch pavement removal and material costs. The chart assumes a 12–15 ft joint spacing and 12 ft wide lanes.

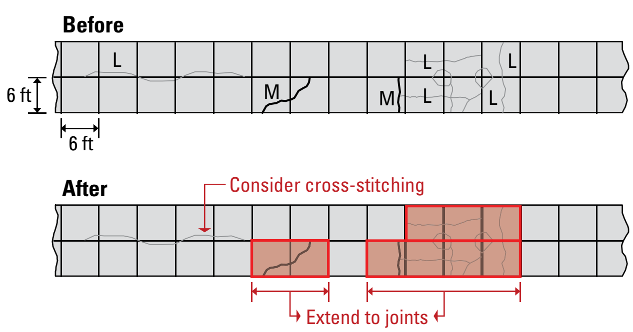

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Figure 12. Full-depth repair boundary recommendation for an overlay joint spacing of 6 ft or less

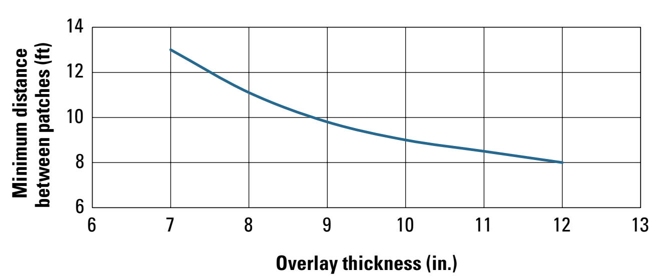

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Figure 13. Chart used to determine when to combine adjacent repair areas based on balancing the cost of additional materials with the cost of perimeter and interior repair joint preparation

Gerald Voigt, Square One Pavement Consulting LLC, used with permission

Figure 14. Clearly marked full-depth repair boundaries

The perimeter joints should be cut using diamond- or abrasive-bladed saws to the bottom of the concrete overlay. It is best to set the saw depth to the nominal thickness of the overlay to avoid damaging the underlying asphalt or concrete layer. A second sawcut about 1 ft inside the perimeter may be helpful to minimize damage to the adjacent panels while removing the material. Sawing to the full depth (to the bottom) of the concrete overlay is precise and allows for the controlled removal of concrete with less joint spalling, making this technique suitable for creating clean edges and straight lines for repair boundaries. If the repair is for access to a utility below the pavement, see the Utility Considerations chapter in this guide.

Removing concrete within the boundaries of the repair area involves one of three main methods (Figure 15):

1. **Break-up and cleanout.** Jackhammering or breaking is a mechanical method where pneumatic or hydraulic hammer tools are used to break up and remove the damaged concrete. This method is effective for preparing smaller areas for removal quickly but may result in damage to the underlying layer(s) if not properly controlled. For the quantity of removals typically involved in overlay repair, smaller handheld hammers (30 lb max) or skid steer-mounted hammers are typical. If larger equipment is warranted for higher productivity or quantities, care must be used to control the breaking energy to prevent damaging the underlying layer(s). A buffer cut is useful to dampen the breaking energy, preventing damage to surrounding panels (Figure 16). Additionally, the operator should start breaking up material near the center of the removal area and work toward the perimeters, stopping at buffer cuts. A backhoe or skid steer loader is used to scoop broken pieces out of the removal area and place them in dump trucks for transport.

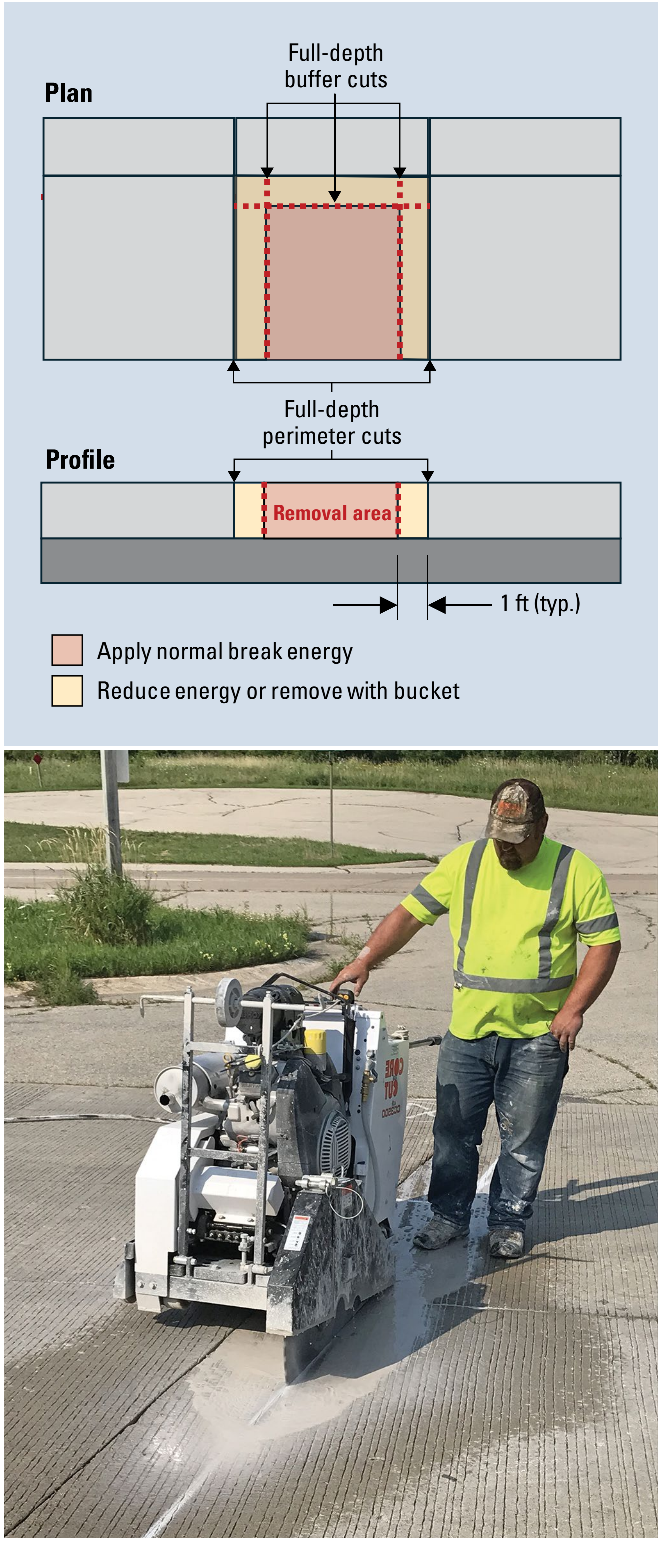
2. **Lift-out.** Lift-out involves removing larger segments of the overlay using a forklift or special slab-lifting tool (slab crab) mounted to an excavator or backhoe.

   This method may not work efficiently for COA–B or COC–B overlays if the layers remain well adhered to the underlying pavement. To get the lift-out process started, one or more overlay panels may need to be broken up and removed first so the lifting equipment can properly approach the remaining segments. As the segments are lifted out of place, operators can stack them on a truck for transport.

3. **Milling.** Milling machines can also be used for removal of repair areas, but this equipment would likely only be cost-effective for projects with very large removal quantities and longer removal segments. For more information on milling concrete, see the End-of-Life Strategies chapter in this guide.

Gerald Voigt, Square One Pavement Consulting LLC, used with permission (top) and Steve Waalkes, Michigan Concrete Association, used with permission (center and bottom)

Figure 15. Removal methods for full-depth repair: (a) break-up and clean out, (b) lift-out, and (c) milling



CP Tech Center (top) and Gerald Voigt, Square One Pavement Consulting LLC, used with permission (bottom)

Figure 16. Buffer cut: (a) diagram showing full-depth buffer cuts and (b) sawing buffer cut 1 ft from transverse joint

Each removal method has its advantages in repairing concrete overlays. The method of choice is at the discretion of the entity or contractor based on factors such as the extent of damage, the bond or adherence between layers, the available equipment, and productivity needs.

Removal Depth

In conventional concrete pavements, full-depth repairs involve removing the deteriorated concrete down to the underlying base level and replacing the area with new concrete, matching the thickness of the surrounding concrete. With concrete overlays, the required removal depth may extend into, and even below, the underlying pavement. This develops a deeper cavity and presents the option to either build the repair back in layers or to completely fill the excavation with concrete. The latter approach is the preferred option in most cases based on construction time/cost and repair performance because it is difficult to adequately compact successive layers in the repair area.

Priority must be given to extending the removal depth as far as needed to remove weakened material that caused the overlay to fail in that location. Cores can be used to identify weakened materials, such as an underlying asphalt interlayer or old pavement layer that has experienced stripping. Cores can also indicate whether the overlay and underlying pavement are adhered or separated. Therefore, it is important to extract cores from areas that represent the general surface condition(s).

For removal depth, consider the following general guidelines (Hanson 2023):

1. If a few panels in a long length of overlay are distressed, it is likely that a removal depth equal to the nominal overlay thickness will be sufficient.
2. If an overlay panel is shattered, it is likely because the overlay has lost support from the underlying pavement, either because the overlay is less than the design thickness at that location or because the overlay has lost adherence to the old pavement. In either case, a deeper removal (thicker repair) is recommended. The removal of all or a portion of the underlying pavement is required in the repair area to create a thicker repair.
3. If panel movement is evident, a removal depth to the bottom of the existing pavement is recommended to reestablish sound support.

It is advisable to identify problems with thin overlay sections or loss of adherence or support during the evaluation stage and not once excavations have begun. If the contractor starts removing panels and finds that they are thin, the contractor must discuss the discovery with the engineer to determine whether to extend the repair depth and build the full-depth repairs thicker than anticipated.

Interface Considerations

It is important to consider the potential impact of the full-depth repair process at the interface between the overlay and the separation layer and/or the underlying pavement layer. For COC–U overlays, it may not be possible to salvage the separation layer because this layer may be damaged as part of the distress being repaired or during the removal process. For COA–U overlays, the surface of the underlying pavement may be similarly damaged during removal. In cases where there is adherence between layers, removing the concrete overlay will damage and dislodge portions of the separation layer or underlying pavement, leaving an uneven surface for the base of the repair. Table 3 provides considerations for preparing the bottom of the removal area.

When it becomes necessary to reestablish separation for a COC-U overlay, placing concrete on a nonwoven geotextile fabric or applying a wax-based curing compound over the bottom of the repair is more effective than trying to build back the same layers, even if geotextile fabric was not the original type of separation medium used in the existing COC-U overlay. Using a geotextile or curing application is also advised when repairing a COA-U overlay, even if a separation medium is not required. Doing so avoids the difficulty and time required to reestablish asphalt layers in the confined space.

Perimeter Joints

Load transfer at the smooth-faced perimeter joints of full-depth concrete overlay repairs is critical to maintain structural continuity, distribute load stresses, limit faulting, and ensure the long-term performance and durability of the repair. Consideration of the size and spacing of load transfer mechanisms, such as dowel bars or tie bars, is essential to achieve these objectives and optimize the performance of the repaired overlay. Size and spacing recommendations for dowel bars and tie bars in full-depth overlay repairs are provided in Tables 4 and 5, respectively.

Table 3. Preparing the bottom of the removal area depending on the removal depth and type of overlay

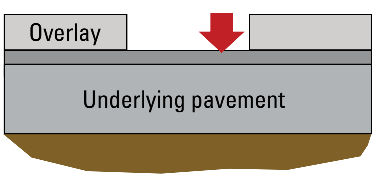
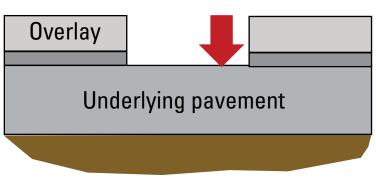
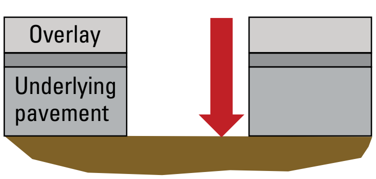
Removal Depth	Preparing Bottom of Removal Area
	**When Removing the Overlay Layer Only** • Clean out loose material. • COC–U and COA–U: Place interlayer fabric at the bottom of the repair. • COA–B: Place the repair directly on the bottom of the removal area.
	**When Removing the Overlay and Interlayer or a Portion of the Underlying Pavement** • Clean out loose material. • COC–U and COA–U: Place interlayer fabric or two coats of wax-based curing compound at the bottom of the repair. • COA–B: Place the repair directly on the bottom of the removal area. • COC–B: Abrasive-blast the old concrete surface prior to placing the repair.
	**When Removing the Entire Pavement to the Underlying Base or Subgrade** • Clean out loose material. • COC–U, COC–B, COA–U, and COA–B: Place the repair directly on the bottom of the removal area.

Table 4. Dowel bar size and spacing guidelines for the transverse perimeter joints of full-depth overlay repairs

Overlay			Dowel Bars			
Type(s)	Thickness (in.)	Joint Spacing (ft)	Diameter (in.)	Length (in.)	Spacing (in.)	Location
COC–U COA–U COA–B	≤6	≤6	None			
	≤6	≥10	0.75	14	12 in. on center/5 per wheel path	Mid-depth of overlay
	6.5–8.0		1.00			
	8.5–9.5		1.25			
	≥10		1.50			
COC–B	≤6.5	Any	None	14	12 in. on center/5 per wheel path	Mid-depth of monolithic section
	7		1.00			
	7.5–9.5		1.25			
	≥10		1.50			

Adapted from Smith et al. 2022

Table 5. Tie bar size and spacing guidelines for the longitudinal perimeter joints of full-depth overlay repairs

Overlay		Tie Bars				
Overlay Thickness (in.)	Joint Spacing (ft)	Bar Size	Bars/Panel[1]	Center-to-Center Spacing (in.)	Distance from Repair Corner to First Bar (in.)	Depth of Tie Bar
<5	≤9	Not Recommended				
5–6	≤9	#3	3	30	30	Varies based on overlay type[2]
	10	#4	3	30	30	
	12		3	36	36	
	15		4	36	36	
7–8	10	#4	3	30	30	
	12		3	36	36	
	15		4	36	36	
≥9	10	#5	3	30	30	
	12		3	36	36	
	15		4	36	36	

1. The number of tie bars for a longitudinal repair joint only applies once the total repair length exceeds 12 ft or two panels.

2. Tie bars should be placed within the middle third of the overlay depth for COC–U, COA–U and COA–B overlays. Tie bars should be positioned in the middle third of the monolithic section for COC–B overlays.

For overlays less than 5 in., it is not usually feasible from a constructability standpoint to place dowel bars or tie bars in the overlay because of a lack of cover and support, which is reflected in Tables 4 and 5. Fortunately, this does not present a major long-term performance concern because thin overlays likely do not require dowel bars or tie bars in their original design.

When bars are used, proper anchoring is key to the long-term performance of the repair. The correct method starts by carefully marking the locations for dowel bar placement on the existing pavement (following the guidelines in Tables 4 and 5). Use a hydraulic gang drill with a bit sized to create an annular gap slightly larger than the bar diameter or size to establish parallel holes in the existing pavement at the marked locations. Before anchoring the bars, ensure that the holes are clean and free of debris by flushing them with oil-free compressed air. Finally, insert anchoring epoxy or grout into the back of the holes before inserting the bars. Once set, dowel bars or tie bars that are properly encased with anchoring material will provide effective load transfer and structural continuity between the old and new concrete sections.

Placing and Finishing the Repair

The method of placing concrete in the removal area, such as by chute, pump, or wheelbarrow, depends on the volume of material and the equipment available. The most important requirement is to distribute the concrete evenly within the repair area to achieve the desired thickness, to achieve evenness with surrounding overlay surfaces, and to avoid segregation. Consolidating the concrete using vibrators to remove air pockets is essential.

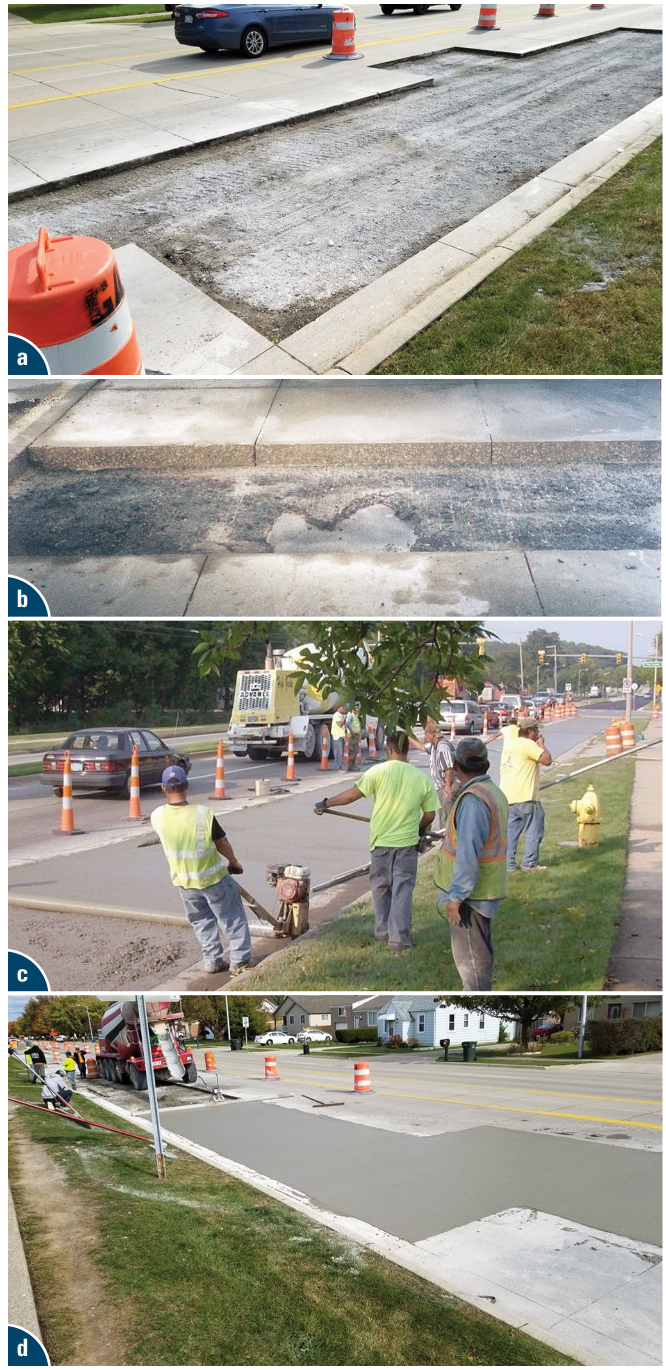
Screeding the surface of the fresh concrete should always be done in the direction of traffic to achieve the desired elevation, slope, and smoothness at transitions between the new repair area and the remaining segments of the old overlay. Screeding can be done using a straightedge or a specialized tool. Figure 17 illustrates the steps involved in placing and finishing a full-depth overlay repair.

The last steps involve texturing the surface, if necessary, to match the surrounding pavement and applying curing compound to the exposed surfaces of the repair to promote proper hydration and strength development in the concrete. Although recommended, it is not required to fill the repair perimeter or interior repair joints with a joint sealant (see the Joint Resealing section in this chapter).

Partial-Depth Repair

Partial-depth repair of concrete pavements is a common maintenance technique used to address localized damage or deterioration in the top portion of a concrete pavement or overlay panel, typically extending to a depth of about one-third to one-half of the panel thickness (Smith et al. 2022). This method involves removing the deteriorated concrete to the depth of solid material, preparing the repair area, and then filling the void with a suitable patch material. The goal is to restore panel integrity and pavement smoothness while minimizing disruption to traffic and extending the pavement's service life.

Partial-depth repair for spalled joints/cracks and other isolated near-surface overlay distresses is only likely to be a feasible option for thicker concrete overlays with a longer joint spacing. Full-depth repairs are almost always more cost-effective for isolated surface distresses in overlays 6 in. thick or less or with a joint spacing of 6 ft or less. However, project experience in Iowa and Minnesota has demonstrated that the partial-depth repair technique can be applied effectively on overlays as thin as 5 to 6 in. (Hanson 2023).



Steve Waalkes, Michigan Concrete Association, used with permission

Figure 17. Placing and finishing a full-depth overlay repair: (a) COA–B removal area following joint lines, (b) COC–U removal area leaving the interlayer in place (note where a portion of the interlayer dislodged with the concrete), (c) screeding concrete in the repair area, and (d) concrete after screeding

When evaluating repair options for a thin overlay restoration, it is advisable to begin with the assumption that a full-depth panel replacement is likely the most cost-effective solution and then determine whether a partial-depth repair may be optimal. When joint/crack spalling is especially extensive in a thin overlay, for example, when joint deterioration arises due to substandard, nondurable concrete, the analysis may lead to either more extensive lengths of full-depth repair or overlay replacement. In thin pavements, full-depth repairs, even over extensive lengths of a project, can likely be executed just as quickly or more quickly at a similar expense (with higher material costs but lower labor costs) compared to partial-depth repairs.

For thicker overlays (7 in. or more), regardless of type, partial-depth repairs can be a cost-effective solution, especially for smaller or shallower areas of distress.

The partial-depth repair process begins with sawcutting or milling the damaged area to create a clean and straight-edged repair boundary. Any loose or unsound concrete is removed to expose a sound substrate. The repair area is then thoroughly cleaned to remove dust, debris, and contaminants that could affect adhesion. Depending on the severity of the damage and the specific requirements of the repair, various materials, such as rapid-setting concrete, epoxy mortar, or polymer-modified concrete, may be used to fill the void and restore the surface to its original elevation. Proper consolidation and finishing techniques are important to ensure a durable and smooth repair that blends seamlessly with the surrounding pavement, minimizing the potential for future deterioration.

Figure 18 illustrates the milling process and the completed pavement on a partial-depth repair project of a COA–U overlay in Michigan. For more details on the best practices for partial-depth repair, see Chapter 5 of the *Concrete Pavement Preservation Guide*, Third Edition (Smith et al. 2022) and ACPA (2008).

Dowel Bar Retrofit

Dowel bar retrofit is an option for overlays greater than 6 in. thick, especially those with a longer transverse joint spacing (10 ft or more). The repair involves adding dowel bars to existing concrete overlays as a strengthening and preventative measure at transverse joints or cracks that are rated in a low-severity condition.

Steve Waalkes, Michigan Concrete Association, used with permission

Figure 18. COA–U partial-depth repair project in Michigan: (a) milling to remove deteriorated material and expose sound concrete and (b) after concrete material placement

The process involves cutting slots into the overlay in the same way that slots are cut for conventional pavements. The dowel bars are placed into the slots, which are backfilled, again in the same fashion as that used for conventional pavements, using the same typical details and nonshrink materials. Dowel bars must be placed parallel to the direction of traffic to help transfer loads between adjacent concrete panels, reduce joint faulting, and slow pavement distress and roughness development.

Table 6 provides recommended dowel dimensions for dowel bar retrofit in concrete overlays. Dowel bar retrofit has limited application in overlays 6 in. or less because of the slot depth required and the limited concrete cover available above and below the bar. However, 1 in. diameter dowel bars have been proven effective in overlay sections as thin as 6.5 in. A project in Olmsted County, Minnesota, used 26,882 1 in. diameter dowel bars in a 6.5 in. thick COA–U overlay (Figure 19). Dowel bars with a 1 in. diameter are well suited for thinner concrete pavement sections and provide effective load transfer at the pavement joint (IGGA 2017, Dispenza 2017).

Table 6. Recommended dowel dimensions for dowel bar retrofit

Overlay Thickness (in.)	Dowel Diameter (in.)	Minimum Length (in.)	Spacing (in.)
≤6 in	Not Recommended		
≥6.5 to <8	1.0	14	12
≥8 to <10	1.25		
≥10	1.5		

Adapted from Smith et al. 2022

Highway Materials, LLC, used with permission

Figure 19. Dowel bar retrofit in a COA–U overlay in Olmsted County, Minnesota: (a) 1 in. bars, (b) bars inserted into parallel slots, and (c) backfilling

Cross-Stitching

Cross-stitching is a useful repair/preservation technique for all concrete overlay types, and experience has found this method to be effective on overlays as thin as 6 in. thick (Blanchette et al. 2020). The repair technique stabilizes and prevents the widening of existing longitudinally oriented cracks in overlay panels.

Cross-stitching involves drilling holes at an angle through a crack and inserting deformed steel tie bars into the holes to provide mechanical interlock across the plane of the crack. The tie bars are anchored into the concrete from alternating sides of the crack to distribute loads and restrain movement.

The process begins with identifying and marking the location of the crack on the concrete pavement. Then, holes are drilled perpendicular to the crack at regular intervals along its length. The diameter and depth of the holes are based on the size and spacing of the tie bars to be installed (see Table 7 and Figure 20).

After the holes are drilled, the tie bars are inserted into the holes and anchored securely using epoxy adhesive or grout. Steel tie bars are then placed across the crack and connected to the dowel bars, forming a continuous reinforcement system that helps distribute loads and prevent further cracking or movement. Figure 21 illustrates the steps involved in marking, drilling, and inserting tie bars for cross-stitching longitudinal overlay cracks.

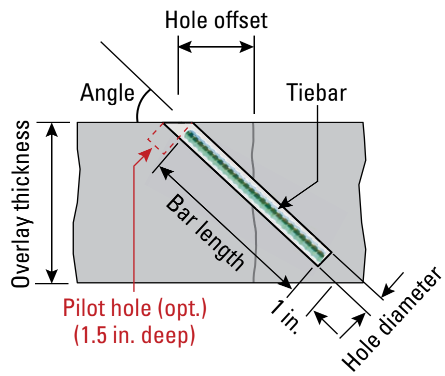
Cross-stitching is effective in improving the structural integrity and longevity of concrete overlay panels, particularly in areas prone to heavy traffic or dynamic loading conditions. More details on this method are found in Chapter 8 of the *Concrete Pavement Preservation Guide*, Third Edition (Smith et al. 2022), and ACPA (2008).

Table 7. Dimensions for cross-stitching overlay panels

	Overlay Thickness (in.)[1]						
	6	7	8	9	10	11	12
	Tie Bar Size						
	#4	#4	#6	#6	#6	#6	#6
Angle	**Tie Bar Length (in.)**						
35°	7.00	8.00	9.50	11.00	12.50	14.50	16.00
40°	—	—	—	—	—	12.50	14.00
45°	—	—	—	—	—	—	12.00
Angle	**Hole Offset from Crack/Joint (in.)**						
35°	4.25[2]	5.00	5.75	6.50	7.25	7.75	8.50
40°	—	—	—	—	—	6.50	7.25
45°	—	—	—	—	—	—	6.00
	Max. Hole Diameter (in.)						
	0.875	0.875	1.125	1.125	1.125	1.125	1.125

1. *For COC–B overlays, include the overlay plus the underlying pavement.*
2. *Drill optional pilot hole to avoid chipping the surface toward the crack.*

Source: ACPA 2024f



After ACPA 2024f

Figure 20. Dimensions for cross-stitching overlay panels

Gerald Voigt, Square One Pavement Consulting LLC, used with permission

Figure 21. Key steps in cross-stitching: (a) marking hole locations on alternating sides of the crack, (b) marking hole offsets from the crack, (c) drilling holes with a cross-stitching rig, and (d) inserting and grouting bars into the holes after drilling

Diamond Grinding

Diamond grinding is useful for all concrete overlay types to restore functional capacity to the pavement. It removes surface irregularities created from the repeated action of traffic loading over time. The process typically shaves roughly ¼ in. from the pavement surface to improve smoothness. The result is a consistently textured pavement surface that provides a safe, smooth, and quiet driving experience.

The operational aspects of diamond grinding a concrete overlay are the same as those for grinding a conventional concrete pavement. For a detailed discussion of this method, see Chapter 9 of the *Concrete Pavement Preservation Guide*, Third Edition (Smith et al. 2022), and ACPA (2008).

Some important operational considerations for grinding concrete overlays include the following:

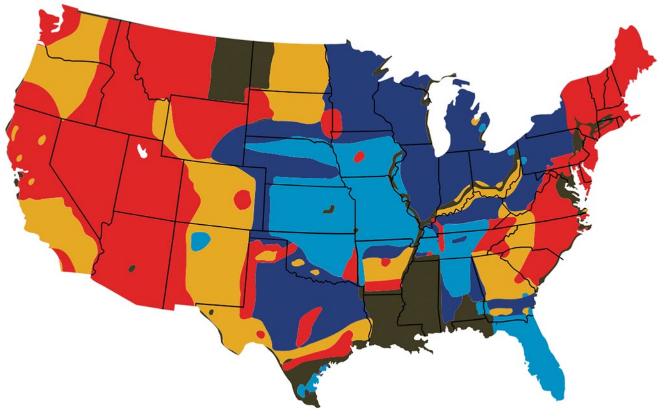
1. **Equipment size.** There are several sizes of diamond grinding equipment available in the industry, including large profile grinders, intermediate-size profile grinders, and bump cutters. Large profile grinders have wider grinding widths (up to 4 ft) and more horsepower than other types of grinders to provide higher productivity. These types of grinders are well suited for full surface grinding of overlays on Interstates, state roads, and other major arteries. Production rates vary, but they can be up to 40 ft per minute. Intermediate-size profile grinders are well suited for urban overlay projects where larger grinding machines may present maneuverability challenges (Figure 22). Production grinding rates for intermediate-size machines range from about 8 to 20 ft per minute depending on the conditions.
2. **Equipment weight.** There is no limitation on using larger diamond grinding machines on thinner (≤6 in.) concrete overlays from a structural standpoint. Commonly available machines have been used successfully on 6 and 6.5 in. COA–B overlay grinds in Minnesota (Blanchette et al. 2020).
3. **Sequencing.** Diamond grinding should follow all repairs aimed at addressing an overlay's stability and structural integrity (Figure 10). The effectiveness of diamond grinding depends to a large degree on the stability of the pavement being addressed; if the cause of faulting is not addressed, faulting will return (Blanchette et al. 2020). If the field performance review indicates that overlay panels are rocking (deflecting excessively) or otherwise exhibiting movement, the net improvement may not be significant after the grinding operation. Also, unless rocking slabs are stabilized or replaced, they will continue to move/rock after the procedure.
4. **Urban projects.** Diamond grinding of municipal concrete overlays requires additional considerations for drainage, driveways, curb and gutter, utilities, and other conditions unique to urban pavements. Water valves, manholes, and drainage inlet castings may be high-set or low-set in the overlay, and it could cost a considerable amount to reset them. If they are not reset, however, they may impact the resulting ride comfort. Similarly, curbs and cross-streets must also be accommodated, in some cases limiting the degree of smoothness improvement that can be achieved.

Proper blade and spacer selection for the grinding head is an important consideration in the successful grinding of overlays because both factors impact grinding quality, production rates, and overall economics. One of the key factors in selecting the appropriate blades for the project conditions is the type and hardness of the aggregate in the concrete. A Mohs hardness kit is an inexpensive way to characterize aggregate hardness. With this kit, one can simply scratch the aggregate using different tool picks to estimate hardness.

Figure 23 provides a map indicating the typical Mohs hardness for different regions of the country. Although these types of maps are convenient, they are not specific to any project, and one should always investigate individual project conditions.

ACPA, used with permission

Figure 22. Intermediate-size diamond grinding machine



Mohs Hardness	Commonly Used Concrete Pavement Aggregate
8	**Very hard** - flint, chert
7	**Hard** - quartz, hard gravels
6	**Medium hard** - gravels, granites
5	**Medium soft** - soft granite, dolomite
4, 3	**Soft, abrasive** - limestone

Adapted from ©1994 Industrial Diamond Associations of America, Inc.

Figure 23. Industrial Diamond Association of America color-coded map of typical Mohs hardness for aggregates in different regions of the country

For larger overlay restoration projects, it is advisable to perform a more involved investigation. A core or concrete overlay fragment can be sent to a laboratory or blade manufacturer for analysis to characterize the nature of the concrete's coarse and fine aggregates. The contractor or blade supplier will use this sample to select blades and design the most effective grinding head for the project.

Any concrete overlay, like any conventional pavement, can receive multiple diamond grinding treatments over its lifetime. While theoretically the structural capacity of the in-place pavement may be reduced slightly with each intervention, nearly all concrete pavements and overlays are built with the following excess capacity in thickness and strength to accommodate these later-in-life procedures:

- **Sacrificial thickness.** The as-built thickness of pavements, including overlays, generally exceeds the design plan requirement by 0.1 to 0.25 in. because paving contractors set elevation controls to avoid thickness penalties. Therefore, it is a reasonable assumption that the typical thickness overbuild can accommodate at least one grinding cycle without affecting the design structural capacity. (Note that in some cases, the owner/agency may include 0.25 to 0.5 in. of extra thickness in the original overlay as sacrificial thickness for later diamond grinding.)
- **Long-term strength gain.** Continued concrete strength development from long-term cement hydration (from 28 days to the time of intervention years into the future) provides another significant factor of safety to accommodate future reductions in thickness from grinding operations (Rao et al. 1999). Taylor et al. (2019) indicate that 90-day strengths are as much as 10% to 15% higher than the 28-day strengths used in design analyses. For example, a typical 6 in. thick concrete overlay with a 650 lb/in.² design flexural strength at 28 days will reach a flexural strength of at least 715 lb/in.² later in its life. Accounting for the additional 65 lb/in.² of flexural strength in a structural equivalency analysis indicates that a 5.6 in. thick overlay with a 715 lb/in.² flexural strength accommodates the same level of traffic as a 6.0 in. thick concrete overlay with a 650 lb/in.² flexural strength. Therefore, an additional 0.4 in. (or two grinding cycles) is available before the design structural capacity is affected.

Rao et al. (1999) demonstrated that the fatigue life of a pavement panel is extremely sensitive to its thickness. The effect was modeled, and it was determined that a 0.2 in. reduction in slab thickness (about the amount removed when diamond grinding) results in about a 30% reduction in fatigue life if both cases (i.e., the pavement before and after grinding) are evaluated at the same concrete strength. However, the impact of even modest increases in long-term concrete strength will more than offset any reduction in fatigue life from the incremental reduction of slab thickness (Rao et al. 1999).

Figure 24 shows a typical fatigue relationship for thin COA–U or COC–U overlays. The figure, developed using *PavementDesigner.org* (ACPA 2024d), indicates a strength gain similar to the example discussed above. A 10% increase in concrete strength between 28 days and the time of the grinding allows about 0.3 in. of thickness removal without compromising the design life predicted based on the design strength. If the long-term strength is instead 15% higher, then 0.36 in. may be removed by diamond griding without impacting the structural strength of the pavement. Even as truck traffic increases and other performance factors come into play (such as faulting), a 0.18 in. surplus remains. This analysis suggests that most concrete overlays may be diamond ground at least once and likely twice without compromising the overlay's fatigue life. This relationship assumes that areas of compromised support are properly restored prior to the diamond grinding applications.

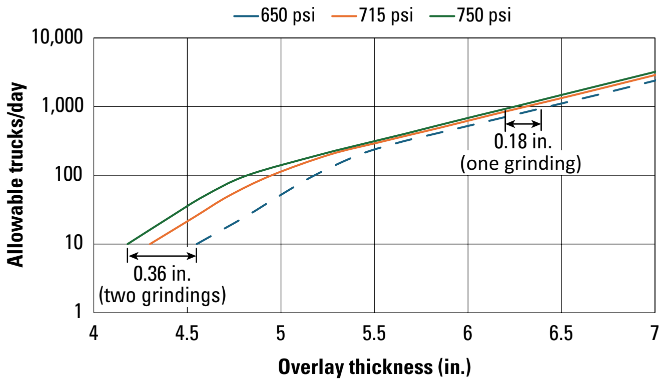


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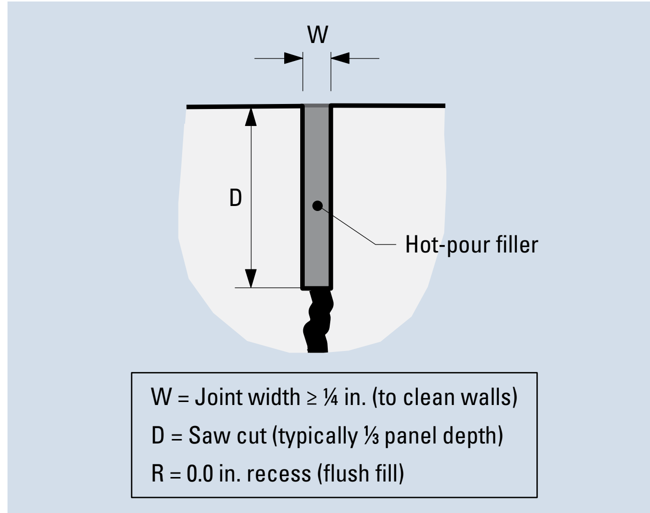
Figure 24. Effects of thickness and concrete strength on the fatigue life of a typical COA–U or COC–U overlay

Joint Resealing

When restoring a concrete overlay, it is advisable to follow the same replacement/reseal strategy as that used for conventional pavements. If the overlay was designed and has been performing adequately without filled or sealed joints, then a secondary application is considered unnecessary. However, if evidence in the performance review suggests that compression issues are at play, such as joint migration, spalling, or tenting/buckling, then joint filling as a preservation procedure is advised.

Because concrete overlays are still a relatively new pavement type, guidance on filling or sealing joints has been evolving with experience over the years. Many overlays have been constructed with unsealed joints in situations where best practices today would call for filled joints. Even if an existing project with unsealed joints has performed well to date, an agency may consider a precautionary joint filling or sealing application, if its maintenance budget allows it, to slow or prevent future deterioration.

If an existing overlay included filled or sealed joints as part of its initial construction, then replacing the material at the time of restoration is advisable. ACPA (2018) indicates that it is likely to be detrimental to remove joint sealant materials from a jointed pavement that was originally designed with sealed/filled joints. A widened joint reservoir intended for a sealant will allow for more water and incompressible penetration if left completely open. Previously sealed/filled joints should be resealed/refilled as necessary during concrete overlay preservation activities. In wet or freezing climates, joint filling/sealing is also recommended for transverse and longitudinal joints in COA–B overlays (ACPA 2018). Figure 25. shows suggested dimensions for flush-filled overlay joints (ACPA 2018).



ACPA 2018, used with permission (top) and Gerald Voigt, Square One Pavement Consulting LLC, used with permission (bottom)

Figure 25. Dimensions of filled overlay joints and performance after 14 years of service

Another factor to consider is the roadway design speed. According to ACPA (2018), concrete overlays on roadways serving low-speed traffic (45 mph or less) should be designed with filled joints. This includes overlays on applications such as urban arterials, collectors, residential streets, and rural two-lane roadways, as well as any sections with curb and gutter. Sealing joints on sections with curb and gutter is advised because curbs can readily trap incompressibles and slower traffic is not as capable as faster traffic of generating sufficient air movement to blow the incompressibles off the pavement surface.

It is recommended to fill the reservoir flush with the overlay surface when applying a hot-poured sealant material. Long-term observation has found that filled joints perform better when flush filled. Flush filling allows tire impacts from traffic to keep the material pliable, and studies indicate that flush filling also eliminates or reduces wheel slap (ACPA 2004).

For more detailed information on the best practices for joint sealing/filing, see *Concrete Pavement Joint Sealing/Filling* (ACPA 2018).

End-of-Life Strategies

Once a concrete overlay has reached the end of its useful life, the available strategies include (1) placing another overlay on top of the existing overlay (with or without some thickness removal), (2) removing the entire existing overlay to place an inlay, or (3) removing the entire pavement down to the original base or subgrade layers and reconstructing the section.

Key Considerations

The extent of deterioration evident in the overlay dictates how invasive the replacement strategy must be. Other principal factors affecting the optimal strategy include the constraints and costs associated with raising the pavement grade. The following grade-related considerations must be assessed as part of the feasibility decision process:

1. **Structural capacity.** Adding another concrete overlay on top of all or part of the existing overlay entails relying on the underlying pavement structure for further decades of service. The structural capacity of the existing concrete overlay, including the underlying pavement, subbase, and base layers, must be evaluated to ensure that the structure can function as a stable platform for the new overlay without experiencing excessive deformation or failure. A regime of coring through the pavement layers and falling weight deflectometer (FWD) testing is recommended when making this assessment.
2. **Slope and drainage.** Raising the pavement grade with another overlay or partial inlay may require other grade-related work, including raising shoulders, fore- and back-slopes, and appurtenances, and building transitions to lower the overlay elevation at bridges and intersecting crossroads or ramps. Raising the grade also affects surface drainage patterns, which may require adjusting curb and gutter and drainage inlets. It is essential to evaluate the costs associated with these additional requirements. In some cases, a partial removal of the existing concrete overlay can help reduce the increase in elevation to just a few inches, allowing the option to be feasible.
3. **Utility adjustments.** Raising the pavement grade may require adjustments to existing utilities, such as manholes and valve boxes, to accommodate the new elevation. Coordination with utility owners and proper adjustment procedures are essential to avoid conflicts and ensure that the utility infrastructure continues functioning. Many details for raising in-pavement castings are found in the *Guide to Concrete Overlays*, Fourth Edition (Fick et al. 2021).
4. **Accessibility.** Changes in pavement grade can affect accessibility for pedestrians, cyclists, and individuals with disabilities. Compliance with accessibility standards, such as the Americans with Disabilities Act (ADA), should be considered when raising the overlay grade to ensure that sidewalks, curb ramps, and other facilities remain accessible to all users.
5. **Transition zones.** Smooth transitions between the existing pavement grade and the new overlay grade are essential for safety and ride quality. Proper design of transition zones, such as tapering or feathering of the overlay edges, can minimize abrupt changes in elevation and reduce the potential for vehicle discomfort and tire damage. See the *Guide to Concrete Overlays*, Fourth Edition (Fick et al. 2021), for additional details.

By considering these key factors, engineers can make the best-informed decision on how much the pavement grade can be raised and which end-of-life strategy is the most suitable. Figure 26 provides a basic decision tree illustrating the decision process.

Advantages and Disadvantages of the Options

Building on top of an existing overlay requires that the new overlay be designed in the COC–U style because the new overlay is placed onto an existing concrete pavement layer. This solution also requires an increase in the grade or pavement elevation; the grade change is mitigated through milling (see Figure 27). It is recommended to leave 4 in. of the existing concrete overlay as a supporting layer beneath the new concrete overlay.

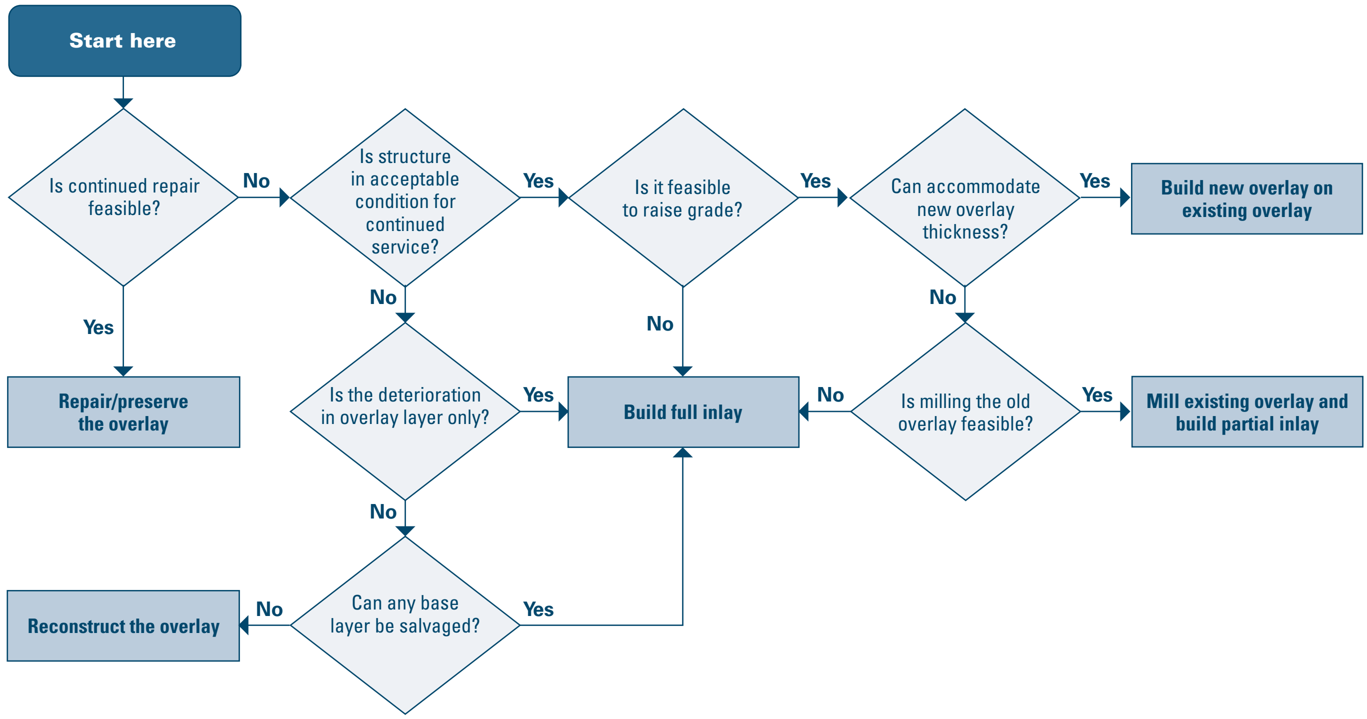


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Figure 26. Decision tree for determining the optimal end-of-life strategy for replacing a concrete overlay

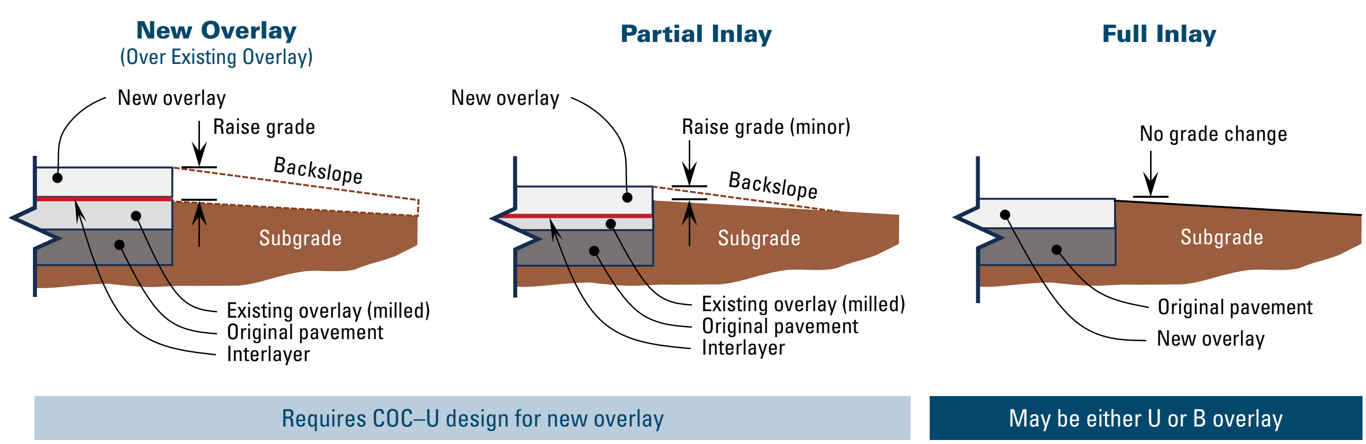

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Figure 27. Impact of the three end-of-life replacement strategies on grade and overlay style

Of the options for replacing an old concrete overlay, a full or partial inlay allows for the most optimization. An inlay can replace one lane or all lanes, which is not possible with a new overlay or full reconstruction. An inlay also allows for shoulders and curb and gutter to be salvaged. Where access for construction vehicles is limited, the option to salvage existing shoulders may be advantageous for the maintenance of traffic plan. Existing shoulders may serve as stable haul roads for batching operations during construction. A lane-specific inlay alternative provides the option to replace an overlay that has experienced inconsistent deterioration between lanes. However, the lane(s) in better condition must be deemed sound enough to remain in service (ACPA 2024b).

Generally, rebuilding an overlay as an inlaid section does not require significant elevation adjustment to adjacent highway appurtenances or slopes. The same is also usually true of the reconstruction option because of the flexibility derived from the opportunity to remove as much pavement as needed to rebuild within the same elevation profile. The implications of raising the pavement elevation can be significant. Many non-pavement improvements are necessary when a new concrete overlay is added over an existing one. Guardrails, median barriers, signs, cross-slopes, vegetation, right-of-way, and ramps all require adjustment when the roadway elevation changes appreciably (ACPA 2024b). One older report suggested that these additional items could cost up to a third of the per-mile cost of a structural overlay (Voigt and Knutson 1989). Because of these impacts, the opportunities to build a concrete overlay on the surface of an existing concrete overlay are limited. However, where feasible, such as in rural areas, the option to build on top of an existing overlay may be the least costly.

Full reconstruction is the most invasive and least desirable scenario in terms of cost- and resource-intensiveness, but this option may be necessary for overlays exhibiting material-related distress or extremely poor condition traced to the underlying pavement structure. Replacement of an existing overlaid pavement with a new pavement should follow the agency's full-depth pavement reconstruction process, but the layers that may be salvaged from the existing pavement structure should be considered. Agencies should avoid applying their "new pavement template" without first determining whether the existing base or subbase layers can serve well under a new surface pavement. Maintaining the use of existing pavement layers is cost-efficient asset management and represents a sustainable solution compared to replacing the overlaid pavement structure with virgin materials.

Removing the Overlay

In a concrete overlay replacement project, where new concrete is placed within the confines of an existing concrete overlay, several methods can be used to remove existing layer(s). These methods are milling, rubblizing, and lift-out. Rubblizing and milling may also be used as a combined process. Figure 28 provides images of the methods.

The method that presents the best choice will depend upon project conditions and the availability of contractors and/or equipment to perform the work.

Steve Waalkes, Michigan Concrete Association, used with permission (a); Resonant Machines, LLC, used with permission (b); ACPA, used with permission (c)

Figure 28. Overlay removal methods: (a) milling a 5 in. overlay in Michigan, (b) rubblizing with a resonant breaker, and (c) lift-out using a slab crab

Each removal method is described in detail below. Table 8 indicates which removal methods are likely to work for each type of overlay.

Milling

Milling equipment has improved over the past decade and is now an effective equipment option for removing most concrete and asphalt materials. With modern cutting technology and the ability to apply different milling drum speeds, milling machines provide contractors more flexibility now than in the past.

Equipment Considerations

Manufacturers produce milling machine models to suit different applications. The heaviest machines, with higher torque and horsepower, are generally the best options for large-scale concrete milling. When equipped with a cutter drum and teeth designed to remove concrete, large milling machines can achieve the production and quality necessary for removing concrete overlays. Machines with at least 800 to 1000 hp are best suited to the task of milling to remove old concrete overlays.

Machine size is not the only consideration. The difference between milling concrete and milling asphalt is that asphalt cutter-head teeth shear through asphalt materials while concrete cutter-head teeth shatter the concrete. This is primarily because asphalt is softer and typically has a higher air void volume and larger voids than concrete. Due to concrete's higher modulus of elasticity, greater forces work against a milling machine. A machine needs to work harder milling concrete than it does milling asphalt with the same cutter drum, which correspondingly leads to faster machine and tooth wear. Though milling remains a feasible solution for concrete, contractors must account for this difference in bidding and operations.

For efficient concrete removal, contractors also must employ the right cutting equipment on their machines. One of the more important technological advancements has been in the cutter (milling) drum. A cutter drum must generally fulfill three primary tasks:

- Cutting and breaking out material particles from the concrete
- Transporting loosened material particles to the area of the extractor
- Extracting the material particles onto the loading belt

Figure 29 shows three basic options for the cutter drum. (Note that different manufacturers may use different names for the options and offer slightly different tooth configurations.) Greater breakout force per tooth is achieved with a coarse-cutting drum, which is why it is the preferred choice for milling concrete.

The type of teeth outfitted on the drum is also an important consideration. Manufacturers now make a wide array of cutting teeth for different applications, including concrete-specific teeth. The carbide tip extends deeper into a tooth's core for milling concrete versus asphalt, as shown in Figure 30). This helps eliminate carbide shattering and extends the tool's life when milling harder material. A contractor may mill concrete using a standard asphalt cutter drum with teeth designed for asphalt, but the production rate and the life expectancy of the teeth will be greatly reduced.

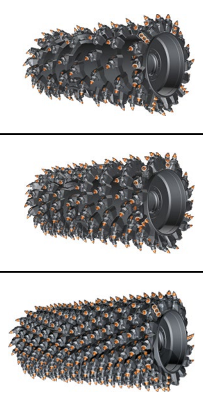
Production Rate and Control

There are no studies or rules of thumb based on aggregate hardness or concrete age/strength to precisely determine the production rates for milling concrete. Until a contractor starts milling, it is difficult to predetermine the optimal speed and depth for the concrete. Once milling has begun, however, it is relatively easy for the contractor to determine the optimal speed and depth to achieve good production without overstressing the machine.

The hardness of the concrete's coarse aggregate will influence the production rate. Aggregates that have a higher Mohs hardness, such as granite or quartz, will require more energy than softer aggregates, such as limestone or dolomite. Refer to Figure 23 for a simple list of aggregates and their relative hardness.

Aggregate hardness can greatly affect the optimal depth and speed of milling. Figure 31 provides the general relationship among the variables involved in production milling.

The contractor must balance these variables to achieve a removal production rate where the machine is the most productive while running at an optimum level. For thinner overlays, this may allow full removal in one pass, while thicker overlays may require multiple passes. A contractor may find that the machine mills nicely at 40 ft per minute, but when the rate is increased to 45 ft per minute, the machine may struggle, requiring a shallower milling depth. Contractors must balance the variables to find the optimal combination for the machine, concrete, and desired removal depth. The bottom line is that the concrete, machine size, forward speed, drum rotation speed, cutter drum line spacing, tooth size/type, and depth of cut all affect the production rate.



Coarse-Cutting Drum
Tooth spacing: 7.9 to 9.8 in. (200-250 mm)
Maximum mill depth: 14 in. (350 mm)
Uses: Concrete

Standard-Cutting Drum
Tooth spacing: 0.5 to 0.7 in. (12-18 mm)
Maximum mill depth: 14 in. (350 mm)
Uses: Deep cutting asphalt materials

Fine-Cutting Drum
Tooth spacing: 0.3 to 0.4 in. (8-10 mm)
Maximum mill depth: 3.1 in. (80 mm)
Uses: Shallow milling asphalt materials

Figure 29. Milling drum configurations

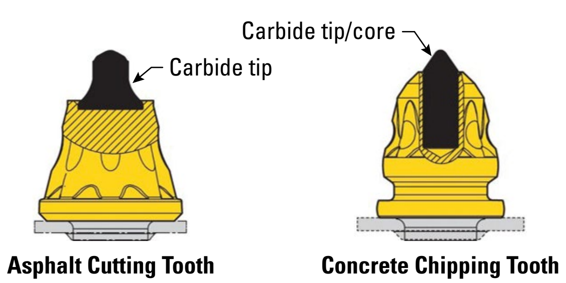


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Figure 30. Difference between carbide teeth for milling asphalt and concrete

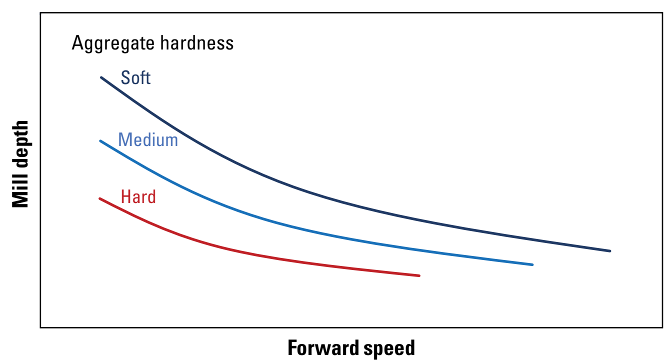

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Figure 31. Relationship among the variables involved in determining the production rate for milling concrete

Depth Control

Operators must be capable of controlling the depth of milling using one of several available methods. Depth control is a significant benefit to this removal option, and maintaining the desired depth of material removal allows for the integrity of the underlying layers to be maintained. Depth control options include the following:

1. **Automatic grade control (AGC).** AGC systems use sensors and/or Global Positioning System (GPS) technology to automatically adjust the milling depth based on a predetermined digital terrain model. This is a very precise and consistent depth control system.
2. **Sonic/Slope control.** These noncontact systems employ ultrasonic sensors mounted on the milling machine to measure the distance between the milling drum and the road surface. Operators set a target depth, and the system automatically adjusts the milling depth to maintain a consistent distance, thereby achieving the desired depth of cut.
3. **Depth control wheels.** Depth control wheels are attached to the milling machine and can be manually adjusted to set the desired milling depth. These wheels physically limit the downward movement of the milling drum, ensuring uniform depth across the milled surface.
4. **Stringline guidance.** Stringline guidance systems involve setting up a stringline along the desired milling path. Sensors mounted on the milling machine track the position of the stringline, allowing operators to maintain a consistent milling depth relative to the reference line.
5. **Combination systems.** Many modern milling machines offer combination depth control systems that integrate multiple technologies, such as AGC with sonic/slope control, to provide enhanced accuracy and flexibility in various milling conditions.

The means of depth control, based primarily on the available equipment and project size/productivity requirements, should always remain a contractor option. Removing a concrete overlay may require several milling passes, and the efficiency depends on the equipment, aggregate hardness, and desired properties of the chippings. Many machines can remove material down to 6 in. below the surface. Larger equipment can remove an entire 12 ft width in one pass. Most projects will achieve single-pass removal of about 3 to 4 in. (ACPA 2024b).

Chippings

Milled concrete can be recycled into granular aggregate for shoulders, gravel road surfaces, and fill material (ACPA 2009). The sizing of the recycled material cannot be controlled precisely. The concrete chipping size is highly dependent on the same variables that control production rate, concrete hardness, machine speed, drum speed, mill depth, and the cutter drum tool.

Once a contractor establishes the optimum settings for production, the chipping size will also be established and will stay relatively uniform (assuming the in situ concrete is uniform). In general, the slower the milling machine moves forward, the more times the cutter teeth will impact the concrete, creating smaller chippings. The faster the machine moves forward, the higher the probability of creating larger chippings and a coarser pattern in the surface from fewer impacts. Correspondingly, particle size consistency increases with faster and shallower removal. The type of cutting head also plays a large role in the resulting size of the material produced. Fine and standard cutting drums are more likely to produce finer chippings than a coarse cutting drum. Figure 32 shows fine chippings from a concrete overlay removal in Michigan that employed a standard drum.

Embedded Steel Considerations

Milling is an excellent method for removing concrete overlays since many are built without embedded steel reinforcement or dowel bars. The milling process induces little damage to the substructure even if the material has bonded to the underlying material. Milling can also be a viable option if reinforcing steel is present in the overlay, but embedded steel bars can break carbide milling teeth, so some precautions and an assessment are necessary.

Steve Waalkes, Michigan Concrete Association, used with permission

Figure 32. Fine chippings from concrete overlay removal

Continuous steel, wire mesh, or bars exceeding 24 in. in length are the primary concern. Long bars can become wrapped around the milling head, so reducing the bars to size is advisable. Sawing through the steel is the simplest option, which can be carried out by sawing, for example, along longitudinal joints to sever tie bars or at regular intervals to sever distributed bars. Another option to consider is limiting removal to a depth above any embedded steel. Milling between tied longitudinal joints may also aid in the feasibility of the technique, as some overlays only contain tie bars in the outermost longitudinal joints.

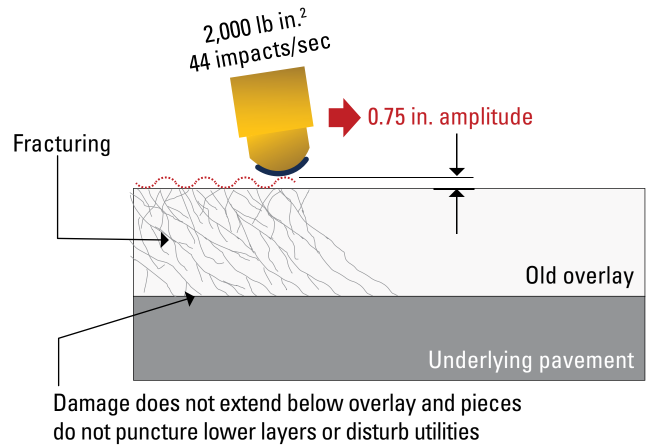
Contractor Options

The cost of milling concrete containing hard aggregate or a significant amount of embedded steel may be prohibitive. It is important to provide the contractor with options for removal and not lock specifications to one method. The onus is on the contractor to evaluate the feasibility of milling before selecting the use of milling as the means and method for removal.

Rubblizing

Rubblizing involves fracturing the existing concrete overlay into small, rubble-like pieces using specialized equipment. The equipment repeatedly strikes the concrete surface, causing fractures. Rubblization equipment falls into two categories: resonant frequency breakers (RFB) and multi-head breakers (MHB). RFBs are recommended where more precise control of breaking energy is required and for thinner concrete pavements (TRB 2006). Most concrete overlays fit into this category, so RFBs are preferred for breaking up existing concrete overlays for removal.

Unlike breakers that drop heavy hammers from a height of several feet at intervals of several feet, RFBs employ a comparably light 2,000 lb/in.2 pressure 44 times per second at a 0.75 in. amplitude (Figure 33). Rubblizing can preserve the integrity of the underlying pavement layers and is often employed when the underlying pavement layers are in good condition and can continue to serve as structural layers for the new concrete overlay (the full inlay strategy). Another advantage of the rubblizing method is that the size of the rubble can be controlled for ease of handling, transport, and crushing (Snyder et al. 2018).



Adapted from RMI 2024

Figure 33. Diagram illustrating the rubblization process

Rubblizing is a straightforward and cost-effective method. However, the contractor must exercise care in controlling the depth of the break-up energy to avoid damaging the underlying layers or surrounding pavement. To avoid damaging any pavement intended to be left in place, it is advisable for the contractor to make full-depth buffer sawcuts along the areas to remain, similarly to the process used when preparing an area of pavement for full-depth repairs. With buffer cuts in place, the contractor can employ the pavement breaker to reduce the concrete into smaller pieces without the concern of breaking the surrounding pavement inadvertently.

The contractor should start with the RFB along the center of the section being broken and work toward the buffer cuts to the outside edge of the overlay. An RFB head is 8 in. wide, requiring up to 20 passes to fully break a 12 ft wide lane. RFB equipment weighs as much as 70,000 lb, with wheel loads of up to 20,000 lb, so the existing overlay and shoulders must be structurally adequate to safely support the equipment (TRB 2006).

RFBs offer the best option for energy control. Table 8 describes several methods a contractor can employ to control the depth of damage when using an RFB to break an existing concrete overlay. While other types of breaking equipment may be used, including guillotines or drop hammers, the force involved with these machines is not as easily controlled. Such equipment more easily damages the underlying layers or surrounding pavement. Extra attention is needed if drop hammer equipment is allowed or employed when the underlying pavement layers must be preserved.

Table 8. Methods to control collateral damage of rubblizing for concrete overlay removal using RFBs

Method	Description
Adjust Excitation Frequency	Resonant breakers operate at specific frequencies to induce resonant vibrations in the pavement, causing it to fracture. By adjusting the excitation frequency on the breaker, contractors can control the depth of damage. Lower frequencies typically result in deeper fractures in the pavement, while higher frequencies produce shallower fractures.
Adjust Amplitude	The amplitude of the resonant breaker's vibrations influences the intensity of the fracturing action. Contractors can adjust the amplitude settings to control the depth of damage. Lower amplitudes produce less forceful vibrations, resulting in shallower fractures, while higher amplitudes increase the depth of damage.
Adjust Speed and Number of Passes	The forward speed of the breaking equipment and the spacing of breaker passes can be used to control the break size. It is up to the contractor to develop a breaking pattern that produces desirable results.
Monitor Pavement Conditions	Contractors should closely monitor the condition of the pavement during the rubblizing process to ensure that the desired depth of damage is achieved without excessive fracturing. Visual inspections and testing methods such as ground-penetrating radar can help contractors assess the depth of damage and adjust the breaker settings accordingly.
Calibrate Equipment	Proper calibration of the resonant breaker is essential to ensure consistent performance and accurate control of the depth of damage. Contractors should follow manufacturer guidelines for equipment calibration and maintenance to optimize the rubblizing process.
Create Pilot Holes or Test Sections	Before conducting full-scale rubblization, contractors can create pilot holes or test sections to assess the effectiveness of the resonant breaker and fine-tune the settings that control the depth of damage. This allows contractors to make adjustments before proceeding with the entire pavement area.

Operators should receive thorough training on the use of resonant breakers and proper techniques for controlling the depth of damage. Experienced operators can effectively adjust breaker settings based on pavement conditions and project requirements to achieve optimal results. Implementing quality control measures throughout the rubblizing process can also help ensure that the desired depth of damage is consistently achieved. Measures may include regular inspections, testing, and documentation of pavement conditions and breaker settings.

When using RFBs, the desired size of broken pieces is about 6 in. or less (Snyder et al. 2018). After the material is rubblized, contractors use front-end loaders to pick up the broken concrete and load it into dump trucks for disposal or processing into recycled concrete aggregate. If steel was present in the old concrete overlay, then it must be separated (as discussed further below).

One drawback of the rubblizing method for overlay removal is that the process can generate significant noise, vibration, dust, and debris, requiring appropriate safety measures and environmental controls. Rubblizing may therefore be better suited to areas outside of urban environments.

Combining Rubblizing and Milling

Resonant breaking followed by use of a milling machine may be a particularly useful combination, especially when removing thicker overlays. The combined process allows for fast removal of the rubble and control of the material size. Rubblized concrete processed by a milling machine may be used as gravel-size fill material directly from the grade without further post-removal processing.

Combining the two techniques starts with the same considerations for any project in which rubblization is used to break down an old concrete overlay. After resonant breaking, the material remains in place on grade, interlocked and stable. The contractor can then use a milling machine to break down the rubble into smaller pieces and conveyor it directly into dump trucks for removal. Breaking apart interlocked rubble is likely to be faster and easier than attempting to mill concrete alone, but it does require a two-pass operation and additional equipment (or a subcontractor to perform this operation). For thinner existing overlays and overlays with softer aggregates, milling alone may prove to be more cost-effective, but because of the potential savings, the combination of rubblizing and milling warrants consideration for any sizeable project.

Another area of savings from the combined method is in the removal and hauling of the materials. Conveying material directly into haul trucks will result in considerable time savings compared to traditional removal methods that use front-end loaders, and fewer haul trucks will be needed because the material will compact better in the dump trucks after secondary processing by the milling machine. Both factors can contribute to reduced energy consumption, providing sustainability benefits to the project.

Lift-Out

The lift-out method for overlay removal employs the same or similar methods used when lifting out panels or larger segments of concrete for full-depth repairs, except it operates in a higher production mode. The intent of the method is to perform removal with minimal risk of damage to the underlying pavement layer. The productivity of this method stems from removing the overlay in large, manageable pieces rather than reducing the concrete into small pieces for removal. This method is particularly suitable for thicker concrete sections where precision removal is desirable.

Segmenting plain concrete overlays may be as simple as lifting each slab, but for overlays with longer, 12 to 15 ft panels, the process may also require sawing the pavement into smaller panels of a size and weight capable of being removed and transported safely and efficiently. Determining the practical panel size must include consideration of the overlay thickness and the lift and transport equipment's loading capacities, which may take several trials. Front-end loaders equipped with a forklift or slab crab attachment are typically employed for the purpose of removing and lifting the slabs onto flatbed or other suitable trucks for removal to a crushing plant.

One limitation of the method is that it may not be possible to remove adhered overlay panels without damaging the surface of the underlying pavement. As lifting begins, a COA–B or COC–U overlay bonded to the underlying asphalt pavement or separation layer may tear or shear the asphalt material, leaving an uneven surface. In comparison to milling or rubblizing, this possibility might make lift-out unattractive. In certain cases, such as for COC–U overlays built on a fabric separation layer, bonding of the fabric to the underlying pavement may be negligible.

Because the method involves a drop hazard risk, lift-out requires careful planning and coordination to ensure the safety of workers and equipment.

Special Removal Considerations

Cost Estimates for Removal Options

Comparing the costs associated with each removal method is an essential element of assessing the feasibility of an overlay replacement strategy. If cost information is not readily available in the agency's cost tracking system, it is advisable to consult with industry and federal partners that can provide cost information from projects in other areas. (The National Concrete Consortium [NCC] is another excellent resource for sharing experiences.) A cost comparison can also help an engineer assess any cost and productivity trade-offs. For example, if the project involves concrete containing coarse aggregates with a high Mohs hardness number, the break-up option may be less costly than lift-out or milling.

Embedded Steel

The presence of steel in the existing overlay may limit removal options to the rubblizing or break-up methods. Milling can handle the presence of dowel bars and longitudinal joint tie bars, but distributed steel or wire mesh may exclude milling as a viable option unless the pavement is sawed into segments (severing the steel bars) beforehand.

Resonant breakers can debond embedded steel reinforcement, including dowel bars, tie bars, distributed steel, and wire mesh. Contractors report that the breaking process separates roughly 80% of the steel cleanly and all of the wire mesh reinforcement completely (Figure 34). The loose reinforcing steel is removed from the broken concrete by hand or by using a rhino horn or other suitable attachment to a machine loader, backhoe, or skid steer.

Resonant Machines, LLC, used with permission

Figure 34. Steel separated by rubblization and gathered for removal

COC–U Separation Layers

Experience with COC–U overlay removal indicates that fabric separation layers will need to be replaced when the overlay is replaced but that it may be possible to salvage an existing asphalt separation layer to acceptable reuse with some repairs. Occasionally, segments of an asphalt separation layer will stick to the overlay during removal. If a sizable portion of the interlayer adheres, then it will need to be fully removed and replaced, but if only smaller segments adhere, then spot repair may be cost-effective. Unfortunately, the degree of bonding will not be known at the time of bidding.

If the intent is to recycle the old COC–U overlay into a controlled aggregate material for use in a concrete mixture, it is best to carefully control the removal depth so as not to intermingle the asphalt separation layer material with the concrete overlay material. Removing the separation layer during a separate operation is advisable in that case. If the intended use of the old concrete overlay material is for base, fill, or unbound road material, intermingling of materials is not a concern.

If a fabric separation layer is present in the existing COC–U overlay, it is likely to be well adhered to the underside of the overlay. Experience has shown that in most removals for full-depth repair, the separation layer is well adhered to the overlay and is ripped out by the lift-out process. To avoid this possibility, the best way to remove a COC–U overlay without contaminating the removal material with fabric is to either mill the overlay to a controlled depth or use a combination of resonant breaking and milling. Depth control in milling is important to avoid getting fabric fragments into the recycled concrete aggregate. Any material removed during a final pass that penetrates through the interlayer level and slightly into the underlying pavement, intermingling materials and fabric, may need to be considered waste material.

Post-removal Inspection

Once the old concrete overlay is removed, it is important to closely examine the exposed pavement layer and reassess the severity and extent of deterioration that may not have been fully evident when the overlay was still in place. Additional spot repairs may be advisable before placing the new overlay.

Construction Sequence

The contractor should carefully plan the construction sequence to minimize disruptions to traffic and facilitate the installation of the new overlay. This may involve phased construction, temporary pavement markings, and coordination with other construction activities to ensure a smooth transition between the existing pavement and the new overlay. The contractor must take proper measures to maintain traffic flow and ensure the safety of road users during construction, as required by the specifications. For more information on maintenance of traffic options for concrete overlay projects, see the *Concrete Pavement Preservation Guide*, Third Edition (Smith et al. 2022).

Utility Considerations

Underground utilities that pass under or along an overlaid roadway require some special considerations.

For overlay replacement projects, it is advisable to mark the locations of underground utilities and structures if the overlay will be removed using milling or rubblizing. Special attention should be given to identifying and marking manhole or handhold covers and shutoff valves within the overlay surface. If the utility is considered sensitive to damage by vibration, the contractor should reduce the breaking energy on RFB equipment when nearing the sensitive utilities to avoid damage (TRB 2006). The contractor should also consider using jackhammers in the areas immediately surrounding a sensitive utility or around embedded castings.

Occasionally, there may be a need to repair underground utilities that cross under or run parallel to an overlaid pavement, especially in urban areas. Effective coordination between the contractor, utility company, and specifying agency will streamline the repair process and minimize delays.

Detailed information is available in FHWA (1996) and ACPA (2024e) on how to properly prepare for and execute the excavation and subsequent replacement of a concrete pavement structure for utility repairs. For a pavement that includes a concrete overlay, some additional considerations are outlined below.

Preparing for the Work

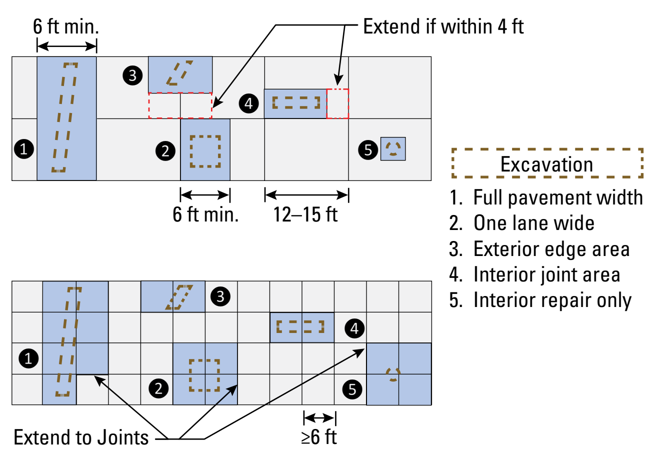
Before any cutting begins, it is important to accurately locate the underground utilities that need repair. This may involve using utility maps, ground-penetrating radar, or other specialized equipment to determine the exact location and depth of the utilities. Depending on the location and extent of the required excavation, traffic management measures may be necessary to safely divert vehicles and pedestrians away from the work area. These measures are usually simple but sometimes require lane restrictions or road closures.

Marking and Layout

Once the utilities are located, the contractor must mark the area designated for pavement removal on the concrete overlay surface. As a starting point to access and repair a utility, the trench width should equal the width of the utility (pipe) plus a minimum of 18 in. on either side. Any required shoring or bracing may necessitate a wider trench (FHWA 1996). The contractor should extend the location of the perimeter pavement cuts beyond the anticipated trench size. The extended removal will later allow the concrete patches to span the trench(es) with full support from a rim of undisturbed subgrade/subbase. While typical requirements allow for the rim to be as narrow as 6 in., for concrete overlays, a rim of undisturbed subgrade/subbase of 12 to 24 in. is recommended.

The size and shape of a utility cut in a concrete overlay also depend on the location of the cut relative to the joints and edges of the existing overlay. See Figure 35 for recommendations on how to locate the perimeters of a utility cut for overlay panels of different sizes. For short-panel pavements (those with a joint spacing of 6 ft or less), line up the utility cut perimeter with existing pavement joints (transverse and longitudinal). For conventional panels (those with a transverse joint spacing of 12 to 15 ft), line up the perimeter with the nearest existing joint if the perimeter is within 4 ft of a joint. Do not create small segments of existing pavement, as these tend to subsequently rock or crack under vehicle loads. Also, keep the perimeter cuts in line with (parallel to) either longitudinal or transverse joints, and do not introduce angled patch joints into the overlay.

If the utility excavation exceeds the length of an overlay panel, then the subsequent patch will require interior transverse joints matching the spacing of the existing overlay joints. If dowel bars are required in the installation, a minimum length of 6 ft is recommended to allow for the use of gang drills.



Adapted from FHWA 1996

Figure 35. Recommended location of perimeters for utility cuts through concrete overlays

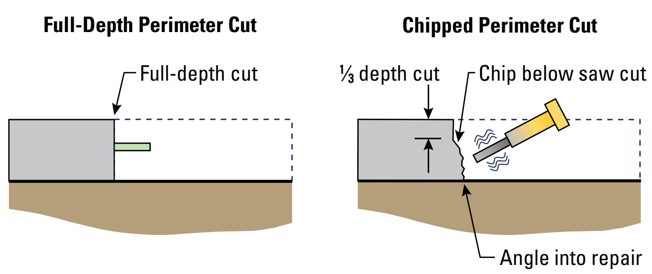
Cutting the Pavement

Using a concrete saw with a diamond blade, the contractor will make straight sawcuts in the overlay along the marked lines (through existing joints as necessary). For doweled perimeter joints, cut the pavement to its full depth, and for undoweled perimeter joints, use a chipped face. See Figure 36 for an illustration of the perimeter joint types. For chipped joints, cut to a depth of about one-third of the slab thickness and prepare the remainder of the joint face with a jackhammer, being careful not to undercut the perimeter. When a chipped cut is later backfilled with concrete, the rough face will provide aggregate interlock.

If the combined thickness of the overlay and the underlying concrete pavement is too thick for a single cut due to the saw/blade diameter, make a second rim by cutting through the overlay first another 12 to 24 in. from the intended perimeter. The second cut should provide enough access for the sawing equipment to cut the underlying pavement separately. The final cut through the underlying pavement should extend 2 in. into the subgrade (FHWA 1996).

Pavement Removal

After the cuts are made, remove the pavement within the marked area using lift-out equipment or jackhammers to break up the material for removal by backhoe or other equipment. The contractor must be careful to avoid damaging the utilities or surrounding pavement during the removal process. It is also important to leave the 12 to 24 in. rim of compacted material along the perimeter of the excavation. The rim provides assurance against a loss of support material beneath the surrounding pavement, as well as a stable platform against which to compact backfill materials.



Adapted from ACPA 1995, used with permission

Figure 36. Utility cut perimeter joint types

Utility Repair or Installation

With the overlay and underlying pavement removed, the underground utilities can be accessed for repair or replacement. Activities involve repairing damaged pipes, replacing sections of pipe, or installing new utility lines as needed. Proper shoring and bracing may be required to ensure the safety of workers during the excavation.

Backfilling and Compaction

Once the utility work is complete, the next step is to backfill the trench with a suitable material, such as a controlled-density (flowable) fill or dense-graded gravel. ACPA (2024e) provides more information on these materials. Unstabilized backfill materials must be properly compacted to ensure that they provide proper support for the repaired utilities and pavement. Schaefer et al. (2005) suggest backfilling in compacted lifts no greater than 12 in. and using relative density rather than standard Proctor testing to measure and verify the degree of compaction. A relative density value of 65% or greater indicates a densely compacted material. Regardless of the method or testing, the rim and backfilled trench should be fully compacted before the concrete patching material is placed.

The best practice for the thickness of the concrete slab depends, in part, on the overlay type and the combined thickness of the overlay and underlying pavement. For COA–U, COA–B, and COC–B overlays, a minimum of 12 in. is suggested for the thickness of the concrete utility patch, with deeper excavation as necessary to achieve this patch thickness. In most cases, this will completely fill the trench from the level of the subgrade rim up to the surface. In all cases, no more than 4 in. of additional backfill material is recommended to exceed the level of the subgrade rim to achieve adequate compaction. A better practice is to use concrete to completely fill the void from the subgrade rim to the surface. (Note that a flowable backfill is self-leveling and can be poured into the utility trench, requiring no compaction. The material solidifies sufficiently to support loads and allow for concrete placement after about four hours.)

For COC–U overlays, the recommendation is to backfill in layers to accommodate effective positioning of the load transfer dowel bars. For COC–U overlays less than 7 in. thick, dowel bars are anchored in the underlying pavement, and for overlays 7 in. thick or more, dowel bars are anchored into the overlay concrete. In both cases, a layer of fabric separator is required to reestablish the independence of the overlay from the underlying concrete pavement.

Preparing Joints

Before new concrete is placed into the backfilled trench, the contractor should prepare the perimeter joints. Depending on the type of overlay, this may involve drilling holes for dowel bars into either the overlay or the underlying concrete pavement. For undoweled perimeter joints, a chipped face joint is recommended. See Figure 37 for details on utility repair by overlay type.

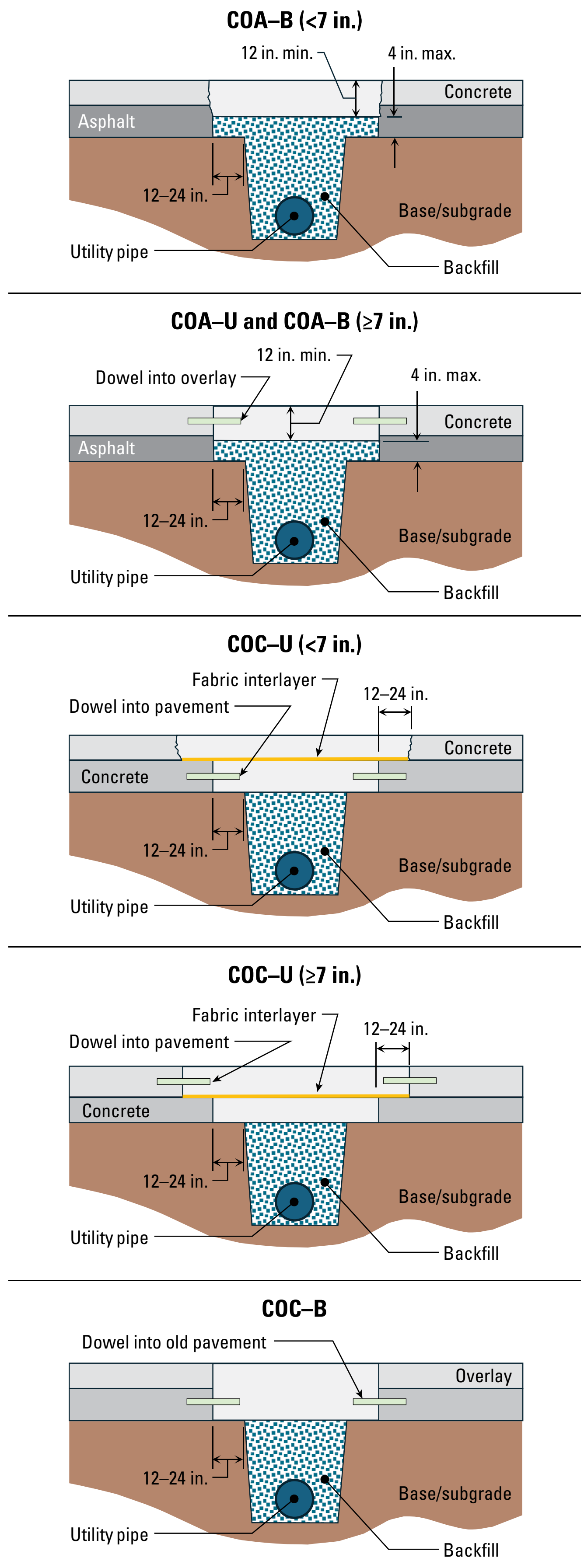
A gang drill rig is the best option for drilling multiple holes simultaneously while maintaining proper alignment; the machines will work well for most utility repairs. However, the stepped nature of utility perimeter cuts in COC–U pavements may limit the drill choice to either a machine-mounted unit or a small grade-reference drill rig (Figure 38). In both cases, these drills are capable of drilling holes into the perimeter faces of the underlying concrete pavement.

Pavement Replacement

Finally, the excavated area is filled with concrete and properly finished to restore the pavement surface to its original condition. In most cases, the thickness of the utility repair should exceed the thickness of the overlay, per the details. The contractor should match the texture and appearance of the surrounding pavement for a seamless repair.

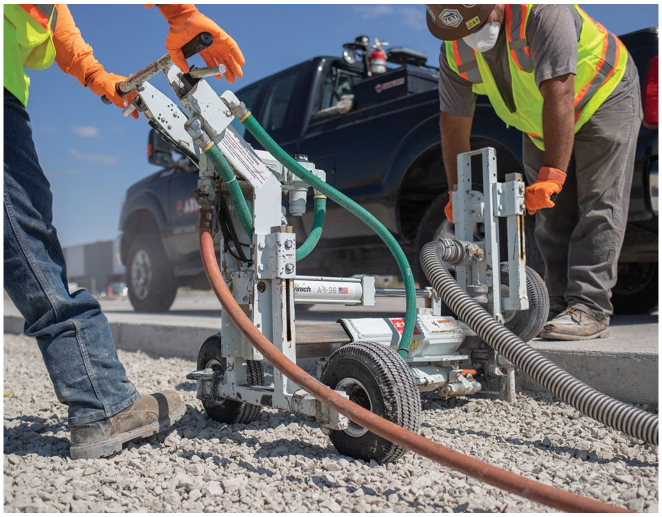
Keyhole Alternative

An alternative to a full utility cut is keyhole technology. Keyholes involve core drilling through the pavement (including the concrete overlay and underlying layers) to access and view underground utilities. This technology contributes to sustainability goals by reducing the introduction and disposal of new materials for underground utility repairs. After coring, hard paving materials (concrete or asphalt) are saved for replacement. Unbound materials are vacuum extracted to expose the utilities beneath the pavement layers. The same pavement materials that were used to build the overlay are replaced after the repair and excavation is backfilled.



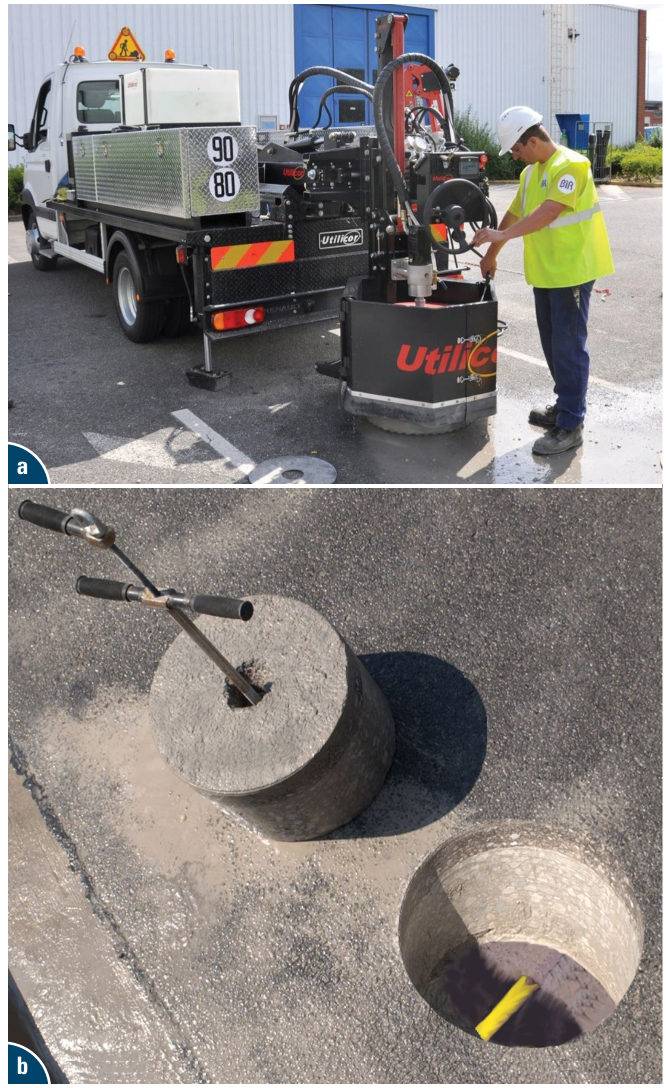
Adapted from ACPA 2024e, used with permission

Figure 37. Utility cut repair details by overlay type



Minnich Manufacturing, used with permission

Figure 38. Small grade-reference drill rig



Utilicor Technologies, Inc., used with permission

Figure 39. Keyhole coring: (a) truck-mounted keyhole coring drill and (b) example of a keyhole core removed from a pavement with an exposed utility pipe

Coring units are mounted to a truck or skid steer (Figure 39). A typical keyhole coring unit produces an 18 in. diameter hole, which is helpful for identifying the source of leaks or other problems at potential sites in gas, water, sewer, and fiber optic cable utilities (Pollock 2009). The core hole may be large enough to carry out some repairs without the need for larger excavations. The advantages of this method are that the size of the pavement penetration is small and its circular shape makes for simple backfilling. A flowable mortar backfill ensures that any voids created under the pavement are filled effectively to avoid the settling of the repair.

Summary

Concrete overlays undergo distinct stages of performance throughout their life cycles. Properly designed and constructed overlays can offer long-term service, with effective repair and preservation strategies contributing to extended functionality. Careful consideration of end-of-life options ensures the sustainable management of concrete overlay systems in the overall pavement network.

Concrete overlays have come of age and represent an outstanding value to owner-agencies. A comprehensive set of repair procedures and end-of-life strategies is now available to ensure that concrete overlays continue to serve as a renewable and cost-effective pavement asset.

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Additional Resources

The following documents and other resources provide in-depth information on the design and construction of concrete overlays and are available on the CP Tech Center's website, https://cptechcenter.org.

Guide to Concrete Overlays (Fourth Edition) (Fick et al. 2021). The purpose of the guide is to fill the knowledge gap among practitioners about concrete overlays so that pavement owners can confidently include concrete overlays in their toolbox of pavement solutions and make more informed decisions about their design and construction. Another goal for the guide is to help owner-agencies understand and appreciate the versatility of concrete overlay solutions.
https://intrans.iastate.edu/app/uploads/2021/11/guide_to_concrete_overlays_4th_Ed_web.pdf

Concrete Overlay Field Application Program Final Report: Volume I (Fick and Harrington 2012). The CP Tech Center conducted a four-year, multi-state concrete overlay construction program to demonstrate and document the concept and benefits of various concrete overlay applications and provide real-world lessons. This report outlines the results of the field application program and the key lessons learned.
https://intrans.iastate.edu/uploads/2018/03/OverlayFieldAppFinalReport.pdf

Concrete Overlay Field Application Program – Iowa Task Report: US 18 Concrete Overlay Construction Under Traffic (Cable 2012). The CP Tech Center, Iowa Department of Transportation, and FHWA set out to demonstrate and document the design and construction of portland cement concrete (PCC) overlays on two-lane roadways while maintaining two-way traffic. This report documents the planning, design, and construction of an 18.82 mi project in northeast Iowa and lessons learned.
https://publications.iowa.gov/13635/1/US_18_overlay_construction_web.pdf

National Concrete Overlay Explorer (ACPA 2021). This online database provides information about concrete overlay projects in the United States and Canada since 1900 in three formats: map view (which shows the locations of all projects on an interactive map), table view (which lists the type of overlay and specific application, state, year constructed, and overlay thickness for each project, with links to project details), and details view (which provides in-depth information about each project, including photos of many projects).
http://overlays.acpa.org/webapps/overlayexplorer/index.html

Case Studies of Concrete Inlay/Overlay Projects (CPAM 2021). The Concrete Paving Association of Minnesota (CPAM) provides case studies of 10 concrete overlay projects.
http://www.concreteisbetter.com/elibrary/elib-casestudies/

Mechanistic-Empirical Design Procedure for Bonded Concrete Overlay of Asphalt (Vandenbossche 2013). This website is a repository of information relating to the bonded concrete on asphalt mechanistic-empirical (BCOA-ME) design method. The BCOA-ME method was developed at the University of Pittsburgh under FHWA Pooled Fund Study TPF-5(165).
https://www.engineering.pitt.edu/Vandenbossche/BCOA-ME/

Concrete Overlays – The Value Proposition (Cackler 2021). This technical brief explains the short- and long-term value that concrete overlays offer to agencies.
https://intrans.iastate.edu/app/uploads/2021/12/concrete_overlays-the_value_proposition.pdf

Concrete Overlays – A Proven Technology (Cackler et al. 2021). This technical brief introduces concrete overlay selection, design, and construction practices to those who may not be familiar with this rehabilitation option. The material includes a technical overview of concrete overlays, guidance on effective deployment, and lessons learned from decades of projects.
https://intrans.iastate.edu/uploads/2021/12/concrete_overlays-a_proven_technology.pdf

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