U.S. Department of Transportation
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Technical Brief

Unbonded Portland Cement Concrete Overlays

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Introduction

An unbonded portland cement concrete (PCC) overlay is a pavement rehabilitation technique in which a separator layer (generally hot-mix asphalt [HMA]) is placed between the existing PCC pavement and a new PCC overlay (see figure 1). This separation layer is placed to ensure independent behavior between the two slabs, thereby minimizing the potential for reflection cracking. Unbonded PCC overlays are typically constructed between 152 and 305 mm (6 and 12 in) thick.

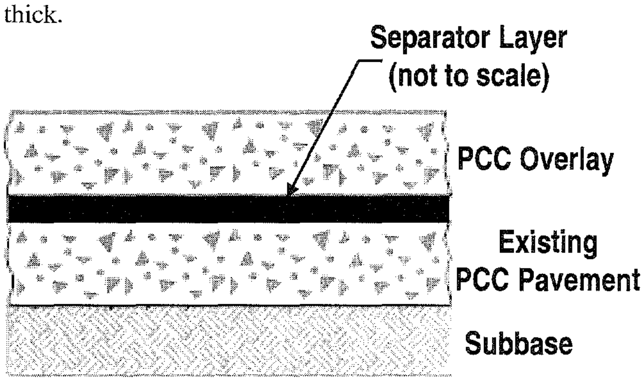

Figure 1. Unbonded PCC overlay (McGhee 1994).

Unbonded PCC overlays are a feasible rehabilitation alternative for PCC pavements in practically any condition because the performance of unbonded overlays is relatively insensitive to the condition of the existing pavements. However, the most likely candidate pavements are typically those with extensive deterioration, including those with material-related distresses (MRD) such as alkali-aggregate reactivity (AAR) or D-cracking. Because the performance of the PCC overlay is less dependent upon the underlying pavement condition as compared to other overlay techniques (including HMA overlays and bonded PCC overlays), minimal preoverlay repairs are required. Unbonded overlays can be constructed as jointed plain, jointed reinforced, or continuously reinforced concrete pavement (JPCP, JRCP, or CRCP), although unbonded JPCP overlays are by far the most common. Current pavement practice is away from JRCP designs, and these are rarely constructed any more.

Although the performance of unbonded PCC overlays has generally been good, there are several unresolved aspects of unbonded PCC overlay design. For example, the effects of preoverlay repair and separator layer design on the performance of unbonded overlays cannot be shown conclusively with the available performance data, analysis tools, or performance models. Also, in the past, any bonding between the pavement layers in unbonded overlays was thought to cause poor performance; however, current thinking is that a certain amount of bonding (or friction) between the separator layer and the overlay is essential for good performance.

General Design Considerations

The design of unbonded overlays requires consideration of factors that are applicable to both new and rehabilitation design, as shown in table 1. In urban areas, where traffic congestion is already a daily problem, management of detour traffic during construction can also be a critical issue. For projects in congested areas, the use of fast-track paving techniques may be appropriate to minimize lane closure time. With fast-track paving techniques, PCC pavement reconstruction and PCC overlays can be constructed with weekend lane closures.

Pavement Evaluation

The existing pavement condition is a key input to overlay design. Field evaluation of candidate pavements for unbonded overlays typically consists of a visual distress survey, deflection testing using falling weight deflectometer (FWD), and coring. If MRD such as D-cracking or alkali-silica reactivity distress is present, laboratory testing of the cores may also be needed to verify the nature of MRD and to avoid similar problems in the overlay PCC. The structural integrity of the existing pavement is typically estimated based on visual distress surveys and FWD testing results. The condition survey is also important for identifying the areas that should be repaired prior to overlaying and for identifying MRD or drainage problems that may require special design considerations.

Table 1. Key design factors for unbonded PCC overlays.

Design Factors Unique to Rehabilitation Design	Design Factors Common to New and Rehabilitation Design
• Existing pavement condition • Existing pavement type • Overlay pavement type • Preoverlay repair • Separator layer design	• Slab thickness • Joint spacing • Load transfer design • Reinforcement design • Edge support (tied PCC shoulder or widened slab design) • Subsurface drainage • PCC mix design

FWD testing is also extremely valuable in characterizing the existing pavement condition. The information that can be obtained through FWD testing includes the following:

- Backcalculated subgrade k-value and PCC modulus.
- Subgrade variability.
- Load transfer efficiency.
- Presence of voids under joints and cracks.

The backcalculation can be accomplished using any established procedures, such as those included in the 1993 AASHTO Design Guide (AASHTO 1993) or in the 1998 AASHTO Supplement (AASHTO 1998). More detailed information on PCC pavement backcalculation is provided by Hall (1992).

Preoverlay Repair

As previously mentioned, unbonded PCC overlays generally require minimal preoverlay repairs. Only major distresses that cause a major loss of structural integrity, such as shattered slabs and punchouts, require repair. The recommended preoverlay repairs for unbonded overlays include the following (Hutchinson 1982; ACPA 1990; ERES 1999):

- Full-depth repair of shattered slabs, punchouts (CRCP), and high-severity transverse cracks.
- Slab stabilization of unstable or rocking slabs.
- Diamond grinding or milling if faulting exceeds 6 mm (0.25 in). Alternatively, a thicker separator layer (50 mm [2 in] HMA) may be used to address faulting greater than 6 mm (0.25 in).
- Patching of high severity spalling with HMA.
- Leveling up of significant settlements with HMA.

In general, if an unbonded CRCP overlay is to be constructed, more attention must be paid to preoverlay repair activities to ensure that the existing distresses do not reflect through the new overlay (ERES 1999). Depending upon the condition of the existing pavement, a thicker separator layer, a higher steel content, or a thicker overlay may be used to address concerns for reflection cracking.

As an alternative to preoverlay repairs, the existing pavement may be fractured to provide more uniform support under the overlay. For pavements with severe MRD, slab fracturing may be particularly applicable. If left intact, the continued progression of MRD in the original pavement can cause premature deterioration of thin (178 mm [7 in]) unbonded overlays (ERES 1999).

Structural Design

Thickness Design

The required overlay thickness is typically determined using either AASHTO (1993) or the Portland Cement Association (PCA) (Tayabji and Okamoto 1985) design procedures. However, thickness design is an area of critical deficiency in current practice for unbonded overlays, as all major design procedures have significant limitations. Some of the major flaws include the following:

- Lack of consideration of layer interaction. The structural contribution of the separator layer and the effects of friction between the overlay and the separator layer and between the separator layer and the underlying PCC pavement are ignored.
- Excessive credit given to existing pavement in some cases. Design procedures that are based on structural deficiency (e.g., AASHTO [1993]) tend to produce unconservative results when the existing pavement is relatively thick.

- Lack of consideration of curling and warping stresses. This is a particularly critical deficiency for unbonded JPCP overlays that often leads to unconservative overlay thicknesses.

An alternative to the use of the existing overlay design procedures is to use the 1998 AASHTO Supplement Procedure, which although for new pavement design may be used as it accounts for the friction between the slab and a stiff base as well as the interactive effect of joint spacing (AASHTO 1998). However, the overlay thickness alone does not by itself ensure good performance, and other factors such as preoverlay repairs, separator layer design, and joint design must be adequately considered.

Separator Layer Design

The separator layer performs the following key functions (ERES 1999):

- Isolates the overlay from the underlying irregularities to allow uninhibited horizontal movement.
- Provides adequate friction to ensure proper formation of joints in JCP and cracks in CRCP. The friction between pavement layers also contributes to the composite action that is beneficial to overlay performance.
- Provides a level surface for the overlay construction.

The recognition that total debonding of the pavement layers is not essential or desirable for proper functioning of unbonded overlays is an important recent development in unbonded overlay design. However, the modeling of the structural effects of the separator layer is an area needing further research.

A variety of separator designs have been used in unbonded PCC overlay construction. The design that has given the best results are thick (minimum 25-mm [1-in]) HMA layers (Voigt, Carpenter, and Darter 1989; ACPA 1990; Hall, Darter, and Seiler 1993, ERES 1999). Although the use of thin layer materials (such as chip seals or slurry seals) have worked well in some applications, their use is generally not recommended because they erode easily near joints and they do not provide adequate isolation of the overlay PCC from underlying deterioration if the existing pavement has significant roughness from faulted joints and cracks (ACPA 1990; ERES 1999).

Joint Spacing

Because of the concern for high curling stresses, a shorter joint spacing is typically recommended for unbonded JPCP overlays. The current AASHTO guide recommends limiting the maximum joint spacing to 21 times the slab thickness. In general, this recommendation is reasonable for slab thicknesses up to about 229 mm (9 in), except that joint spacing less than 3.7 m (12 ft) is not warranted because that would make the slabs shorter than the lane width. However, for thicker slabs (e.g., more than 240 mm [9.5 in]), the joint spacing based on 21 times the slab thickness is excessive, which increases the risk of premature slab cracking. In general, this risk can be greatly minimized by limiting the maximum joint spacing to 4.5 m (15 ft), even for very thick overlays.

Current pavement design practices are away from the use of JRCP designs, and they are rarely constructed any more. If used, the recommended maximum joint spacing for JRCP is 9.1 m (30 ft) (FHWA 1990).

Load Transfer Design

The joint performance is significantly better in unbonded overlays than in new JPCP because of the load transfer provided by the underlying pavement (Hall, Darter, Seiler 1993; ERES 1999). However, doweled joints are still highly recommended for pavements that will be subjected to heavy truck traffic to avoid corner breaks and to minimize faulting. Without dowels, the risk of corner breaks is high in unbonded overlays because of the very stiff support conditions. To maximize the benefits of load transfer from the underlying pavement, it is recommended that the joints in the overlay be mismatched from those in the underlying pavement (see figure 2).

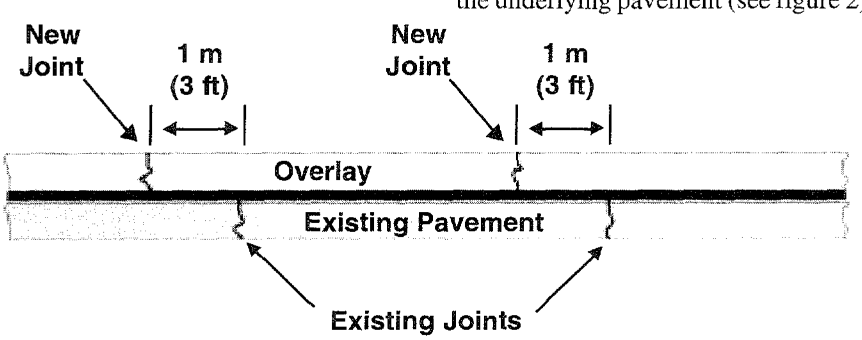

Figure 2. Illustration of mismatched joints (ACPA 1990).

Job-Site Considerations

Because unbonded overlays add significant thickness to the overall pavement cross section, short sections of reconstruction may be required at bridge underpasses to maintain adequate overhead clearance. In such cases, transition sections are required at both ends to provide smooth transition from the overlay elevation to that of the reconstructed section. The recommended taper length is 90 to 150 m (300 to 500 ft). A similar transition section is also needed at bridge approaches.

Performance of Unbonded Overlays

In general, the performance of unbonded overlays has been very good (McGhee 1994; ERES 1999). Where premature failures have occurred, the failures have been attributed to poor separator layer design, excessive joint spacing, or inadequate slab thickness (McGhee 1994; ERES 1999). Field performance data suggest that the risk of poor performance is high for thinner unbonded overlays (less than 152 mm [6 in] for JPCP and less than 178 mm [7 in] for CRCP).

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