

Concrete Overlays for Pavement Rehabilitation

Reported by ACI Committee 325

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This report provides information on the use of concrete overlays for rehabilitation of both concrete (rigid) and asphalt (flexible) pavements. Selection, design, and construction of both bonded and unbonded overlays are discussed. The overlay categories reviewed include bonded concrete overlays, unbonded concrete overlays, whitetopping overlays, and concrete overlays bonded to asphalt (ultra-thin and thin whitetopping). Information is also provided on selecting overlay alternatives. Significant portions of this document are based on a synthesis report prepared for the Federal Highway Administration (FHWA) by Applied Pavement Technology, Inc., under contract number DTFH61-00-P-00507. The report, "Portland Cement Concrete Overlays: State of the Technology Synthesis," is available from the FHWA as publication FHWA-IF-02-045.

Keywords: bond; concrete; joint; overlay; pavement (concrete); rehabilitation; repair.

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CHAPTER 1—INTRODUCTION**1.1—Background**

Hydraulic cement concrete overlays are used as a rehabilitation technique for both existing concrete and asphalt pavements. Concrete overlays offer the potential for extended service life, increased structural capacity, reduced maintenance requirements, and lower life-cycle costs when compared with hot-mix asphalt overlay alternatives.

Concrete overlays have been used to rehabilitate existing concrete pavements since 1913 and to rehabilitate existing asphalt pavements since 1918 (Hutchinson 1982). Beginning around the mid-1960s, many highway agencies began to search for alternative means of rehabilitating existing pavements, and the use of concrete overlays increased significantly (McGhee 1994). In the 1990s, there was an even higher increase in the use of concrete overlays, spurred by improvements in concrete paving technology. For example, the use of zero-clearance pavers, fast-track paving concepts, and high-early-strength concrete mixtures greatly increased the ability of concrete overlays to serve as a viable rehabilitation alternative.

Parallel with the increased use of concrete overlays, significant research aimed at advancing the state of the knowledge of concrete overlays was conducted. One impetus for this research was the Intermodal Surface Transportation Act (ISTEA) of 1991, which included a provision under Section 6005 allocating designated funding for the assessment of thin bonded concrete overlays and surface lamination technology. The goals of the assessment were to evaluate the feasibility, costs, and benefits of the techniques in minimizing

overlay thickness, initial laydown costs, and time out of service, and also to maximize life-cycle durability. As part of this effort, the Federal Highway Administration (FHWA) participated in funding 12 test-and-evaluation projects throughout the country (Sprinkel 2000).

Other examples of ongoing studies of concrete overlays are those being conducted under the FHWA's Long-Term Pavement Performance (LTPP) program. The LTPP program is divided into two complementary studies: the General Pavement Studies (GPS) and the Specific Pavement Studies (SPS). Under GPS-9, the performance of unbonded concrete overlays is being investigated; currently, 14 projects are being evaluated. Under SPS-7, the performance of four bonded overlay projects is being studied. The long-term monitoring of these GPS and SPS projects is expected to provide valuable information on the design and construction of concrete overlays. Additional information may be obtained by visiting the LTPP website at www.tfhr.gov/pavement/ltppltp.htm.

Resurfacing asphalt pavements with concrete overlays, a process known as whitetopping, is another example of overlay research. In particular, several studies on the use of ultra-thin whitetopping (UTW), a very thin (2 to 4 in. [50 to 100 mm]) layer of concrete bonded to an existing asphalt pavement, have been conducted. In the 1990s, this technique evolved from a radical rehabilitation concept to a mainstream rehabilitation alternative. Several studies on whitetopping overlays are currently being conducted by the FHWA. Additional information may be obtained at www.tfhr.gov/pavement/utwweb/utw.htm.

1.2—Purpose of report

Two ACI Committee 325 reports (ACI Committee 325 1958, 1967) discussed the pioneering work by the U.S. Army Corps of Engineers to develop design procedures for concrete overlays. The equations developed by the Corps for bonded, partially bonded, and unbonded concrete-on-concrete overlays are still used. The report suggested the design of concrete overlays on flexible pavement using the flexible pavement as a stiff base.

During the 1980s and 1990s, two National Cooperative Highway Research Program (NCHRP) syntheses were prepared on concrete overlays: "Resurfacing with Portland Cement Concrete" (Hutchinson 1982), and "Portland Cement Concrete Resurfacing" (McGhee 1994). There has been considerable work, however, in the area of concrete overlays since the most recent NCHRP synthesis. There is a need to assemble and synthesize information on the selection, design, and construction of concrete overlays for pavement rehabilitation.

This report discusses the selection, design, construction, and performance of concrete overlays. It is intended to provide the current state of the technology (as of 2004) of concrete overlays of both existing concrete pavements and existing asphalt pavements.

1.3—Definitions and notation

1.3.1 Definitions—This section presents definitions and notations unique to this report. Additional definitions for

common concrete terminology can be found in ACI 116R. Definitions shown in italics are terms that may be found in ACI 116R, but have been redefined for this report.

break and seat—technique similar to crack and seat, except conducted on jointed reinforced concrete pavements and using higher impact energy; uses more impact energy to rupture the steel or break its bond with the concrete to ensure independent movement, and seating with a heavy roller.

crack and seat—technique involving fracturing the existing jointed plain concrete pavements into pieces 1 to 4 ft (0.3 to 1.2 m) on a side by inducing full-depth cracks using a modified pile driver, guillotine hammer, whip hammer, or other equipment, and seating with a heavy roller.

curling—concrete distortion, usually in a slab, resulting from differential temperatures.

drainage, subsurface—inclusion of specific drainage elements in a pavement structure intended to remove excess surface infiltration water from a pavement.

equivalent single-axle loads (ESALs)—summation of 18 kip (80 kN) single-axle load applications used to combine mixed traffic to design traffic during the analysis period.

falling weight deflectometer—device in which electronic sensors measure the deflection of the pavement as a result of an impact load of known magnitude; results can be used to estimate the elastic moduli of subgrade and pavement layers and the load transfer across joints and cracks.

faulting—difference of elevation across a joint.

fracturing, slab—technique in which an existing portland-cement concrete pavement is cracked or broken into smaller pieces to reduce the likelihood of reflection cracking.

hot-mix asphalt (HMA)—an asphalt cement-aggregate mixture that is mixed, spread, and compacted at an elevated temperature; also commonly referred to as “asphalt concrete” or “asphalt.”

joint orientation—alignment of transverse joints in a concrete pavement with respect to the centerline of the pavement.

layer, separator—layer of hot-mix asphalt, bituminous material, or other stress-relieving material used at the interface between an unbonded concrete overlay and the existing concrete pavement to ensure independent behavior.

leveling course—thin layer of hot-mix asphalt or other bituminous material to produce a uniform surface for paving.

load transfer—means through which wheel loads are transferred or transmitted across a joint from one slab to the next.

life-cycle cost analysis (LCCA)—economic assessment of competing pavement design alternatives in which all significant costs over the life of each alternative are considered. LCCA is used to evaluate a design solution. Life-cycle costs may be measured for different designs to determine which design will meet the economic and performance goals.

mill—process using drum-mounted carbide steel cutting bits to remove material from a pavement and provide texture to promote bonding with an overlay.

overlay, bonded concrete—hydraulic cement concrete overlay bonded directly to an existing concrete pavement to form a monolithic structure.

overlay, partially bonded—hydraulic cement concrete overlay that is placed directly on an existing portland-cement

concrete pavement with little or no surface preparation; consequently, partial bonding between the two pavements is expected.

overlay, unbonded concrete—hydraulic cement concrete overlay placed on an existing distressed concrete pavement such that the overlay is separated from the existing pavement through a separator layer.

pavement, continuously reinforced concrete (CRCP)—pavement with uninterrupted longitudinal steel reinforcement and no intermediate transverse expansion or contraction joints.

pavement, jointed plain concrete (JPCP)—hydraulic cement concrete pavement system characterized by short joint spacings and no distributed reinforcing steel in the slab, with or without dowels.

pavement, jointed reinforced concrete (JRCP)—hydraulic cement concrete pavement system containing dowels, characterized by long joint spacings and distributed reinforcing steel in the slab to control crack widths.

repair, preoverlay—repair or renovation activity performed on an existing pavement before the placement of an overlay.

roughness—irregularities in the pavement surface that adversely affect ride quality, safety, and vehicle maintenance costs.

rubblize, rubblization—breaking the existing pavement into pieces no larger than 6 in. (150 mm) on a side using a vibratory beam breaker or resonant frequency pavement breaker.

shotblasting—surface preparation technique in which steel shots are propelled against the surface of a portland-cement concrete pavement, effectively cleaning and preparing the surface to receive a bonded concrete overlay.

slab, shattered—concrete pavement with extensive longitudinal and transverse cracking.

slab, widened—concrete pavement slab that is paved wider (usually at least 18 in. [450 mm] wider) than a conventional 12 ft (3.7 m) traffic lane to increase the distance between truck tires and slab edge, thereby reducing edge stresses due to loading.

stripping—separation of asphalt cement from aggregate due to moisture attack.

user costs—in a life-cycle cost analysis, costs incurred by the user, such as delay costs, vehicle operating costs, and accident costs.

variable joint spacing—series of different joint spacings repeated in a regular pattern intended to reduce the rhythmic response of vehicles traveling over uniformly spaced joints.

warping—concrete distortion caused by differential moisture.

whitetopping—concrete overlay placed on an existing asphalt pavement. Whitetopping may be used in referring to conventional whitetopping, thin whitetopping, or ultra-thin whitetopping.

whitetopping, conventional—overlay placed on asphalt pavement, typically with a thickness higher than 8 in. (200 mm).

whitetopping, thin—bonded concrete overlay of thickness between 4 and 8 in. (100 and 200 mm) and typically having a joint spacing between 6 and 12 ft (1.8 and 3.7 m) placed on milled asphalt pavement.

Table 2.1—Recommended load transfer designs (Smith and Hall 2001)

Design feature	Recommendation
Dowel diameter	Design catalog (Darter et al. 1997) <30 million ESALs 1.25 in. (30 mm) bar 30 to 90 million ESALs 1.5 in. (38 mm) bar >90 million ESALs 1.625 in. (41 mm) bar Industry (ACPA 1991a) <10 in. (250 mm) slab 1.25 in. (30 mm) bar ≤10 in. (250 mm) slab 1.5 in. (38 mm) bar
Dowel length	18 in. (450 mm)
Dowel spacing	12 in. (300 mm) center-to-center across the joint <i>Alternative: cluster dowels in wheel path (Fig. 2.1)</i>
Dowel coating	Epoxy

whitetopping, ultra-thin (UTW)—bonded concrete overlay of thickness less than 4 in. (100 mm) and typically having a joint spacing less than 6 ft (1.8 m) that is placed on a milled asphalt pavement.

whitewashing—application of a lime slurry to an asphalt pavement surface to reduce the surface temperature.

1.3.2 Notation—

CF	= condition factor estimated based on remaining life (Section 4.2.3.1)
D	= actual thickness of existing slab, in. (mm) (Section 4.2.3.1, 5.2.4)
D_{eff}	= effective thickness of existing slab, in. (mm) (Section 4.2.3, 5.2.4)
D_f	= required thickness of new concrete pavement for future traffic loadings, in. (mm) (Section 4.2.3.1, 5.2.4)
D_{max}	= maximum thickness of slab, in. (mm) (Section 6.3.5)
D_{nom}	= nominal thickness of slab, in. (mm) (Section 6.3.5)
D_{OL}	= thickness of bonded or unbonded overlay, in. (mm) (Section 4.2.3.1, 5.2.4)
E_c	= modulus of elasticity of concrete, psi (MPa) (Section 5.2.6)
F_{dur}	= durability adjustment factor (Section 4.2.3)
F_{fat}	= fatigue damage adjustment factor (Section 4.2.3)
F_{jc}	= joint condition adjustment factor for bonded overlays (Section 4.2.3)
F_{ju}	= joint condition adjustment factor for unbonded overlays (Section 5.2.4)
k	= modulus of subgrade reaction, psi/in. or lb/in. ³ (MPa/mm) (Section 5.2.6, 6.2.2, 7.2.2)
ℓ	= radius of relative stiffness, in. (mm) (Section 5.2.6)
L	= joint spacing, in. (mm) (Section 5.2.6)
L_{max}	= maximum joint spacing, in. (mm) (Section 7.2.5)
M_R	= resilient modulus (Section 6.2.2, 7.2.2)
SC_{eff}	= effective structural capacity of existing pavement (Section 4.2.3.1, 5.2.4)
SC_f	= structural capacity of new pavement (Section 4.2.3.1, 5.2.4)
SC_O	= original structural capacity when pavement was first constructed (Section 4.2.3.1)
SC_{OL}	= structural capacity of new overlay (Section 4.2.3.1, 5.2.4)
μ	= Poisson's ratio (Section 5.2.6)

CHAPTER 2—CONCRETE OVERLAY TYPES AND CONSTRUCTION MATERIALS

2.1—Introduction

This chapter presents general information on the different types of concrete overlays that are typically used in pavement

rehabilitation and some of their common features. Concrete overlays for both existing concrete and existing asphalt pavements are described, including a summary of their defining characteristics. This chapter serves only as an introduction to the different concrete overlay types; detailed information is presented in later chapters.

Materials used in construction of concrete overlays are also described in this chapter. This includes a summary of concrete paving materials and mixture proportions, as well as interface materials and other aspects of construction.

2.2—Types of concrete overlays

2.2.1 Concrete pavement types—Concrete overlays and existing concrete pavements may be one of three basic types: jointed plain concrete pavement (JPCP), jointed reinforced concrete pavement (JRCP), and continuously reinforced concrete pavement (CRCP). Although in theory any type of concrete pavement could be used for an overlay, in practice, jointed plain concrete pavement (with and without dowels) is by far the most common.

2.2.1.1 Jointed plain concrete pavement—JPCP is a hydraulic cement concrete pavement system characterized by short joint spacings, no distributed reinforcing steel in the slab, and with or without dowels. Maximum slab length is typically 20 ft (6 m). Undoweled or aggregate interlock joints are generally used for short slabs, thin slabs, or both. For most pavements, however, adequately sized dowels should be provided to reduce faulting (Snyder et al. 1989; Smith et al. 1997). Dowel diameter is often selected based on slab thickness, but traffic may be a more important factor for consideration. Recommended load transfer designs are summarized in Table 2.1.

For concrete overlays, the recommended number and spacing of dowels is the same as those for new pavements. In general, uniform 12 in. (300 mm) spacing is recommended, but nonuniform spacing has also been used successfully. In the nonuniform dowel spacing design, the dowels are concentrated in the wheel paths (Darter et al. 1997). One recommended design for variable dowel bar spacing is illustrated in Fig. 2.1.

In general, joints perpendicular to the direction of traffic are recommended. On new JPCP, skewed joints can be effective in reducing faulting on nondoweled pavements, but have no effect when used on properly doweled pavements (Yu et al. 1998a; Khazanovich et al. 1998). Furthermore, JPCP designs with skewed joints constructed on a subbase (treated cement or lean concrete) are prone to corner breaks.

Table 2.2—Summary of concrete overlays of existing concrete pavements (adapted from Hoerner et al. 2001)

	Bonded	Partially bonded	Unbonded
Typical thickness	• 3 to 4 in. (75 to 100 mm)	• 6 to 8 in. (150 to 200 mm)	• 6 to 12 in. (150 to 300 mm)
How bonding condition is achieved	• Cleaning and preparing surface (such as shotblasting) • Possible application of bonding agent	• No special surface preparation other than sweeping	• Placement of a layer to separate overlay from existing pavement
Condition of existing pavement	• Relatively good condition • No materials-related distress	• Fair to moderate condition	• Fair to poor condition
Preoverlay repair	• All deteriorated cracks, joints, and punchouts	• Most deteriorated cracks, joints, and punchouts	• Limited repair
Special design and construction considerations	• Achieving bond between two concrete layers • Matching joints of overlay with those in existing pavement	• Matching joints of overlay with those in existing pavement	• Achieving separation between two concrete layers • Mismatching joints of overlay with those in existing pavement
Overlay types	• JPCP • JRCP • CRCP	• JPCP • JRCP • CRCP	• JPCP • JRCP • CRCP

2.2.1.2 Jointed reinforced concrete pavement—JRCP is a hydraulic cement concrete pavement system containing dowels, characterized by long joint spacings and distributed reinforcing steel in the slab to control crack widths. Slab lengths are generally more than 20 ft (6 m), and may be as much as 60 ft (18 m). Current pavement practice is away from JRCP designs, and construction is rare because the longer joint spacing results in more joint movement. When midslab cracks occur, the light reinforcing may not be enough to hold the cracks tightly. If JRCP is used, the recommended maximum joint spacing is 30 ft (9 m) (FHWA 1990). Deformed bars or deformed welded wire reinforcement are recommended at a minimum steel content of 0.19% (Darter et al. 1997).

2.2.1.3 Continuously reinforced concrete pavement—CRCP, also known as continuous concrete pavement, is a pavement with uninterrupted longitudinal steel reinforcement and no intermediate transverse expansion or contraction joints. Reinforcement design for CRCP overlays is similar to that for new design. The recommended minimum steel content is 0.60%, and the use of deformed bars is strongly recommended (Darter et al. 1997). The depth of reinforcing steel has a significant effect on crack opening, and steel placement closer to the top surface may provide tighter cracks and better long-term performance (Dhamrait and Taylor 1979; Roman and Darter 1988). A minimum concrete cover of 2.5 in. (65 mm) is recommended for protection of the reinforcing steel against corrosion.

2.2.2 Concrete overlays of existing concrete pavements—Concrete overlays of existing concrete pavements are generally classified according to the proposed bonding condition between the new overlay and the existing pavement. They may be placed in a bonded, partially bonded, or unbonded condition, the selection of which depends largely upon the condition of the existing pavement and on the future traffic levels. Table 2.2 summarizes some key characteristics of each of these concrete overlay types (Hoerner et al. 2001).

2.2.2.1 Bonded concrete overlays—A bonded concrete overlay consists of a thin layer of concrete (typically 3 to 4 in. [75 to 100 mm] thick) that is bonded to the existing pavement (Fig. 2.2). These are used to increase the structural capacity of an existing pavement or to improve its overall ride quality,

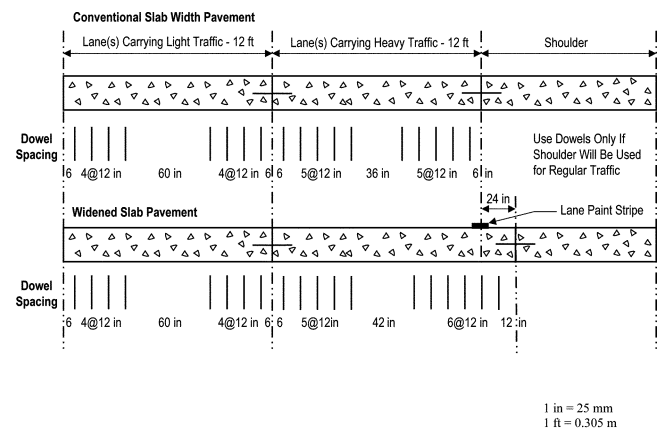


Fig. 2.1—Recommended design for variable dowel bar spacing (Darter et al. 1997).

and should be used where the underlying pavement is free of structural distress and in relatively good condition (ACPA 1990a; McGhee 1994).

Perhaps the most important construction and performance aspect of bonded overlays is achievement of an effective bond between the overlay and existing pavement. This is necessary to create a pavement system that behaves monolithically; if such bonding is not achieved, cracking of the overlay will result due to increased curling, warping, and loading stresses. Surface preparation of the existing concrete pavement is required to produce a clean, roughened surface that will promote bonding between the two layers. This is commonly accomplished using shotblasting, milling, or hydroblasting equipment.

Bonded overlays have been constructed in many states, including California, Illinois, Iowa, Louisiana, New York, Pennsylvania, South Dakota, Texas, and Virginia, and in the countries of Belgium, Canada, Japan, and Sweden. By far the most common bonded overlay type is JPCP, and this has been placed on existing JPCP, JRCP, and CRCP designs (McGhee 1994). Some jointed and reinforced bonded overlays have been used on existing JPCP and JRCP, although presently, they are rarely used. Texas and Virginia have both constructed several bonded overlays on existing CRCP.

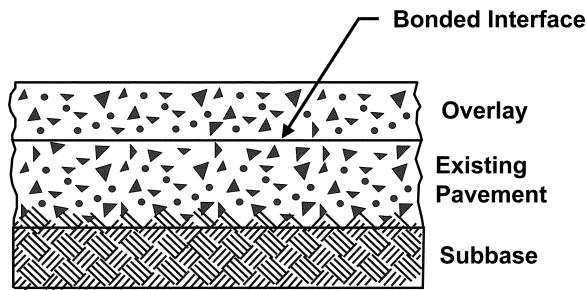


Fig. 2.2—Bonded concrete overlay (McGhee 1994).

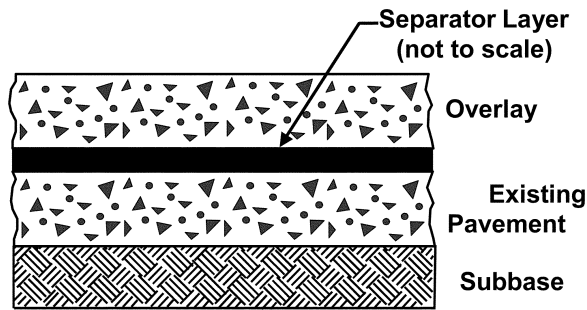


Fig. 2.3—Unbonded concrete overlay (McGhee 1994).

2.2.2.2 Partially bonded concrete overlays—Partially bonded concrete overlays are placed directly on existing concrete pavements with little, if any, surface preparation. These are used when the degree of bonding is not critical to the performance of the overlay (Lokken 1981). Partially bonded overlays are more commonly used on airfield pavement where a thicker overlay is required because of heavy aircraft loads, and where the slabs are more fully restrained. On airfield pavements, partially bonded overlay thicknesses are generally higher than 12 in. (300 mm), whereas on highway applications, thicknesses are generally in the range of 6 to 8 in. (150 to 200 mm).

As previously mentioned, no special measures are taken to either promote or prevent bond. As a result, varying degrees of bonding will occur, so reflection cracking is a potential problem. Consequently, partially bonded overlays should be used only when the existing concrete pavement is in a sound, well-seated condition and with no major distresses, distortions, or rocking slabs (Lokken 1981).

According to the comprehensive list of concrete overlay construction projects prepared by McGhee (1994), most partially bonded overlays are either JPCP or JRCP designs, although a few CRCP designs have been constructed. That same list, however, also shows that partially bonded overlays are not widely used for highway applications.

2.2.2.3 Unbonded concrete overlays—An unbonded concrete overlay (sometimes called a separated overlay) contains an interlayer between the existing pavement and the new overlay (Fig. 2.3). This separation layer is placed to ensure independent behavior between the two slabs, thereby minimizing the potential for reflection cracking. Unbonded overlays are typically between 6 and 12 in. (150 and 300 mm) thick.

Unbonded concrete overlays are used when the existing pavement deterioration is so advanced that it cannot be

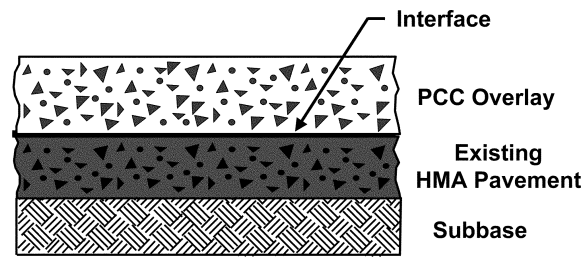


Fig. 2.4—Whitetopping overlay of asphalt pavement (McGhee 1994).

effectively corrected before overlaying (ACPA 1990b). Because the two pavements will be separated, little preoverlay repair is typically required. The separator layer should be effective at ensuring independent behavior between the two rigid layers. Hot-mix asphalt layers (typically approximately 1 in. [25 mm] thick) are commonly used as an interlayer.

In both highway and airfield applications, unbonded overlays have seen far greater use than either bonded or partially bonded overlays. Most unbonded overlays have been jointed plain concrete designs, although a significant number of unbonded continuously reinforced concrete designs have been used.

2.2.3 Concrete overlays of existing asphalt pavements—Whitetopping, the use of concrete overlays of existing asphalt pavements, increased considerably in the 1990s. These overlays are generally classified as conventional, thin, or ultra-thin whitetopping, according to the thickness of the concrete overlay. Table 2.3 summarizes some of the key characteristics of the conventional whitetopping and ultra-thin whitetopping (UTW) concrete overlay types (Grogg et al. 2001).

2.2.3.1 Conventional whitetopping—Conventional whitetopping is the placement of a concrete overlay on an existing asphalt pavement. These are generally designed as new concrete pavement structures, and can range from 4 to 12 in. (100 to 300 mm) thick, although they are typically at least 8 in. (200 mm) thick. A typical cross section of a whitetopped pavement is shown in Fig. 2.4 (McGhee 1994). The interface shown may be on a milled surface, on a hot-mix asphalt leveling course, or may have no treatment at all (direct placement).

Conventional whitetopping is an alternative solution to hot-mix asphalt for rehabilitating deteriorated flexible pavements that exhibit such distresses as rutting, shoving, and alligator cracking (ACPA 1998). Preoverlay repair of badly distressed or failed areas is required, and many agencies cold mill the existing asphalt surface to remove ruts or surface irregularities before placing the overlay (McGhee 1994).

A conventional whitetopping overlay is designed essentially as a new concrete pavement on a treated base course, assuming an unbonded condition between the layers. Some partial bonding between the overlay and existing asphalt pavement can occur, however, which can contribute to the performance of the pavement. Conventional whitetopping has been designed as jointed plain concrete overlays (most common), jointed reinforced concrete overlays (less common), and continuously reinforced concrete overlays.

Table 2.3—Summary of whitetopping and ultra-thin whitetopping overlays (Grogg et al. 2001)

	Conventional whitetopping	Ultra-thin whitetopping
Typical thickness	• 8 to 12 in. (200 to 300 mm)	• 2 to 4 in. (50 to 100 mm)
Condition of existing pavement	• All deteriorated hot-mix asphalt pavements	• Low-volume deteriorated hot-mix asphalt pavements (particularly in areas where rutting is a problem)
Bonding condition	• Designed as unbonded, but some partial bonding occurs (and may enhance pavement performance)	• Strong bond required between existing hot-mix asphalt pavement and new concrete overlay
Preoverlay repair	• Limited repair (failed areas only) • Possible milling to correct profile	• Repair of areas unable to contribute to load-carrying capacity • Milling of hot-mix asphalt surface
Minimum thickness of hot-mix asphalt	• 2 in. (50 mm) (after any milling)	• 3 to 6 in. (75 to 150 mm) (after any milling)
Special design and construction considerations	• Adequate support critical to performance • Adequate joint design (including joint spacing and load transfer) • Placement of a whitewash on hot-mix asphalt surface on hot days	• Bonding with hot-mix asphalt pavement • Concrete mixture proportioning is often high-strength, fiber-modified, or both • Extremely short joint spacings (typically between 2 and 6 ft [0.6 and 1.8 m])
Concrete overlay types	• JPCP • JRCPP • CRCP	• JPCP

2.2.3.2 Ultra-thin and thin whitetopping—UTW and thin whitetopping overlays are both designed assuming that the overlay bonds to the existing asphalt. Most overlays in this category are UTW, although there have been a few thin whitetopping projects constructed; this is an area of increasing research interest. Thin whitetopping represents an extension of the UTW to thicker overlays for pavements carrying heavier traffic.

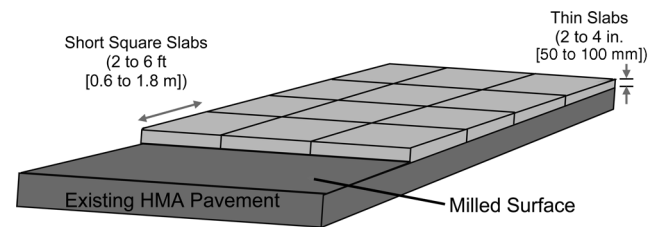
UTW is a process in which a thin layer of concrete (between 2 and 4 in. [50 and 100 mm] thick) is placed over a rutted or cracked asphalt pavement (ACPA 1998). In a UTW project, the existing hot-mix asphalt surface is cold milled to enhance the bond between the concrete overlay and the pavement to create a monolithic structure. Milling also removes surface irregularities and provides a more uniform surface for overlay placement.

UTW was originally intended for parking lots, residential streets, low-volume roads, general aviation airports, and hot-mix asphalt intersections where rutting is a problem but no other significant structural deterioration is present (ACPA 1998). Since the mid-1990s, its use has been extended to highway applications in Alabama, Kansas, Missouri, and other states.

UTW overlays employ short slabs, typically square and with joint spacing between 2 and 6 ft (0.6 and 1.8 m). This is to help reduce bending and thermal curling stresses. Figure 2.5 shows a schematic of a UTW overlay (Grogg et al. 2001).

The use of UTW grew rapidly during the 1990s, with over 200 projects in 35 states since 1992 (ACPA 2000a). As of 2003, Tennessee had constructed the most UTW projects, followed closely by Kentucky and Kansas. All UTW projects have been jointed, plain concrete overlay designs, but some have used fiber-reinforced concrete (FRC).

Thin whitetopping overlays are between 4 and 8 in. (100 and 200 mm) thick concrete slabs with joint spacing between 6 and 12 ft (1.8 and 3.7 m) that are placed on a milled asphalt pavement. As with the UTW design, milling of the asphalt surface is intended to promote bonding between the overlay and the existing pavement. This bonding is accounted for in design, and improves the performance of the overlay. Thin

**Fig. 2.5—Schematic of UTW overlay (Grogg et al. 2001).**

whitetopping overlays have been used by a few highway agencies, primarily on state highways.

An inlay is a variation of UTW and thin whitetopping overlays where one or more of the travel lanes of an existing pavement are milled, and the concrete overlay is placed in that milled area. This technique has the advantages of targeting only the distressed lanes, maintaining existing pavement elevations, and eliminating the need for any unnecessary shoulder work or repair. A 6 in. (150 mm) thick thin whitetopping inlay was placed in October 2001 on U.S. 78 in Jasper, Ala. (Delatte et al. 2001).

2.2.3.3 Summary of whitetopping overlay characteristics—

The following design and construction characteristics can be used to distinguish between the various types of whitetopping overlays:

- Conventional whitetopping is designed essentially as a new pavement on a stabilized base and assumes an unbonded condition between the concrete overlay and the pavement, even if the pavement is milled. Conventional whitetopping can be used on any type of pavement facility;
- Thin whitetopping is a moderately thin concrete overlay (thicknesses between 4 and 8 in. [100 and 200 mm]) that is placed on a milled asphalt pavement. Bond between concrete overlay and asphalt pavement is considered in design, and short joint spacing (between 6 and 12 ft [1.8 and 3.7 m]) is used. Thin whitetopping overlays have been used most often on state highways and secondary routes; and

- UTW is similar in concept to thin whitetopping in that the overlay is bonded to a milled asphalt surface, and bonding is considered in the design. The concrete overlay thicknesses are between 2 and 4 in. (50 and 100 mm), and square slabs (between 2 and 6 ft [0.6 and 1.8 m] in plan) are used. FRC is commonly used. UTW overlays are commonly used on urban streets and intersections.

2.2.4 Other concrete overlay types—A review of the available literature reveals several other types of concrete overlays that have been used. These primarily include fiber-reinforced overlays and prestressed-concrete overlays. These, however, represent changes to the concrete mixture or pavement construction method, and do not alter the way of classifying overlays into the existing categories already defined.

Prestressed overlays have seen limited use in the U.S., and are not discussed in this report. FRC overlays have been used since the 1950s, and have since seen an increase in use as part of many UTW projects. Some additional information on the use of fiber in concrete is presented in ACI 544.1R.

2.3—Overlay materials

This section describes materials used in overlays. Conventional portland cement concrete is by far the most commonly used paving surface material, although other hydraulic cements and fiber-reinforced portland cement concretes are also used to construct overlays.

2.3.1 Portland and hydraulic cement concrete—Conventional concrete paving mixtures are typically used to construct overlays. As with conventional concrete pavements, properly proportioned mixtures are essential to satisfactory performance. Each of the components used in a concrete mixture should be carefully selected so that the resulting mixture is dense, relatively impermeable, and resistant to both environmental effects and deleterious chemical reactions over its service life (Van Dam et al. 2002). Additional information on mixture proportioning can be found in ACI 211.1, 211.2, 211.3R, 211.4R, 211.5R, and PCA's "Design and Control of Concrete Mixtures" (2002).

As with conventional concrete pavements, Type I and II cements are commonly used in concrete mixtures for overlays. In situations where high early strength is desired, some agencies use Type III cement, which may have a slightly different chemical composition, and is more finely ground to promote the development of high early strength. Depending on the mixture proportion and strength requirements, cement contents are typically in the range of 500 to 700 lb/yd³ (295 to 415 kg/m³), although higher contents are sometimes used. For more information about types of cement, refer to ASTM C 150, C 595, and C 1157, and ACI 225R.

Aggregates used in paving concrete range from stone to gravel and glacial deposits (McGhee 1994). To help ensure the longevity of the pavement, these aggregates should not only possess adequate strength, but should also be physically and chemically stable within the concrete mixture (Van Dam et al. 2002). Consequently, extensive laboratory testing or demonstrated field performance is often required to ensure the selection of a durable aggregate. Many agencies use

ASTM C 1260 to evaluate aggregates for alkali-silica reaction (ASR). ACI 221.1R contains more information on ASR.

The maximum coarse aggregate size permitted in concrete mixtures is a function of the pavement thickness or the amount of reinforcing steel (if used) (ACI 211.1; PCA 2002). The largest and most practical maximum coarse aggregate size should be used to minimize paste content, reduce shrinkage, minimize costs, and improve mechanical interlock properties at joints and cracks (Van Dam et al. 2002). Although maximum coarse aggregate sizes of 0.75 to 1 in. (19.0 to 25.0 mm) have been common, some agencies are examining the use of larger maximum coarse-aggregate sizes (1.5 to 2 in. [37.5 to 50 mm]) for conventional concrete paving. For thinner overlays (such as bonded concrete or UTW), however, smaller maximum coarse-aggregate sizes are required. For unreinforced pavement structures, the Portland Cement Association (PCA) recommends a maximum aggregate size of one-third of the slab thickness (PCA 2002). For more information on aggregates, refer to ACI 221R and 221.1R.

ACI 211.1 and PCA (2002) provide guidance on the selection of the appropriate water-cementitious material ratio (*w/cm*). A maximum *w/cm* of 0.45 is common for pavements in a moist environment and subjected to cycles of freezing and thawing (PCA 2002). Lower *w/cm* values are used on thinner concrete overlays (bonded overlays and UTW) to accelerate strength gain and to minimize drying shrinkage (McGhee 1994; ACPA 1998). Low water and paste content, however, are more important than the *w/cm* in minimizing shrinkage.

Various admixtures (ACI 212.3R) are commonly introduced into concrete mixtures:

- Air entrainment protects the hardened concrete from freezing-and-thawing deterioration and deicer scaling and also helps increase the workability of fresh concrete, significantly reducing segregation and bleeding (PCA 2002). Typical entrained air contents of concrete pavement are in the range of 4 to 6%;
- Accelerators increase the rate of concrete strength development. In pavement, they are commonly used in full-depth repairs or on fast-track paving projects in which early opening times are required. Calcium chloride is commonly used as a set accelerator. Nonchloride accelerators should be used if steel reinforcement and dowels are present; and
- Water reducers are added to concrete mixtures to reduce the amount of water required to produce concrete of a given consistency. This allows for a lowering of the *w/cm* while maintaining a desired slump, and thus has the beneficial effect of increasing strength and reducing permeability (Van Dam et al. 2002).

Supplementary cementitious materials, such as fly ash, slag cement, and silica fume may be used as additions to concrete mixtures. These materials may be placed in addition to the portland cement or as a partial substitution for a percentage of the portland cement. Of these, fly ash is the most commonly used. Fly ash is a by-product of coal-fired power plants, and may be classified as either Class C (high

calcium fly ash) or Class F (low calcium fly ash). Fly ash helps to improve the workability of the mixture and reduce its permeability. It can also increase the long-term strength of the concrete, although the early-age strength may be less. In addition, Class F fly ash is effective in reducing alkali-silica reactivity. ACI 232.2R provides additional information on fly ash.

Most agencies specify a minimum concrete strength requirement for their pavements. Typical values include compressive and flexural strengths (third-point loading) of 4000 and 650 psi (28 and 4.5 MPa), respectively, at an age of 28 days. Fast-track paving mixtures, using a low w/cm (typically less than 0.43), a higher cement content (typically higher than 650 lb/yd³ [385 kg/m³]), and perhaps a Type III portland cement, rapid-setting hydraulic cement, or chemical-admixture systems have been used by highway agencies to meet opening times of as little as 4 to 8 hours (Hoerner et al. 2001). Fast-track paving technology entails not only the development of fast-setting concrete mixtures, but also the planning and coordination of all construction activities needed to minimize down time (ACPA 1994a; FHWA 1994; ACI 325.11R).

Although the use of fast-track mixtures and paving practices has become more common, there has been some concern regarding the potential detrimental effect of faster-setting cements and reduced construction times on the long-term durability of concrete mixtures (Van Dam et al. 2002). Thus, it may be that both the speed of construction and the long-term concrete durability need to be considered during the mixture proportioning phase of a project.

2.3.2 Fiber-reinforced concrete—FRC is portland cement concrete containing randomly distributed fibers throughout the mixture. The principal reason for incorporating fibers is to increase the toughness of the concrete, which is a measure of its energy-absorbing capacity, and to improve its cracking and deformation characteristics. In some cases, flexural strength may also be increased (PCA 1991).

A wide variety of fiber materials have been used to reinforce concrete; steel, polypropylene, and polyester fibers are most commonly used in the U.S. (PCA 1991). Polyolefin fibers have also been used on several paving projects. ACI 544.1R describes the characteristics of these fibers. Further details are shown in Table 2.4 and provided by Smith et al. (2002).

2.4—Interface materials

Interface materials are used either to enhance the bond between the overlay and the existing pavement (to ensure monolithic behavior) or to separate the overlay from the existing pavement (to ensure independent behavior) (McGhee 1994). Materials commonly used for these applications are described as follows.

2.4.1 Bonding agents—For bonded concrete overlays, bond between the two layers is critical to obtain monolithic behavior of the existing pavement and overlay. To help achieve this, many agencies specify application of a cement grout to the existing concrete pavement just ahead of the paver. Cement grouts are generally produced in a mobile mixer from a mixture of portland cement and water; the

Table 2.4—Summary of fiber usage in concrete overlays (AASHTO 2000)

Location	Year built	Type of overlay	Type of fiber
I-10, Baton Rouge, La.	1990	Bonded	Steel (85 lb/yd ³ [50 kg/m ³])
Cherokee County, Okla.	1994	Bonded	Polypropylene (3 lb/yd ³ [1.8 kg/m ³])
Beltway 8, Houston, Tex.	1996	Bonded	Steel
Beltway 8, Houston, Tex.	1999	Bonded	Steel
Iola, Kans.	2000	Bonded	Polypropylene (3 lb/yd ³ [1.8 kg/m ³])
I-29, Atchison County, Mo.	1998	Unbonded	Steel, polyolefin, and polypropylene
Various projects in Tennessee (Chattanooga, Nashville, Memphis, Knoxville, and others)	1992-present	UTW	Polypropylene (3 lb/yd ³ [1.8 kg/m ³])
Leawood, Kans.	1995	UTW	Polypropylene (3 lb/yd ³ [1.8 kg/m ³])
U.S. Highway 14, Pierre, S. Dak.	1996	UTW	Polyolefin (25 lb/yd ³ [15 kg/m ³])
Various street intersections in Springfield, Mass.	1999	UTW	Polypropylene (3 lb/yd ³ [1.8 kg/m ³])

grout should have a maximum water-cement ratio (w/c) of 0.62 (ACPA 1990a). Before the placement of either type of bonding agent, the pavement surface should have already been prepared and should be surface dry (ACPA 1990a).

Some studies suggest that no bonding agent is necessary for properly prepared surfaces (Whitney et al. 1992; Wells et al. 1999). In addition, there is the possibility that the bonding agent could act as a bond breaker if allowed to dry before the placement of the concrete overlay (ACPA 1990a; Delatte et al. 1998; Sprinkel 2000). Therefore, many practitioners exclude the use of bonding agents.

2.4.2 Separator layers—The performance of unbonded concrete overlays over existing concrete pavements depends largely on effective separation between the overlay and existing pavement. Because unbonded concrete overlays are placed on concrete pavements in a more advanced state of deterioration, distresses in the underlying pavement can reflect through the new overlay and compromise its performance.

To minimize the effect of the distresses in the underlying pavement on the performance of the overlay, a separator layer is placed so that the two pavements act independently of each other. Other functions of the separator layer include providing a leveling layer for uniform overlay thickness construction, and providing sufficient friction so that joints and the proper amount of cracks can form in overlays (ERES 1999a).

A wide variety of materials has been used as separator layers, including polyethylene sheeting, wax-based curing compounds, liquid asphalts, and hot-mix asphalt materials (McGhee 1994). The most successful interlayer, and the one most commonly used, is a thick (1 in. [25 mm] or more) layer of hot-mix asphalt (ERES 1999a). Thin asphaltic interlayers, such as chip seals or slurry seals, have worked well in some cases, but are not generally recommended because they do not provide sufficient leveling capabilities, they do not seal joints, and they do not effectively separate the two layers (ERES

1999a). Polyethylene sheeting and curing compounds are also not recommended because they do not prevent active cracks from reflecting through the new overlay (ERES 1999a).

The hot-mix asphalt separator layer is typically a dense-graded mixture meeting the agency's standard paving specification. A few agencies have experimented with the use of permeable hot-mix asphalt interlayers, but long-term performance data for these types of interlayers are not available (ERES 1999a).

If the temperature of the hot-mix asphalt interlayer is expected to exceed 110 °F (43 °C) at the time of overlay placement, whitewashing of the surface may be required. The light-colored whitewash reflects sunlight and reduces heat buildup. This reduces the temperature of the interlayer before placement of the concrete overlay, and reduces the risk of shrinkage cracking (ACPA 1990b). Whitewashing may be accomplished using either a lime slurry mixture or a white-pigmented curing compound (ACPA 1990b).

2.5—Incidental materials

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

- Dowel bars are typically billet steel, Grade 60 (420) bars that conform to ASTM A 615 or AASHTO M 31. The dowel bar size, layout, and coatings should be selected for the specific project location and traffic levels;
- Tie bars are typically billet steel, Grade 40 (280) or Grade 60 (420) bars that meet ASTM A 615 or AASHTO M 31 specifications. Tie bars are deformed bars, and should be at least No. 5 bars (0.62 in. [16 mm]) spaced no more than 30 in. (760 mm) apart;
- Reinforcement in concrete overlays may be either deformed bars or welded wire fabric (WWF). Deformed reinforcing bars should conform to ASTM A 615 or AASHTO M 31, and WWF should conform to ASTM A 185 or AASHTO M 55. The amount of steel reinforcement should be determined based on the design conditions; and
- Joint sealant materials may be of three major types (see also ACI 504R):
 1. Hot-poured rubberized materials conforming to ASTM D 6690, AASHTO M 301, or a governing state specification;
 2. Silicone materials conforming to a governing state specification; or
 3. Preformed compression seals conforming to ASTM D 2628, AASHTO M 220, or a governing state specification.

2.6—Concrete production, construction, and quality-control issues

2.6.1 Concrete production—Concrete production for overlays is no different than that for conventional pavement construction. ACI 304R provides guidance for materials handling, and requirements for measurements and batching equipment required to supply uniform, quality concrete to a paving job. The document also provides guidance for

transporting concrete in revolving drum truck mixers and open-top truck bodies with and without agitators.

2.6.2 Concrete placement and finishing—The placement of a concrete overlay is generally no different from conventional concrete pavement placement. Specific recommendations for overlay placement include grade adjustments that leave the required thickness of the concrete overlay. The finishing of the overlay surface should follow the same practices used to finish any concrete pavement.

2.6.3 Texturing—Texturing of the finished concrete overlay surface is required to ensure adequate surface friction of the roadway. Initial texturing is often done with a burlap drag or turf drag, with the final texturing provided by tining. For roadways designed for vehicle speeds less than 50 mi/h (80 km/h), texturing the surface with a burlap drag, turf drag, or broom should be adequate, provided the corrugations produced are approximately 0.06 in. (1.5 mm) deep (ACPA 1999a).

For roadways designed for vehicle speeds higher than 50 mi/h (80 km/h), tining of the concrete pavement surface is required (ACPA 1999a). Tining provides macrotexture, which contributes to surface friction by tire deformation, and also channels surface water from between the pavement and the tire.

Tining has traditionally been conducted transversely and at uniform intervals, but some studies suggest that uniformly spaced transverse tining produces irritating pavement noise (Larson and Hibbs 1997; Kuemmel et al. 2000). Consequently, some agencies are experimenting with transverse tining that is randomly spaced and skewed to the centerline of the pavement, the pattern of which should be carefully designed and constructed to minimize discrete noise frequencies that are most objectionable to the human ear. In addition, some agencies are investigating the use of longitudinal tining, which produces lower noise levels than either uniformly or randomly spaced transverse tining. Tining should be performed as soon as the moisture sheen disappears from the concrete surface. Additional guidance on surface tining is found in reports by Kuemmel et al. (2000) and ACPA (2000b).

2.6.4 Curing—ACI 308R discusses curing concrete. Curing of the completed overlay may be accomplished using wet burlap, polyethylene, or liquid membrane-forming curing compounds that meet ASTM C 309 or AASHTO M 148. Proper curing is extremely important to the long-term performance of a concrete overlay.

While factors that have an effect on the curing of a concrete overlay are generally no different than for conventional concrete pavement, there are several characteristics of bonded overlays, UTW, and thin whitetopping that make curing particularly important. These include the presence of the existing pavement with its own thermal properties, the thinness of the overlay, and the lower *w/cm* and higher heat of hydration in bonded systems. With conventional concrete pavement, improper curing affects the rate of strength gain and can lead to drying shrinkage cracking and other surface defects; with bonded overlays, improper curing affects the bond strength and contraction stresses and can lead to overlay failure.

Challenges to proper curing occur at both the surface and the base of the overlay. If the temperature of the existing pavement is either very hot or very cold, it will impact the curing of the overlay. Similarly, if there is low ambient humidity or the ambient temperatures drop substantially after placement of the bonded concrete overlay, conditions are created that have an adverse effect on the curing of the pavement.

The application of a curing compound to the surface and exposed edges should be sufficient to control the rate of drying shrinkage in a bonded overlay. For bonded overlays, UTW, and thin whitetopping, a minimum application rate of 100 ft²/gal. (2.5 m²/L), which is about twice the typical manufacturer's recommended rate, should be used (ACPA 1990a; Delatte et al. 1996a). Under harsh climatic conditions, the use of curing blankets may also be advisable. In some cases, temporarily halting paving when evaporation rates exceed ACI 305R recommendations is the best insurance against plastic shrinkage cracking. Delatte et al. (1996b) provide recommendations for curing under the harsh environmental conditions of southwestern Texas. Under such conditions, it is advisable to use a portable weather station to monitor ambient temperatures, wind speed, and relative humidity for determining rate of evaporation and potential for plastic shrinkage cracking (Delatte et al. 1998).

Because of the sensitivity of thin overlays to curing conditions, consideration may be given to the use of internal curing using a partial replacement of saturated lightweight fine aggregate. Background for internal curing and suggestions for mixture proportioning are given in Bentz et al. (2005) and Lam (2005).

2.6.5 Quality control—As with conventional concrete pavement construction, the quality-control program is an important element of the construction process. The program should be written and should include procedures that ensure all materials comply with job specifications, and that concrete production and construction procedures are consistent with good practice and relevant specifications. Information on programs can be found in ACI 311.4R, 311.5, and 121R. Personnel inspecting, testing, or finishing concrete should be certified, either under the ACI Certification Program or the program required by the state highway agency. Information on the ACI program can be found at www.concrete.org/certification.

CHAPTER 3—SELECTION OF CONCRETE OVERLAY ALTERNATIVES

3.1—Introduction

The selection of a particular type of concrete overlay as a possible rehabilitation alternative for an existing pavement is a subset of the overall pavement rehabilitation selection process. The basic principles of that overall pavement rehabilitation selection process are summarized in several documents, including the 1993 “Guide for Design of Pavement Structures” (AASHTO 1993), “Pavement Rehabilitation Strategy Selection” (ACPA 1993), and the reference manuals for two National Highway Institute (NHI) training courses (Grogg et al. 2001; Hoerner et al. 2001). With the implied goal of optimizing pavement rehabilitation, the process involves first identifying rehabilitation alternatives that are technically feasible, and

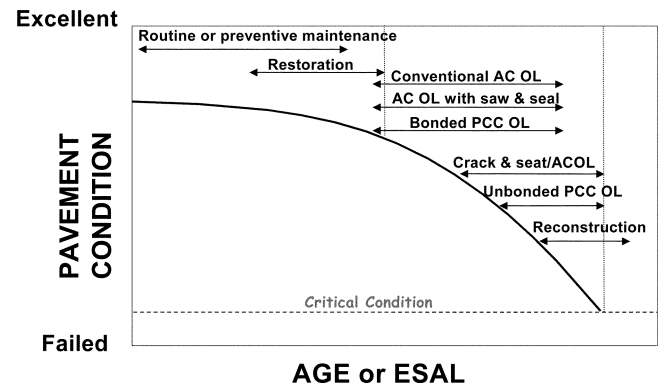


Fig. 3.1—Conceptual relationship between pavement condition and required concrete pavement rehabilitation treatments (Darter and Hall 1990). Note: AC = asphalt concrete (HMA); OL = overlay; and PCC = portland cement concrete.

then evaluating the candidate alternatives in terms of cost and performance benefits to identify the most appropriate option.

Conceptually, a general relationship exists between the existing pavement condition and the required type of rehabilitation, as shown in Fig. 3.1. That is, as pavements reach a more advanced state of deterioration, more substantial rehabilitation measures are required.

The selection process, however, is complicated by the need to consider a variety of factors, many of which are difficult to quantify and evaluate in comparable terms. Examples of such factors include user costs, lane-closure requirements, traffic-control considerations, desired performance life, duration of construction, and local experience with the rehabilitation alternative. The inability to reliably predict the performance of rehabilitated pavements is also a significant shortcoming in the process. Concrete pavement rehabilitation selection has been the topic of several research projects, including NCHRP Web Document 45 and NCHRP Research Results Digest 272, and an FHWA-sponsored research project that is part of the Concrete Pavement Technology Program (Task 54 (99)) entitled “Repair and Rehabilitation of Concrete Pavements.” It can be found at <http://www.fhwa.dot.gov/pavement/concrete/sr04apb2.cfm>.

3.2—Effectiveness of different types of concrete overlays

In practice, candidate alternatives for pavement rehabilitation considerations are not limited to concrete overlays; therefore, where appropriate, hot-mix asphalt counterparts to concrete overlays are also mentioned. Table 3.1 provides a summary of the advantages and disadvantages of different types of overlays.

3.2.1 Bonded concrete overlays—Bonded overlays are appropriate for concrete pavements that are in good condition but are in need of structural enhancement. Bonded overlays can also be used to address various types of functional deficiencies, including the following:

- Poor surface friction;
- Surface roughness (other than faulting);
- Surface rutting caused by studded tires, etc.
- Excessive noise levels.

Table 3.1—Advantages and disadvantages of different types of pavement overlays

Treatment	Applicability	Advantages	Disadvantages	Typical life*
<i>Concrete overlays</i>				
Bonded	Concrete pavement in relatively good condition with no materials-related distress	Significant increase in structural capacity can be achieved with a relatively thin (3 to 6 in. [75 to 100 mm]) overlay	- For pavements in good condition only - Requires extensive preoverlay repairs. Working cracks on existing pavement will reflect through - Bond is essential to good performance - Longer duration of construction than hot-mix asphalt overlays - High initial cost	15 to 25 years
Unbonded	All concrete pavements	- Relatively insensitive to condition of the underlying pavement—can be applied to concrete pavements in poor condition - Requires minimal preoverlay repairs - High reliability	- Vertical clearances can be a problem - Longer duration of construction than hot-mix asphalt overlays - High initial cost	20 to 30 years
Whitetopping	All hot-mix asphalt pavements	- Longer design life than hot-mix asphalt - Can be applied on badly deteriorated hot-mix asphalt pavements - Eliminates rutting and shoving problems - High reliability	- Vertical clearances can be a problem - Longer duration of construction than hot-mix asphalt overlays - High initial cost	20 to 30 years
UTW	Hot-mix asphalt pavements in fair to good condition	- Longer design life than hot-mix asphalt - Eliminates rutting and shoving problems	- Debonding can lead to premature failure - Requires a thicker hot-mix asphalt pavement with adequate structural capacity - Longer duration of construction than hot-mix asphalt overlays - High initial cost	5 to 15 years (estimated)
<i>Hot-mix asphalt overlays</i>				
Hot-mix asphalt overlays without slab fracturing	Concrete pavement in fair to good condition	- Easy to construct - Short duration of construction - Low cost	- Susceptible to reflection cracking - Existing structural distresses should be repaired full depth to avoid reflection cracking - May accelerate materials-related distress	8 to 15 years
Hot-mix asphalt overlays with slab fracturing	All badly deteriorated concrete pavements	- Shorter duration of construction than concrete overlays - High reliability for preventing reflective cracking (rubblization)	- Breaking or cracking and seating may not always prevent reflection cracking - A relatively thick overlay is needed after rubblization to obtain desirable performance - Vertical clearances can be a problem	8 to 25 years

*Life estimates based on data provided by Hall et al. (2001).

Studies on the field performance of bonded concrete overlays have shown mixed results (Hutchinson 1982; Voigt et al. 1989; Peshkin and Mueller 1990; McGhee 1994). Although many projects have provided good long-term performance, several failed within a few years after construction. These failures were often characterized by reflective cracking and corner breaks (in areas where bond was lost). Most of these failures, however, were attributed to the application of the bonded overlay to a pavement that was extensively cracked (McGhee 1994). Others are attributed to inadequate or ineffective preoverlay repair (Peshkin and Mueller 1990). The performance of those projects is summarized elsewhere (Hutchinson 1982; McGhee 1994). Nevertheless, where used in an appropriate application, bonded concrete overlays have provided good performance. Details of case studies are provided by Smith et al. (2002).

When considering a bonded concrete overlay, it is imperative that the existing structural capacity of the underlying pavement not already be compromised. Where structural-related distresses are present, such as pumping, faulting, midpanel cracks, or corner breaks, the load-carrying capabilities of the underlying pavement are already compromised, and a bonded concrete overlay is not an appropriate rehabilitation technique. Furthermore, the presence of D-cracking or other

materials-related distresses in the underlying concrete suggest conditions where the effectiveness of a bonded overlay may be limited.

Structurally, hot-mix asphalt overlays (without slab fracturing) are similar to bonded concrete overlays, so if a 10- to 15-year service life is acceptable, then a hot-mix asphalt overlay could be used to obtain similar performance as a bonded concrete overlay, although with a shorter service life. Concrete pavements overlaid with hot-mix asphalt are subjected to much lower temperature gradients (Nishizawa et al. 2000). Thus, while hot-mix asphalt overlays do not provide the same level of reduction in load stresses as bonded concrete overlays, a reduction in combined stresses can be achieved with a moderate thickness hot-mix asphalt overlay because of the lower thermal curling stresses.

3.2.2 Unbonded concrete overlays—An unbonded overlay is a feasible rehabilitation alternative for concrete pavements in practically any condition, including those with materials-related distresses, such as D-cracking or reactive aggregate. Unbonded overlays are particularly effective on badly deteriorated concrete pavements because they can be placed with minimal preoverlay repairs.

Although unbonded overlays are relatively insensitive to the condition of the underlying pavement, some limited preoverlay repair may be required instead of conducting