New Applications for Thin Concrete Overlays: Three Case Studies

Shiraz Tayabji,[1] Andrew Gisi,[2] Jason Blomberg,[3] and Dan DeGraaf[4]

ABSTRACT

The need for optimizing preservation and rehabilitation strategies used to maintain the Nation's highway pavements has never been greater. Concrete overlays have a long history of use to preserve and rehabilitate concrete and asphalt pavements, and many of the practices are well established. However, of recent origin are techniques that use thinner concrete overlays with shorter joint spacing. Field experience over more than 15 years with the thinner concrete overlays under a range of traffic and site conditions has demonstrated their viability as a cost-effective solution to extend the service life of deteriorated asphalt and concrete pavements.

Concrete overlays can be designed for a range of traffic loadings to provide long performance lives, 15 to 40+ years, and to meet specific needs. Well-designed and well-constructed concrete overlays require low maintenance and can have low life-cycle costs. Thin concrete overlay applications include bonded and unbonded overlays over existing asphalt, concrete, and composite pavements.

This paper provides a review of thin concrete overlays applied as bonded or unbonded overlays. In addition, three recent case studies are presented that illustrate the wide range of applications of thin concrete overlays.

INTRODUCTION

The need for optimizing preservation and rehabilitation strategies used to maintain the Nation's highway pavements has never been greater. Concrete overlays have a long history of use to preserve and rehabilitate concrete and asphalt pavements, and many of the practices are well established. However, of recent origin are techniques that use thinner concrete overlays with shorter joint spacing. Field experience over more than 15 years with the thinner concrete overlays under a range of traffic and site conditions has demonstrated their viability as a cost-effective solution to extend the service life of deteriorated asphalt and concrete pavements.

The Federal Highway Administration (FHWA) has initiated several activities to support technology transfer related to concrete overlays. These activities include reviews, on a regional or statewide basis, of current applications of concrete overlays, identification of gaps in technology, and assistance in developing a program—jointly with State departments of transportation (DOTs) and industry—for technology transfer and demonstration projects. This paper provides a review of thin concrete overlays applied as bonded or unbonded overlays. In addition, three

[1] Shiraz Tayabji, Ph.D., P.E., Senior Consultant, Fugro Consultants, Inc., Columbia, Maryland

[2] Andrew Gisi, Kansas Department of Transportation, Topeka, Kansas

[3] Jason Blomberg, Missouri Department of Transportation, Jefferson City, Missouri

[4] Dan DeGraaf, Michigan Concrete Pavement Association, Okemos, Michigan

new applications are presented that illustrate the wide range of applications of thin concrete overlays to rehabilitate existing distressed pavements.

OVERVIEW OF CONCRETE OVERLAYS

Concrete overlays offer a broad range of applications for preserving and rehabilitating asphalt, concrete, and composite pavements. Concrete overlays can be designed for a range of traffic loading to provide long performance lives, 15 to 40+ years, and to meet specific needs. Concrete overlays can be constructed rapidly and with effective construction traffic management, and well-designed and well-constructed concrete overlays require low maintenance and can have low life-cycle costs. An important benefit of concrete overlays is that concrete overlays can be applied to a wide variety of existing pavements exhibiting a range of performance issues. Applications include the following:

- Over existing asphalt pavements
  - Bonded overlay of asphalt pavements
  - Unbonded (directly placed) overlay of asphalt pavements
- Over existing concrete pavements
  - Bonded overlay of concrete pavements
  - Unbonded (separated) overlay of concrete pavements
- Over existing composite pavements
  - Bonded overlay of composite pavements
  - Unbonded (directly placed) overlay of composite pavements

The family of concrete overlays is illustrated in Figure 1. The applicability of concrete overlays is summarized in Figure 2.

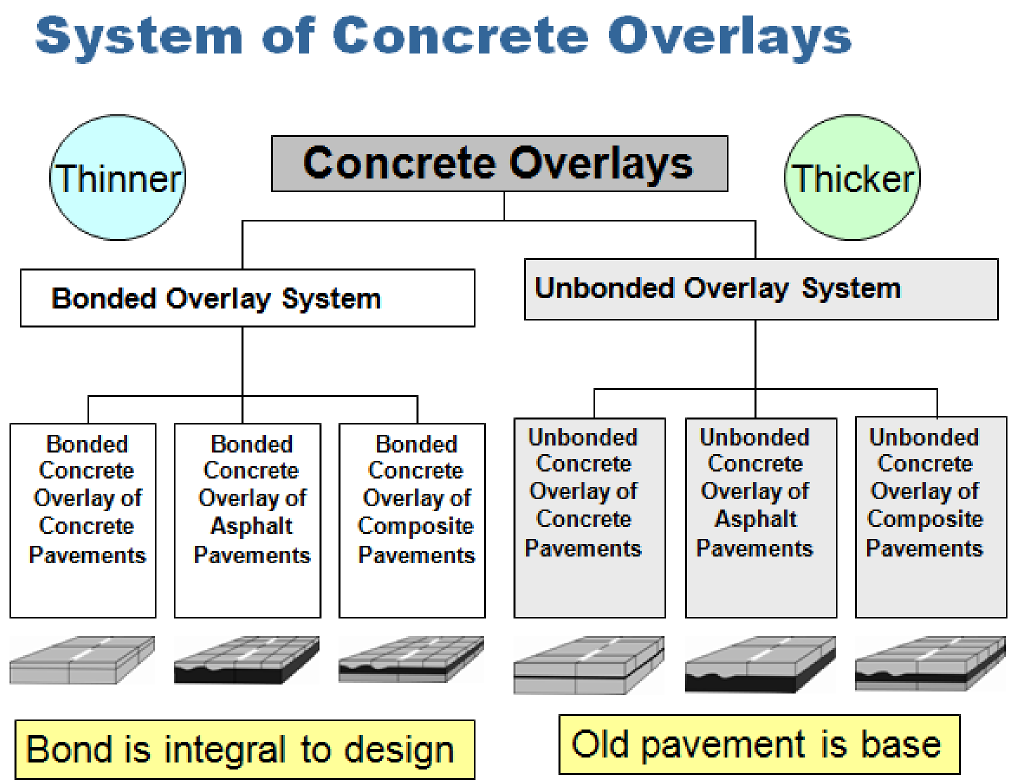

Figure 1. Family of Concrete Overlays (NCPTC 2008).

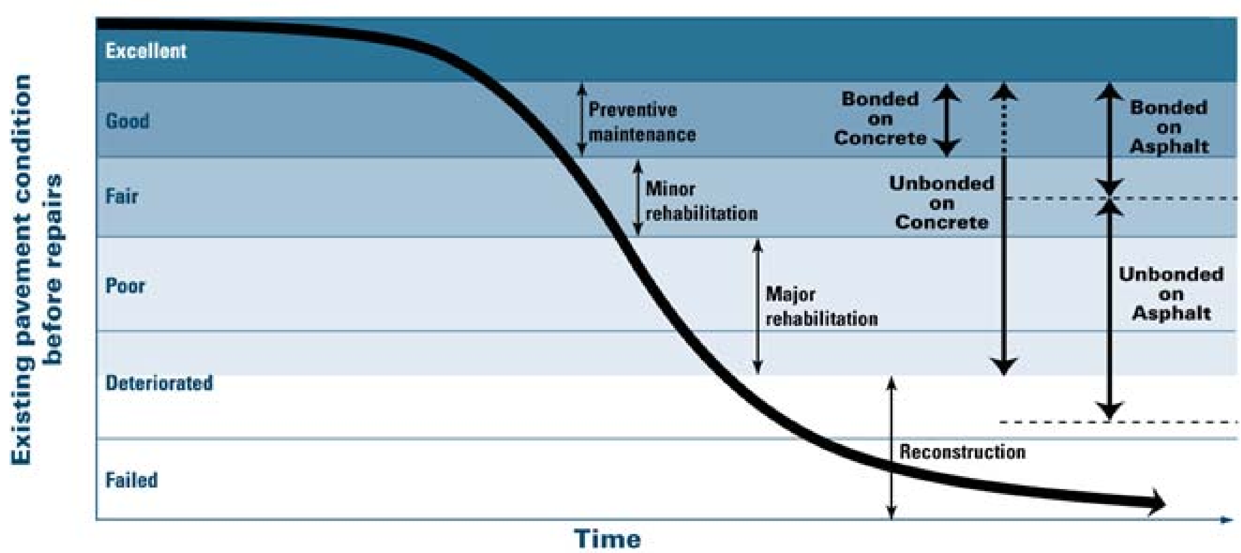

Figure 2. Applicability of Concrete Overlays (NCPTC 2008).

Bonded Overlays

Bonded overlays are typically thin, 2 to 6 in. (50 to 150 mm) in thickness. When bonded to a milled asphalt surface, the overlay panels are typically 6 by 6 ft (1.8 by 1.8 m) or less in dimension. When bonded to a prepared concrete surface, the overlay jointing pattern matches the jointing pattern of the existing jointed concrete pavement. In the case of continuously reinforced concrete pavement, transverse jointing is not provided.

Thin bonded overlays of asphalt concrete (AC) pavement are of recent origin. Even though some early trial installations were constructed during the early 1990s, it was only after the late 1990s that the technique became more widely accepted. As a result, the typical in-service experience with thin bonded overlays over AC pavement is less than 15 years. However, performance of the many miles of thin bonded overlays in many States indicate that properly designed and constructed thin bonded overlays can provide service life of at least 15 years and possibly greater than 20 years.

The use of thin bonded overlays over a composite pavement needs to be carefully assessed. A high potential exists for development of reflection cracking in the overlay if there is a severe level of reflection cracking in the composite pavement and truck traffic volume is high. If the reflection cracking is not extensive, then a bonded overlay may still be considered by using deformed steel bars over the cracking.

The experience with thin bonded overlays of existing concrete pavements has been mixed. For highway applications, these overlays range from 2 to 4 in. (50 to 100 mm) in thickness and are used to eliminate any surface defects in an existing concrete pavement, increase structural capacity; and improve surface friction, noise, and rideability. Typically, bonded overlays of existing concrete pavements are used to increase the structural capacity of existing concrete pavements while the existing pavements are still in good structural condition with only some surface distress. When constructed well, these overlays provide good service, typically 15 to 20 years. However, because these overlays are very sensitive to existing pavement surface preparation and curing and joint sawing operations, these overlays can exhibit early failures, typically joint corner delamination leading to cracking in the overlay. One of the three case studies presented in this paper details an innovative inlay type of application of a thin bonded concrete overlay over a distressed concrete pavement to restore the condition of the existing pavement.

Unbonded Overlays

Unbonded overlays, referred to also as directly placed overlays, are of two types:

- *Conventionally thick overlays,* 6 in. (150 mm) or thicker, are full-width and have transverse joint spacing of 12 to 15 ft. (3.7 to 4.6 m).
- *Thinner overlays* are 4 to 6 in. (100 to 150 mm) thick, and the overlay panels are typically 6 by 6 ft (1.8 by 1.8 m) or less in dimensions.

Irrespective of thickness, unbonded overlays are typically placed over an AC surface—either an asphalt pavement or an asphalt interlayer/resurfacing placed over a concrete pavement. When used over existing concrete pavements, an interlayer is required for good performance.

The role of the interlayer is to:

- Isolate overlay from existing pavement.
  - Prevent reflection cracking.
  - Prevent bonding/mechanical interlocking.
- Provide level surface for overlay construction.
- Provide a softer interlayer—less curling stress.

The interlayer typically used is a dense-graded, hot-mix asphalt 1 to 2 in. (25 to 50 mm) thick. As discussed in this paper, studies are underway to evaluate the use of thicker geotextile fabric as the interlayer material.

Conventionally thick unbonded concrete overlays of AC and concrete pavements are routine in application and are widely used to rehabilitate existing AC and concrete pavements that exhibit a higher level of distress. Unbonded overlays require very little pre-overlay repair. Of recent origin are the thin unbonded concrete overlays of AC and composite pavements. This application is a derivative of the thin bonded concrete overlays of AC pavements. Thin unbonded overlays are typically 4 to 6 in. (100 to 150 mm) thick, and the panels are typically 6 ft by 6 ft (1.8 by 1.8 m). This technique was developed in Michigan where it has been used successfully on many projects. One of the three case studies presented in this paper details such an application in Michigan.

An innovative thin unbonded concrete overlay design incorporates thick geo-fabric as the separator layer. The established practice in the US for a separation layer for unbonded overlays has been to use a 1 to 2 in. (25 to 50 mm) hot mix AC layer. A standard German practice is to use a geo-fabric, 0.2 in. (5 mm) thick, as a separation layer between a cement-treated base and concrete surface for new construction. U.S. investigators are applying this concept to thin unbonded concrete overlays. A project was constructed in Missouri during 2008 that used a thin geo-fabric as a separation layer for a thin unbonded overlay. This project is one of the three case studies presented in this paper.

Thin Concrete Overlay Design and Construction Considerations

The following are key design and construction considerations for use of thin concrete overlays:

1. Overlay type: Plain concrete.
2. Jointing:
   a. No dowel bars at transverse joints (for overlays less than 8 in. [200 mm] thick).
   b. Tie bars may be used along exterior longitudinal joints. Colorado DOT requires use of tie bars along longitudinal joints. The Michigan practice is not to use tie bars.
3. Concrete mixture: similar to conventional concrete paving; use of smaller maximum aggregate size for thin overlays; rapid-setting concrete may be used if needed.

4. Concrete placement.

    a. Similar to conventional concrete paving: slipform or fixed-form construction may be used.

    b. Curing and joint sawing very critical for thin overlays.

5. Surface requirements (ride and texture): similar to conventional concrete pavement.

Concrete Overlays Guide

With support from FHWA, the National Concrete Pavement Technology Center (NCPTC) at Iowa State University has developed a best-practices *Guide to Concrete Overlay Solutions* (NCPTC 2008*)*. Prepared by a joint industry/State DOT Task Force on Concrete Overlays, the guide presents an overview of concrete overlay systems for resurfacing or rehabilitating pavements and includes detailed guidelines for overlay use:

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

RECENT INNOVATIVE THIN CONCRETE OVERLAY PROJECTS

As discussed, thicker unbonded concrete overlays have been routinely used to extend the service life of existing concrete and asphalt pavements. Although thinner bonded concrete overlay of concrete pavements has a long history, the technique has been typically been used to strengthen pavements that are in good condition. The thin bonded overlays of AC pavements are establishing good service records, and the design and construction procedures are becoming more established. Of recent practice is the use of thin unbonded overlays over existing concrete and composite pavements, especially the technique that replaces the standard AC interlayer with a thick geotextile fabric. Case studies of three innovative projects are presented next:

1. Thin bonded inlay of a deteriorated concrete pavement in Kansas.
2. Thin unbonded overlay of a deteriorated concrete pavement in Missouri. This project used a geotextile interlayer in lieu of a standard AC interlayer.
3. Thin unbonded overlay of a deteriorated composite pavement in Michigan.

Thin Bonded Concrete Inlay—Kansas

A thin bonded inlay was constructed during 2008 along a section of I-35 in Johnson County, Kansas. The existing concrete pavement was constructed in 1985 and consisted of a jointed reinforced concrete pavement (JRCP) 9 in. (225 mm) thick over a cement-treated base 4 in. (100 mm) thick. The JRCP joint spacing was 30 ft (9.1 m).

The JRCP was exhibiting joint distress in the form of surface spalls several inches wide and about 2 in. (20 mm) deep. Visual observation of the spalls shows that the sand/cement mortar in the concrete was deteriorating because of a poor entrained air system. The condition of the existing pavement is shown in Figure 3. The coarse limestone aggregate was found to be intact, and only an occasional limestone aggregate appeared to be affected by "D-cracking." The JRCP was reinforced using wire mesh placed about 2.25 to 4.5 in. (57 to 114 mm) from the surface. The concrete flexural strength was estimated to be about 680 lbf/in^2 (4.7 MPa).

The construction process consisted of full-depth patching of some joints, milling 2 in. (50 mm) of the surface, shot blasting of the milled surface, application of a cement slurry (3 parts water and 1 part cement), then application of a plain concrete inlay 2 in. (50 mm) thick. The slurry application and concrete placement are shown in Figure 4. Joints were sawed into the inlay over the existing joints. Sawcut depth was full-depth plus 0.5 in. (12.5 mm). The contractor had 10 weeks to complete the entire project. Four weekends were allowed for the inlay placement. The construction specification allowed the pavement to be opened to construction traffic at 340 lbf/in^2 (2.3 MPa) flexural strength or 1,800 lbf/in^2 (12.4 MPa) compressive strength. The inlay was diamond ground.

Almost a year after construction, the concrete inlay is performing well. There were no early age failures. Kansas DOT estimates that the inlay will extend the service life of the existing pavement by at least 15 years.

Figure 3. Condition of existing concrete pavement.

Figure 4. Slurry application and concrete placement.

Thin Unbonded Overlay—Missouri

A thin innovative unbonded concrete overlay, incorporating a geotextile fabric as an interlayer, was constructed in Missouri during 2008. The 3.13-mi (5-km) long project is located along a section of Route D in Jackson Count, between Routes 150 and 58. The existing jointed concrete pavement, 8 in. (200 mm) thick with 30 ft (9.1 m) joint spacing, was constructed in 1986. One-inch (25 mm) dowel bars were used at transverse joints. As of 2008, the pavement section was exhibiting severe D-cracking along both transverse and longitudinal joints, and it was estimated by the Missouri DOT (MoDOT) that up to 25 percent of the pavement area would need full-depth repair prior to a conventional AC overlay. The existing pavement condition is shown in Figure 5.

Figure 5. Condition of existing concrete pavement.

The MoDOT investigated several alternatives for rehabilitating the Route D pavement. These alternatives included new construction using AC and PCC, conventional unbonded overlay 8 in. (200 mm) thick, and rubblize with 12 in. (300 mm) AC overlay. Based on discussions between MoDOT and industry, it was decided to consider an experimental thin unbonded concrete overlay incorporating a nonwoven geotextile fabric as an interlayer in lieu of a conventional AC interlayer. The concrete overlay design developed required use of an unbonded concrete overlay, 5 in. (12.5 mm) thick with 6 ft by 6 ft (1.8 by 1.8 m) panels. The same design was selected for the shoulders. This technique of using a geotextile fabric as an interlayer is an extension of the German practice of using a geotextile fabric 0.2 in. (5 mm) thick to separate concrete from a cement-treated base for new concrete pavement construction. The Germans have used this application successfully to eliminate bonding between the concrete and cement-treated base and to reduce curling stresses as a result of the cushioning effect provided by the 0.2 in. (5 mm) thick fabric. Two nonwoven geotextile were utilized for this project. These were Geotex 1201 and Geotex 1601, manufactured by Propex. These geotextiles were slightly thinner than the 0.2-in. (5-mm) geotextile fabric used in Germany.

The overlay construction steps included the following:

1. Pre-overlay repairs—Some of the severely deteriorate joint areas were patched using flowable concrete.

2. Fabric placement—The geotextile material was delivered to the project in 300-ft (90-m) rolls, as shown in Figure 6. The fabric was 15 ft (4.6 m) wide. As shown in Figure 6, a telescopic forklift was used to place the fabric. Two rolls of geotextile were used to span the width of the pavement

3. Fabric fastening—A Hilti gas-powered fastening system was used to fasten the fabric onto the underlying concrete pavement.

4. Concrete placement—The geotextile material was wet prior to concrete placement. Concrete was placed using a conventional slipform paver riding directly on the fabric, as shown in Figure 7. No problems were reported with the geotextile during concrete placement.

5. Concrete curing—A curing compound was used and applied at a higher rate than is typically used for new concrete pavement construction.

6. Concrete joint sawing—Joints were sawed in a timely manner and no early-age problems were observed.

The MoDOT is satisfied with the initial project outcome and will be monitoring the performance of the overlay over the next few years. The thin unbonded overlay is performing well after about 9 months of service.

Figure 6. Geotextile fabric placement.

Figure 7. Slipform paver over the fabric and completed unbonded overlay.

Thin Unbonded Overlay of a Composite Pavement—Michigan

In summer 2003, the Michigan Department of Transportation (MDOT) Metro Region decided to pursue a thin concrete overlay demonstration project on M-3 (Gratiot Avenue) between I-75 and I-94 in the city of Detroit. The length of the project was 3.17 miles, encompassing approximately 198,000 yd^2 (165,000 m^2) of pavement. The original underlying concrete pavement dates back to the early 1900s and had been overlaid several time with hot-mix AC. The pavement consists of nine lanes; a parking lane, three through lanes in each direction, and a common center turn lane. Based on the review of the available plans, the existence of underlying brick pavers along the outside parking lane was discovered. The surface condition of the composite pavement had deteriorated significantly and rehabilitation of the roadway was considered necessary. Visual inspection of the composite pavement lane indicated localized areas of questionable base support. In general, an AC overlay will take the shape of the base below, and areas of poor support are easy to identify. Once the surface AC milling was completed, an immediate site review was conducted to determine the extent of potential support problems. Figure 8 shows the condition of the composite pavement.

Figure 8. Condition of existing composite pavement.

Based on discussions between MDOT and the industry, it was decided to construct a thin unbonded concrete overlay, with smaller 6 by 6 ft (1.8 by 1.8 m) panels, over the composite pavement. Nationally, very few composite pavements have received this type of rehabilitation treatment. From October 2003 through April 2004, a cross-functional team had six working meetings to develop strategies and specifications for the application of this pavement treatment. The project was let for bid during August 2004. The lowest bid was $ 7.17 million.

Areas of weakest base support, typically near inlets, were repaired using full-depth patches, and areas exhibiting less severe deterioration were repaired using partial-depth removal of concrete with hand-patched asphalt or concrete replacement. An asphalt milling depth of 5 in. (12.5 mm) was established to maintain curb depth and cross-slope. There were 350 manhole structures in the composite pavement, and a core drill 5-ft (1.5-m) in diameter was used to isolate manhole structures from the pavement. Prior to milling the AC surface layer, each phase of the core containing the manhole casting was removed. The castings were adjusted to the new pavement grade prior to concrete placement. After cold milling of the AC surface layer, a 4-in. (100-mm) concrete overlay was placed over a 1-in. (25-mm) asphalt separator layer. As part of this project, experimental sections with two different asphalt separator mixes and sealed versus unsealed joints were also constructed. The slab panels were 6 in. (150 mm) thick and 6 by 6 ft (1.8 by 1.8 m) (maximum) in dimension. The majority of the work was initiated in 2005 and completed in late fall 2005. Figure 9 shows the pre-overlay activities—full-depth repair and median strengthening. Figure 10 shows the AC interlayer placement to provide a smooth and uniform grade for concrete placement. Concrete was placed using slipform paving as shown in Figure 10. The completed thin unbonded concrete overlay is shown in Figure 11.

The MDOT Metro Region is satisfied with the initial project outcome and is planning additional demonstration projects. The unbonded overlay is performing well after about 3 years of service.

Figure 9. Pre-overlay repairs.

Figure 10. AC interlayer and concrete placement.

Figure 11. Completed thin unbonded overlay.

SUMMARY

As discussed in this paper, thin concrete overlays can provide cost-effective solutions for rehabilitation of existing asphalt, concrete, and composite pavements. The three case studies presented illustrate new applications for thin concrete overlays. These applications were made possible because of sound engineering decisions and a desire to continue to explore new ways to extend existing technologies. The success of these innovative applications will provide pavement engineers with new tools that can be used with confidence to cost-effectively rehabilitate existing pavements. A key advantage of using thin concrete overlays is that it allows existing pavement to remain in place, thus significantly reducing the construction time for the rehabilitation activity.

REFERENCES

1. National Concrete Pavement Technology Center, 2008. *Guide to Concrete Overlays*, 2nd Ed., Iowa State University, Ames.

ACKNOWLEDGMENTS

The opinions presented are those of the authors and do not necessarily reflect the views or opinions of the Missouri Department of Transportation, the Kansas Department of Transportation, or the Michigan Concrete Pavement Association.

The authors would like to acknowledge the support provided by many individuals and organizations in developing the information presented in this paper.