THIN CONCRETE OVERLAYS

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INTRODUCTION TO OVERLAYS

Thin concrete overlays have been successfully used in the United States for extending the life of existing concrete, asphalt, or composite pavements. These overlays can accommodate a variety of needs, such as extending performance lives by as much as 15 to 20 years, meeting rapid construction requirements, and conforming to any specific traffic management constraints (Tayabji et al. 2009). In addition, a properly designed and constructed concrete overlay requires little maintenance over its service life, resulting in reduced life-cycle costs. Concrete overlays less than 6 inches (152 mm) thick are commonly identified as "thin" concrete overlays, while the term "ultra thin" is sometimes used to refer to overlays less than 4 inches (102 mm) thick. These thin overlays also feature smaller slab sizes, with 6 ft by 6 ft (1.8 by 1.8 m) panels commonly used. This technical brief provides a review of thin concrete overlays, and is supplemented with a summary of four case studies to illustrate the range of applications for thin concrete overlays.

Thin Concrete Overlay Types and Definitions

Thin concrete overlays are classified according to the type of the existing pavement and the design composite action (i.e., bonding condition). When the overlay is bonded to the existing pavement in order to behave as a monolithic structure, the overlay is referred to as "bonded." If the overlay is separated from the underlying pavement (by placing a separator layer) or designed assuming some degree of slippage at the interface with the existing pavement, the overlay is considered "unbonded." Concrete overlays placed on existing asphalt or composite (i.e., asphalt overlay of a concrete pavement) pavements are sometimes called "whitetopping." These concrete overlay types are summarized in figure 1.

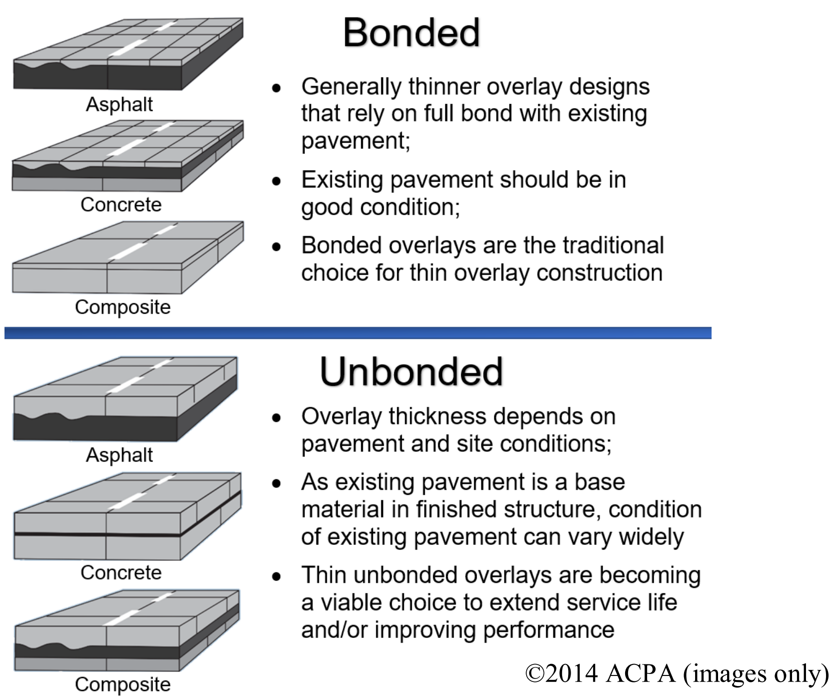

Figure 1. Concrete overlays for different pavement systems (images from Harrington and Fick 2014).

OVERVIEW OF THIN CONCRETE OVERLAYS

Over 20 years of extensive field experience has revealed that thin concrete overlays are a viable, cost-effective solution that can be used to extend the service life, increase the structural capacity, and improve the ride quality of existing pavements under a range of traffic and site conditions. An important benefit of thin concrete overlays is that they can be applied to pavements with a variety of conditions and exhibiting a wide range of performance issues.

Key Concepts

Thin overlays, either bonded or unbonded, can be applied to existing asphalt, concrete, and composite pavements. The selection of a bonded or unbonded overlay is largely dependent on the condition of the existing pavement. In general, thin bonded concrete overlays can be used over existing pavements that do not exhibit significant structural distresses (except rutting of the existing asphalt pavement) or durability problems. As the existing pavement condition deteriorates, the use of unbonded concrete overlays becomes an attractive rehabilitation option, as unbonded overlays require very little pre-overlay repair. In either case—bonded or unbonded—the thickness of the thin overlay will vary based on the type of application, the design traffic loadings, and the condition of the existing pavement.

Evaluating Existing Pavement Structures for Thin Concrete Overlays

The evaluation of the existing pavement is the first step in determining the appropriate rehabilitation alternative. The evaluation seeks to identify and characterize the existing pavement in terms of distresses (e.g., cracking, rutting), structural condition (i.e., ability to carry load), functional performance (e.g., roughness, noise), and material-related issues (e.g. D-cracking). An understanding of these characteristics will help guide the selection of the appropriate type and thickness of the overlay.

There are a number of resources available that provide detailed procedures to evaluate a pavement prior to placing an overlay (e.g., Harrington and Fick 2014). The evaluation process varies by project but ultimately results in a general condition assessment profile, as illustrated in figure 2. The application of this procedure will result in a full project evaluation that can be used to determine the type and thickness of overlay.

The majority of overlays placed in the field are unbonded overlays. This is due primarily to their ability to accommodate high traffic volumes and most any type of distress in the existing pavement. Thus, in figure 2, the first and third portions of the project describe two candidates for unbonded overlays of different thicknesses. The first portion, given the severity of cracking and high traffic, may be more suited for a conventional unbonded overlay. The third portion may be a candidate for a thin unbonded overlay, given the low traffic volumes and the assumption that the existing pavement is suitable.

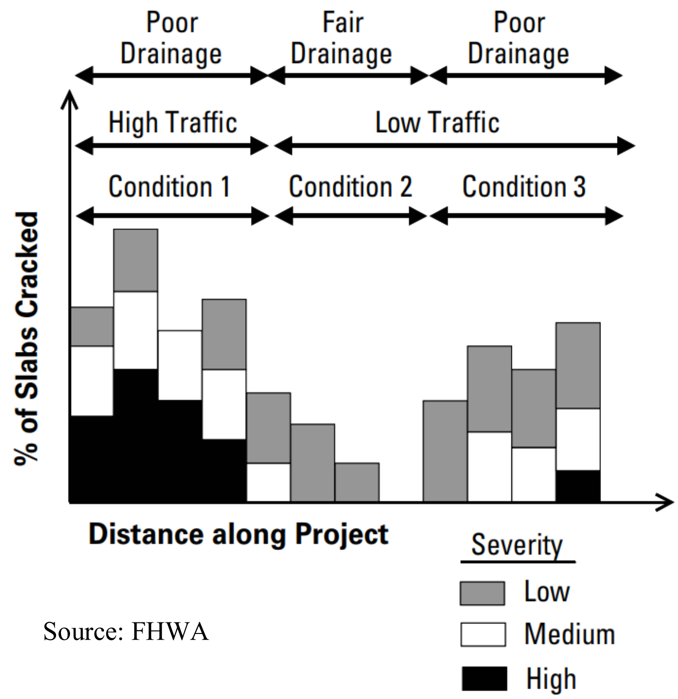

Figure 2. Example condition profile illustrating distress levels in an existing pavement (Smith et al. 2014).

In general, when existing concrete pavements present any level of material durability issues, unbonded overlays should be selected. Likewise, in existing asphalt pavements with either higher levels of cracking or rutting that are not restricted to the asphalt layers, unbonded overlays are more appropriate.

However, if an existing pavement is in good structural condition (i.e., it requires minimal pre-overlay repair), one may consider the use of bonded overlays. Therefore, the middle portion of the example project in figure 2 may be a candidate for a bonded overlay, as this portion has little cracking, is exposed to lower traffic volumes, and exhibits fair drainage, which in combination with adequate base layer construction should provide uniform support for the existing slab and bonded overlay.

Effectiveness and Limitations

Thin bonded concrete overlays are a proven, cost-effective rehabilitation solution for existing asphalt pavement that are in good structural condition, including asphalt pavements with severe rutting (Han 2005). They are especially effective for cases where the existing asphalt pavement is subjected to heavy traffic and/or braking areas where traffic comes to stop.

For existing concrete pavements, thin concrete overlays can be effective in the following cases:

- If the design period is relatively short (10-15 years), a thin unbonded overlay is a cost-effective alternative to an asphalt overlay.
- For low-to-medium levels of traffic, a thin unbonded overlay is a cost-effective alternative to conventional unbonded overlays.
- If grade limitations do not allow for a conventional unbonded overlay, then a thin unbonded overlay may be a cost-effective alternative to reconstruction.
- For rehabilitation cases when an increase in heavy traffic is expected, thin bonded overlays can be effective if the structural capacity is accounted for in the design. However, the long-term performance of a thin bonded overlay relies heavily on the overlay bond with an existing concrete pavement. Thus, while thin bonded overlays can succeed, their demands in both design and construction make them a high-risk/high-reward rehabilitation solution.

The implementation and successes of thin concrete overlays have grown since their emergence in the late 1990s. However, some of those early overlays did show some premature failures—particularly in the application of ultra-thin overlays—due in part to construction issues but also to the design thickness and inappropriate use. For instance, some industry recommendations point to the use of thin bonded overlays in rehabilitating existing asphalt that has experienced thermal cracking. This should be considered carefully given that the presence of full bond may lead to considerable reflective cracking if the extent of thermal cracking has been even marginally underestimated. Figure 3 illustrates corner breaks in a thin unbonded concrete overlay, which may be due to compromised support conditions due to neighboring asphalt thermal cracking and moisture penetration. Likewise, bonded overlays may be even more sensitive to thermal cracking in the existing pavement (or shoulder).

Figure 3. Corner-cracked panel adjoining thermally cracked asphalt shoulder in 5-inch (125 mm) unbonded overlay along TH-53 in Minnesota.

In general, the pavement evaluation and selection process is most effective when it includes both agency and contractor experience. Each agency may have its own evaluation procedure, and the selection process should consider agency experience with overlays and agency design practices. Furthermore, local contractor experience with thin overlay construction should be taken into account.

DESIGN OF THIN CONCRETE OVERLAYS

Two general design procedures are available for concrete overlays:

- The 1993 AASHTO Guide for Design of Pavement Structures, 4th Edition (AASHTO 1993) is applicable to the design of bonded concrete overlays.
- The current AASHTO Mechanistic-Empirical (M-E) procedure can be used for the design of bonded and unbonded concrete overlays of 4 inches (102 mm) in thickness or more and joint spacing greater than 12 ft (3.6 m), as implemented in the AASHTO Pavement ME Design software and described in the AASHTO MEPDG Manual of Practice (AASHTO 2015).

In addition, several procedures are available that specifically address the design of bonded concrete overlays of asphalt pavements:

- The BCOA-ME method and associated software, both of which were developed under FHWA Pooled Fund Study TPF 5-165 (University of Pittsburgh 2012; Vandenbossche, Dufalla, and Li 2013).
- AASHTO Pavement ME Design Version 2.3 includes an adaptation of the TPF 5-165 design procedure for thin, bonded concrete overlays of asphalt pavements with joint spacings greater than 5 ft (1.5 m).
- The American Concrete Pavement Association (ACPA) method and software, which can also be applied to bonded concrete overlays of composite (i.e., asphalt over concrete) pavements (ACPA 2006).
- The Colorado Department of Transportation (CDOT) method (Tarr, Sheehan, and Okamoto 1998).

Both the BCOA-ME method and the ACPA method are capable of designing bonded concrete overlays of existing asphalt pavements as thin as 3 inches (76 mm).

Finally, there are several procedures available for the design of unbonded concrete overlays of existing concrete pavements. Because those procedures typically produce thicker overlays, their application to thin overlay projects should be considered as a preliminary design. These procedures include:

- The Portland Cement Association (PCA) method (Tayabji and Okamoto 1985).

- The Minnesota Department of Transportation (MnDOT) method (MnDOT 2010), which uses an average of the Army Corps of Engineers Rigid Overlays for Airfields method (UFC 2001) and the PCA method as a recommended overlay thickness.

Design Features

Joint Spacing and Layout

An important design concern for thin concrete overlays is the joint spacing and layout. As mentioned previously, thin concrete overlays typically use joint spacings and layouts that are much shorter than conventional joint spacings, with the following considerations:

- To reduce curling stresses in the overlay and shear stresses at the concrete/asphalt interface, the bonded overlay panels of asphalt pavements are typically 6 ft by 6 ft (1.8 m by 1.8 m) or less in dimension.
- The jointing pattern of the bonded concrete overlay of existing concrete pavement must match the jointing pattern of the existing pavement to avoid reflection cracking.
- Another important issue with the use of short joint spacing is the joint layout in relation to the location of traffic loads. For example, the Minnesota Road Research facility (MnROAD) observed that 4 ft by 4 ft (1.2 m by 1.2 m) panels failed before 6 ft by 6 ft (1.8 m by 1.8 m) panels because the use of 4 ft by 4 ft (1.2 m by 1.2 m) panels places a longitudinal joint directly in the wheelpath of the trucking lane (Burnham 2008).

Interlayer

An interlayer (or separation layer) is used in unbonded overlays of existing concrete pavements to separate the overlay from the existing pavement. The interlayer is commonly referred as the “stress-relief” or “crack arresting” layer; that is, the interlayer is a region that allows the overlay and existing pavement to move independently in the horizontal direction. Thus, distresses in the existing pavement are less likely to propagate into the overlay. Interlayers are typically constructed using roughly 1 to 2 inches (25 to 51 mm) of asphalt, however some agencies have experience using geosynthetic fabric as an alternative interlayer.

Joint Load Transfer

Dowel bars are not used in bonded overlays. For thin unbonded overlays the presence of dowels in thin overlays creates constructability issues (e.g., paver clearance over dowel baskets), and the low concrete cover may lead to spalling. Fibers may be added to improve load transfer between panels, and may also be important to prevent erosion of the interlayer and base material and later distress issues (Hansen and Liu 2013). The use of tie bars for longitudinal reinforcement is recommended when heavy traffic loads are anticipated. Both Colorado and Iowa have documented their experience with the use of tie bars in both thin and ultra-thin overlay projects (Rasmussen and Rozycki 2004).

Shoulder

Shoulder type selection is often influenced by existing conditions and constructability considerations. For example, the presence and type of widening units in the existing pavement can influence shoulder selection. Also, lack of clearance or right-of-way can prevent the construction of concrete shoulders. Regardless of the selection, available design procedures can accommodate and compare different options for the shoulder. Whereas some methods, such as the CDOT method, assume concrete shoulders with tied longitudinal joints by default, the AASHTO M-E method allows for the selection of tied shoulders with variable load transfer efficiencies.

Drainage

Prior to the design process, the drainage capability of the existing pavement should be evaluated to determine if steps should be taken to provide adequate drainage. This may include cleaning existing measures (e.g., underdrains, outlets) to improve drainage during the overlay preparation process. For unbonded overlays, an additional drainage concern is the drainage capacity of the interlayer. In dry climates, the interlayer may not require attention in terms of drainage; however, when moisture penetration is a concern, interlayer design should address the need for moisture to exit the interlayer. One solution is to use fabrics with higher levels of permeability and transmissivity.

CONSTRUCTION OF THIN CONCRETE OVERLAYS

The construction of thin concrete overlays is well established in existing literature, and detailed guidelines for concrete overlay construction are available (Harrington and Fick 2014). The most notable concern for overlay construction, particularly for bonded overlays, is adequate preparation of the existing pavement for the overlay. The following subsections highlight some overlay construction issues that are particularly relevant to thin overlays.

Concrete Mixture

Overlay mix designs are typically similar to conventional paving mixes. There are, however, a few unique considerations that may require a special mix design.

- Thin concrete overlay designs may call for the incorporation of fibers into the overlay paving mix. The use of fibers is accommodated by both the ACPA and BCOA-ME methods for the design of thin bonded overlays of asphalt or composite pavements.
- For bonded concrete overlays of existing concrete pavements, the use of a concrete mix with similar thermal properties as the existing pavement is

recommended to minimize the shear stress at the new and old concrete interface.

- Since thin overlays are often used as rapid rehabilitation solutions, narrow time-to-opening windows may require the use of special concrete mix designs. In this case, the agency should prescribe a mix design for the overlay that provides the needed strength (or other performance measures) at a specified time.

Pre-Overlay Repair

For overlays of asphalt pavements, pre-overlay repair operations are controlled by the type of overlay and the condition of the pavement after milling (if performed). For bonded overlays of asphalt, milling of the existing surface is conducted to promote good bonding and minimize shear stresses at the concrete–asphalt interface. For unbonded overlays of existing asphalt, milling may be required if there is shoving or rutting in excess of 2 inches (51 mm).

Typically, unbonded overlays of asphalt require very little pre-overlay repair. For bonded overlays of existing asphalt pavements, pre-overlay repairs after milling will focus on local issues such as potholes, areas of severe alligator cracking, and/or areas that indicate poor slab support. Transverse thermal cracks can be cleaned and filled to ensure proper support for the overlay under loading (Harrington and Fick 2014).

For overlays of existing concrete pavements, the required pre-overlay repairs will depend on the type of overlay selected (which in turn is decided primarily by the level of distress). For unbonded overlays of concrete, pre-overlay repairs should focus on providing a sound underlying structure for the interlayer and overlay, although Harrington and Fick (2014) note that some agencies choose to increase overlay thickness as an alternative to pre-overlay repair. For bonded overlays of concrete, pre-overlay inspection and repair should make certain that support conditions are uniform and that any existing distresses are accounted for. Voids under the existing slab should be stabilized, and existing cracks or patches should be addressed to ensure uniform bond between the overlay and existing slab.

In addition, prior to the placement of the interlayer, improvements to the existing pavement system to improve drainage may be warranted. These activities may include cleaning of existing drains or installing a retrofitted drainage system. Drainage should not be overlooked in the process, as Hansen and Liu (2013) observed poor drainage conditions in an extensive study of concrete overlays, and they were able to confirm the presence of pumping and base erosion that led to surface distresses (faulting and top-down cracking) and overall reductions in ride quality.

Interlayer Placement

Interlayers help mitigate reflection cracking and reduce peak pressures due to vehicle loads. Interlayers for unbonded concrete overlays are typically constructed using 1 to 2 inches (25 to 51 mm) of asphalt. Recently geosynthetic fabric interlayers have become a popular, more economic option. While the placement of asphalt interlayers is well understood, the use of geotextile interlayers is fairly recent and placement practices vary from agency to agency. Rasmussen and Garber (2009) detail general guidelines for geotextile interlayer installation, which include:

- The geotextile should lay smoothly, without obvious wrinkles and folds.
- The geotextile should be installed no more than 2 to 3 days before the placement of the concrete.
- No more than three layers of geotextile should overlap at any location.

Field trials in Missouri and Oklahoma of fabric interlayers included wetting (but not saturating) the geotextile prior to overlay placement.

Finally, for both bonded and unbonded overlays, interlayer placement may also include “daylighting” or connecting the interlayer to conduits for adequate layer drainage where drainage capacity is a concern.

Concrete Placement and Curing

Aside from adequate surface preparation for bonded overlays, the placement and curing processes are similar to those of conventional concrete paving. As noted in previous sections, excess shrinkage and/or improper surface preparation can lead to debonding at the concrete-asphalt interface. Thus, placement of the thin concrete overlay requires care. For example, if the surface temperature of the existing pavement is particularly high (e.g., in excess of 120 °F [49 °C]), it is recommended to sprinkle the surface with water to cool, and then remove standing water using compressed air just ahead of the paver. In addition, thin bonded overlays should be placed when the difference in the mix temperature and the existing pavement is minimal.

Figure 4 shows the placement of a thin bonded overlay on a milled asphalt pavement in North Dakota.

Joint Saw Cutting and Matching

Joint saw cutting is an important construction step for thin concrete overlays. As an example, in monitoring the construction of a thin overlay along TH-53 near Duluth, MN, MnDOT observed delayed joint saw cutting because the sawing crew was unprepared for the speed of thin overlay placement, which is naturally faster than that of conventional overlays (Watson and Burnham 2009).

Figure 4. Placement of a 4-inch (102 mm) bonded overlay on a milled asphalt pavement near Devils Lake, ND (NDRMPCA 2015).

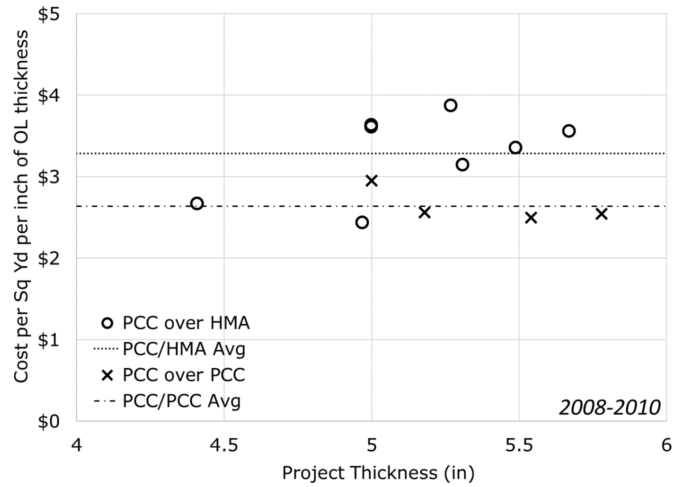

Figure 5. Overlay cost per square yard-inch of overlay thickness for twelve thin concrete overlay projects constructed in 2008 and 2009 in four states (data source: Fick 2010).

In addition, and as described previously, the matching of transverse and longitudinal joints in the overlay to those in the underlying concrete pavement is critical for bonded overlays, and requires careful workmanship in locating those joints and sawing them to the prescribed depth. Furthermore, saw cutting in unbonded overlays of existing asphalt pavements may need to account for rutted asphalt to maintain the specified saw cut depth. That is, it may be necessary to cut deeper to ensure the formation of the weakened plane joint. Recommended minimum saw depths depend on the overlay and joint type, as presented below (Harrington and Fick 2014):

- Bonded concrete on concrete:
  - Transverse: Full thickness of bonded overlay plus 0.5 inch (13 mm).
  - Longitudinal: Minimum 1/2 of the overlay thickness.
- Bonded concrete on asphalt or composite and all unbonded overlays:
  - Transverse: 1/4 to 1/3 of the overlay thickness.
  - Longitudinal: 1/4 to 1/3 of the overlay thickness.

Joint Sealing

Conventional joint sealant materials and methods can be used in thin concrete overlay construction. In general, the use of joint sealing for thin overlays depends on whether the water is assumed to leave the pavement system.

COST

General

A simple overview of thin overlay project costs is provided in figure 5 (Fick 2010). This figure represents project costs for thin overlays bid and constructed during 2008 and 2009, where the total cost in this case excludes the costs of pre-overlay repairs and the costs of the placement of the separation layer (including interlayer material costs and surface preparation).

In general, the costs during this time period for the eight thin whitetopping and four thin overlays of existing concrete projects are fairly stable, and represent projects constructed in Illinois, Iowa, Minnesota, and Oklahoma. The project costs reported in figure 5 are normalized to the project thickness, as raw costs per square yard generally increase with overlay thickness, as noted by Fick (2010). Also indicated in figure 5 is the average cost by reported project type; as of 2010, a thin whitetopping project was reported to cost an average of \$3.28 per yd^2 per overlay inch (\$0.15 per m^2 per overlay mm). Similarly, the average cost for a thin overlay of concrete was \$2.64 per yd^2 per overlay inch (\$0.12 per m^2 per overlay mm).

A study of thin overlay construction costs currently underway surveyed 33 overlay projects in 7 states (J. Gross, July 14, 2017, Personal Communication). Of these projects, 28 had an overlay thickness of 6 inches (152 mm) or less. A summary of the costs for these 28 projects is provided in figure 6. Fifteen of the reported projects are whitetopping, with the remainder being overlays of existing concrete, and the estimated costs are based on design overlay thickness rather than the as-built thickness as in Fick (2010). According to the reported cost data and assumed thicknesses, between 2010 and 2015, a thin whitetopping project cost an average of \$4.32 per yd^2 per overlay inch (\$0.17 per m^2 per overlay mm) whereas a thin overlay of concrete cost an average of \$3.70 per yd^2 per overlay inch (\$0.16 per m^2 per overlay mm). Both average costs represent an increase over the pre-2010 values (see figure 6) of 32 and 40 percent, respectively.

Given the extent of the cost information available from 2008 forward, one can estimate the construction costs of a thin overlay to fall between \$3.00 and \$4.00 per yd^2 per overlay inch (\$0.13 and \$0.16 per m^2 per overlay mm).

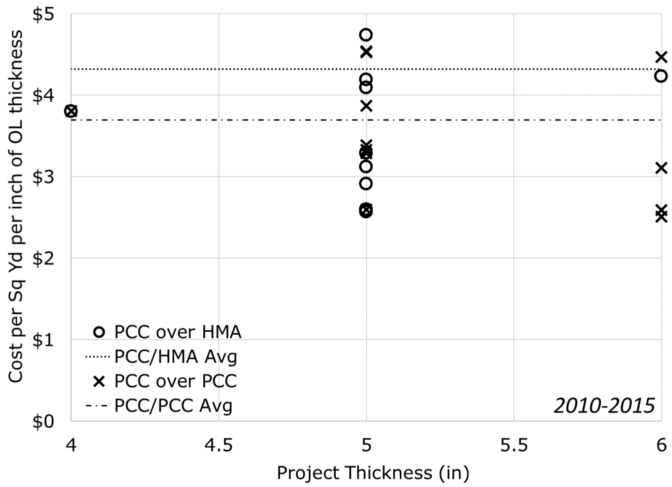

Figure 6. Overlay cost per square yard-inch of overlay thickness for twenty-eight thin concrete overlay projects constructed between 2010 and 2015 in seven states (data source: J. Gross, July 14, 2017, Personal Communication).

Impact of Panel Dimensions on Material and Construction Costs

There is no information available from highway agencies that has provided insight on the correlation of construction costs to the panel size of thin concrete overlays. In general, as panel dimensions decrease, the amount of sawing (in linear feet) required will increase.

Table 1 provides a simple calculation of the amount of sawing required for 60 linear ft (18.3 m) of a two-lane pavement of width 24 ft (7.3 m). As shown in this table, a 6 ft by 6 ft panel (1.8 m by 1.8 m) size requires two and a half times the amount of saw cuts (in linear feet) as a 12 ft by 12 ft (3.7 m by 3.7-m) panel; likewise, a smaller 4 ft by 4 ft (1.2 m by 1.2 m) panel requires nearly four times as much sawing as a 12 ft by 12 ft (3.7 m by 3.7 m) panel.

While the cost of additional sawing does not approach the cost savings associated with using less thickness for the overlay, the “time cost” of sawing and the effects of the need for additional sawing on the project should be considered. As noted in the construction and case studies section, saw cutting crews should account for the faster speed of thin overlay placement relative to its thicker counterpart, and should also recognize the increased joint sawing quantities associated with thin concrete overlays. Moreover, thin concrete overlays have a higher ratio of surface area to volume, making them more susceptible to random cracking if the joints are not sawed in a timely fashion. Thus, sufficient sawing crews and equipment should be mobilized in order to match the pace of paving and to accommodate the required sawcutting quantities.

Table 1. Simple calculation for required saw cutting for various overlay panel sizes over 60 linear ft (18.3 m) of a two-lane (24-ft [7.3-m]) pavement.

Panel Length	Panel Width	Latitudinal Cuts	Longitudinal Cuts	Total Saw Cutting	Amount of sawing relative to 12-by-12 ft. panel
15	12	3 cuts, 72 ft	1 cut, 60 ft	132 ft	90%
12	12	4 cuts, 96 ft	1 cut, 60 ft	156 ft	100%
6	6	9 cuts, 216 ft	3 cuts, 180 ft	396 ft	254%
4	4	14 cuts, 336 ft	5 cuts, 300 ft	636 ft	408%

CASE STUDIES

This section presents four case studies that help to illustrate the application and experience with thin concrete overlays.

Case Study 1: Thin Unbonded Overlay in the City of Toronto

Introduction and Design

In 2003, the City of Toronto rehabilitated a composite pavement at an intersection that received a high volume of bus traffic (Kivi et al. 2013). This rehabilitation involved the use of a 6-inch (152 mm) unbonded concrete overlay and a 1-inch (25 mm) asphalt interlayer atop the existing 8-inch (203 mm) concrete pavement. The finished overlay used a panel size of 5 ft by 5 ft (1.5 m by 1.5 m), and dowel bars were used only at turning or stopping locations to provide structural support for static or slow-moving vehicle loading. The design was intended to accommodate over 30,000 vehicles per day (although in the first 10 years of service, the section experienced an estimated 3.5 million ESALs due to transit buses alone). The rehabilitated intersection comprised nearly 280 ft (85 m) of street pavement.

The project received extensive pre-overlay preparation and repair. The existing composite pavement was milled to remove asphalt, and cracks in the existing concrete slab were routed and sealed. The overlay was placed using formwork.

Section Performance

The section was monitored by researchers from the University of Waterloo for 10 years after overlay construction. In addition to regular observation, the monitoring by researchers included the use of embedded strain gauges to measure slab response to loading. The general performance of the section was very good, and very little distresses were observed over the first 10 years of service. No additional maintenance or rehabilitation was performed over that time.

In addition, the use of strain gauges led to a surprising finding: the lack of tensile strains at the bottom of the overlay suggested the presence of bond in what was intended to be an unbonded design. However, as evidenced by the performance, the bond formed did not lead to the propagation of distress from the existing pavement into the overlay.

Conclusions

The adoption of this thin overlay in an urban setting was considered a major success by the City of Toronto, which had been accustomed to experiencing recurring rutting and shoving in the asphalt surface course due to bus traffic. The City and researchers maintained that the thin overlay would meet and exceed its 25-year service life target (Kivi et al. 2013).

Case Study 2: Thin Whitetopping in Illinois: Highway 4, Piatt County

Introduction and Design

In 2000, the Illinois Department of Transportation (IDOT) rehabilitated a 4.94-mi (8-km) section of Highway 4 in Piatt County using a 5-inch (127 mm) overlay of an existing asphalt pavement. The existing asphalt, after milling, was 4 inches (102 mm) thick and rested on a cement-treated base. The overlay was constructed using two different panel sizes: 5.5 ft by 5.5 ft (1.7 m by 1.7 m) and 11 by 11 ft (3.4 by 3.4 m) with skewed transverse joints. The traffic volume as of 2013 was 2,150 vehicles per day, which included 7.2 percent heavy commercial truck traffic (King and Roesler 2013).

Section Performance

Winkelman (2005) reported that the section experienced very little cracking in its first 4 years of service: 0.2 percent of the 5.5-ft (1.7 m) panels were cracked, whereas 1.0 percent of the 11-ft (3.4 m) panels had cracked. It was noted that many of these reported cracked panels were in fact “sympathy” cracks: that is, cracks induced by neighboring distressed panels or neighboring distresses in the shoulder. For this project, the construction of a driveway in 2003 induced cracking in neighboring panels.

King and Roesler (2013) later summarized a condition survey by IDOT, which found that after 8 years of service the section experienced severe faulting. The observed cracking was found to be longitudinal cracking and corner breaks. During the final survey in 2012, IDOT observed that 1.4 percent of 5.5-ft (1.7 m) panels were cracked, whereas 17.8 percent of the 11-ft (3.4 m) panels had cracked. However, the extent of cracking in the 11-ft (3.4 m) panels may have been as much a local issue as a global one: King and Roesler (2013) note that over half of the reported cracking for the 11-ft (3.4 m) panels is restricted to a local portion of the total project, and this portion of the roadway was slated for rehabilitation as of 2013.

Conclusions

The extent of this case study provides a good basis for comparing the effects of panel size. Both the 4-year and 8-year reports note that the smaller panel size was associated with significantly less panel cracking. However, the correlation between cracking and panel size may be difficult to establish, due to the use of skewed joints. Furthermore, the fact that the majority of cracking was found to be a local phenomenon in this case study points to the importance of pre-overlay repairs and preparation.

Case Study 3: Thin Bonded Overlays in Virginia: I-295 near Richmond and I-85 near Petersburg

Introduction and Design

The Virginia Department of Transportation (VDOT) rehabilitated two stretches of existing continuously reinforced concrete pavement (CRCP) using two thin bonded overlays: a 2-inch (51 mm) overlay along a 1600-ft (488 m) stretch of I-295 near Richmond and a 4-inch (102 mm) overlay 1200-ft (366 m) stretch of I-85 near Petersburg (Mokarem, Galal, and Sprinkel 2007).

- The designs employed in the sections focused primarily on material issues. VDOT used the overlays as an opportunity to investigate high performance concretes utilizing steel and polypropylene fibers and fly ash.
- For each section, the existing slab was 8 inches (203 mm) thick and in relatively good condition, aside from local distresses that were remedied prior to overlay. The I-295 section had 16 years of service prior to overlay while the I-85 section was 26-years old at the time of overlay.
- The pre-overlay preparation included patching of minor spalling and punchouts on a small area of the I-85 section. The existing slabs for both sections were shotblasted to improve bonding.
- The overlays were employed to extend the service life of the pavements and to address either spalling concerns otherwise handled through asphalt overlays (the case for I-295) or structural needs of the pavement to meet anticipated traffic volumes (the case for I-85).
- VDOT estimated the construction cost to be \$18.00 per yd^2 (\$19.69 per m^2) for the I-295 section and \$23.75 per yd^2 (\$25.97 per m^2) for the I-85 section (Sprinkel, Mokarem, and Galal 2006).

Section Performance

VDOT evaluated the thin bonded overlays after 4 and 11 years of service. Pavement performance monitoring included skid resistance and FWD testing. In addition, VDOT also conducted extensive testing on the material properties of the concretes used in the overlay sections, including bond strength testing, chain drag testing to estimate in-situ bond, and permeability tests.

Both sections met performance expectations during the 4- and 11-year assessments. VDOT estimated that the 2- and 4-inch (51 and 102 mm) overlays reduced the pavement deflection under loading at critical locations by 31 percent and 43 percent, respectively. In addition to pavement performance expectations, the concrete mix performance was a major concern for VDOT. The mixes used gave the desired strength (in compression) and durability (chloride permeability testing) properties desired.

Conclusions

The VDOT sections are an example an approach to extending in-service pavements using quality thin overlays. As of 2006, VDOT anticipated that these thin overlays would extend the lives of the pavements for 20 years or more. The success in this case may be due in part to the close attention paid to pre-overlay preparation; in particular, effective shotblasting helped obtain the strong, durable bond needed to ensure long-term overlay performance. One unresolved issue from these sections is the use of fibers in the overlay, as no conclusions were made by VDOT in this regard. This may be due to the fact that the sections suffered little to no distresses and thus offered no data for a comparison by mix type/fiber inclusion.

Case Study 4: Thin Unbonded Overlays in Minnesota: TH-53 near Duluth and MnROAD

Introduction and Design

The Minnesota Department of Transportation (MnDOT) conducted an experimental study of two thin overlay pavements, a 500-ft (152 m) test section at MnROAD (Cell 5) and a 9-mi (14.5 km) stretch of pavement along Minnesota TH-53 near Duluth, MN. The MnROAD section and the southbound segment of TH-53 were constructed in 2008, while the northbound segment of TH-53 was constructed in 2009.

Both sections used thin unbonded concrete overlays of 4- and 5-inch (102 and 127 mm) thickness over 7- and 8-inch (177 to 203 mm) slabs. In addition, both sections utilized asphalt interlayers: the MnROAD section interlayer was 1 inch (25 mm) of a permeable asphalt stabilized stress relief layer (PASSRC), whereas the TH-53 section used a 1-inch (25 mm) thick conventional asphalt interlayer. Other design/construction details of note include (Watson et al. 2010):

- In addition to decreasing the thickness of the overlay, the sections taken together involved three different panel configurations. The MnROAD section utilized a panel of 15-ft (4.5 m) transverse joint spacing with widths of 13 or 14 ft (4.0 or 4.3 m). The TH-53 section used panel dimensions of 12 ft by 12 ft (3.7 m by 3.7 m) for the majority of the project, although a 1000-ft (305-m) stretch used a panel dimension of 6 ft by 6 ft (1.8 m by 1.8 m).
- Neither section used dowel bars in the overlay. The existing MnROAD slab was a jointed plain pavement, and the existing TH-53 slab (constructed in 1973) was a jointed reinforced pavement. However, due to the poor condition of some panels along the TH-53 section, steel reinforcement was used in the thin overlays of sufficiently degraded panels – the total amount of the TH-53 containing this reinforcement in the thin overlay was roughly 3800 ft (1.2 km).

- Because the MnROAD section (constructed in 1993) lacked distress in the existing slab, a guillotine-type breaker, often used for crack-and-seat, was used to artificially create distresses in the existing slab. This was done in the hope of inducing later distresses in the thin overlay in the spirit of experimentation (given the nature of MnROAD).

The two-way average annual daily traffic for the TH-53 section was estimated to be 12,300 vehicles per day, of which 580 were heavy commercial trucks. The MnROAD section traffic was estimated in 2011 to be an average of 3,559 heavy commercial trucks per day (Peterson 2011).

Section Performance

Both of the Minnesota thin overlay sections in this case study were closely observed and tested after construction. This included FWD testing, laser profiling, and regular distress monitoring. In addition, the MnROAD section included embedded electronic sensors to monitor the thermal profile of the section and the response of the section to thermal loads and wheel loads.

The thin overlay section at MnROAD displayed extensive distress. Over 80 percent of the panels with 4-inch (102 mm) overlay thickness were cracked within the first 2 years, which was not unexpected by MnROAD engineers (who, incidentally, also correlated high severity regions of overlay cracking with regions of artificially induced distress in the existing slab). In general, MnROAD engineers attribute the extent of cracking to excessive curl in the thin overlay panels (Burnham 2011). Due to the extent of cracking, the section was replaced in 2011 with a new experimental thin overlay design.

While the thin overlays on TH-53 continue to meet the roadway service demands, the pavement has exhibited panel cracking and joint faulting throughout that period. Within 1 year of construction, non-trivial levels of transverse cracking appeared in the southbound lanes. The general extent of cracking may have been caused by additional loading from the redirection of traffic during the construction of the northbound lanes in 2009.

Later distresses to develop in TH-53 were in the northbound lanes; this was generally joint faulting and later corner cracking in the vicinity of faulted joints. No indications were made by MnDOT as to the performance of TH-53 in the regions in which steel reinforcement had been used as a precaution. In general, the ride quality of TH-53 suffered due to the distresses, as within 3 years the measured IRI increased from initial values in the 40s to just over 80 (Burnham 2011).

Conclusions

The experimental nature of these sections resulted in designs that were less conservative than the typical design that an agency would use; thus, the reported levels of distress were anticipated. In general, both sections were underdesigned and many distresses would have been avoided with additional thickness. Regardless, the TH-53 sections are still in service, although at levels of ride quality that will warrant rehabilitation earlier than hoped.

As noted, one cause for the insufficient thickness in the case of Minnesota TH-53 may have been an underestimation of traffic volume (i.e., the redirection of traffic created additional volumes in the southbound lane). Thus, even at lower volumes, truck estimates should be considered carefully in the overlay thickness design.

SUMMARY

This Tech Brief provides general guidance on the application, design, and construction of thin concrete overlays, commonly defined as overlays that are 6 inches (152 mm) thick or less. These overlays are used to extend the service life, increase the structural capacity, and improve the rideability of existing concrete, asphalt, and composite pavement structures. Moreover, these overlays may be placed in either a bonded or unbonded condition, depending on the degree to which bonding with the existing pavement is either actively promoted or discouraged; in general, pavements in better structural condition are better candidates for bonded overlays whereas more significantly deteriorated pavements are better candidates for unbonded overlays.

In addition to the design and construction guidance, this Tech Brief also provides recent cost data associated with thin concrete overlay construction and presents supplementary case studies that illustrate the range of applications for thin concrete overlays.

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