Executive Summary

IMPROVING CONCRETE OVERLAY CONSTRUCTION

June 2010

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National Concrete Pavement Technology Center

Tech Center

Acknowledgements

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Steven A. Klocke, Snyder & Associates, Inc.
Dale S. Harrington, Snyder & Associates, Inc.

Iowa State University Disclaimer

Introduction

As the US highway system ages and available funding diminishes, transportation agencies are looking for effective methods for preserving and extending the life of existing pavements. These agencies are also being encouraged to minimize construction times and reduce the impact to the traveling public. Currently, the most common method of rehabilitating an existing roadway surface is through an HMA overlay; however, high oil prices have caused designers and agencies to consider other methods. One alternative to the traditional HMA overlay is a concrete overlay. The Iowa Department of Transportation (Iowa DOT) and Iowa counties and cities have completed about 1,000 miles of concrete overlays that are in use and are serving the traveling public today.

Despite the completion of hundreds of projects, some agencies are reluctant to use concrete overlays, believing that they are expensive, difficult to build, and have limited application.

To address these concerns, the National Concrete Pavement Technology Center at Iowa State University developed a guide document to assist engineers in concrete overlay design and construction. The *Guide to Concrete Overlays* was published in September 2008 and includes detailed information on evaluating existing pavements as concrete overlay candidates, selecting and designing the appropriate type of concrete overlay, and guidance on concrete overlay construction. Since the publication of this guide, the need has arisen to develop methods to improve concrete overlay efficiency utilizing current technology, investigate innovative materials for use as bond breakers, and reduce the inconvenience to the public with improved methods of traffic control and increased opening time.

Research Objectives

To alleviate concerns over the use of concrete overlays, the Iowa Highway Research Board (IHRB) and Federal Highway Administration (FHWA) funded a project to develop additional design and construction information to accompany the *Guide*. This project investigated the following areas:

1. Evaluate the feasibility, benefits, and limitations of GPS mapping of the existing roadway surface prior to construction and the use of machine control systems for slipform pavers.

2. Develop methods to ensure that the longitudinal joints in the overlay match underlying joints in the existing pavement.

3. Establish methods to determine the level of milling required for existing asphalt surfaces to reduce project overruns.

4. Evaluate the use of innovative materials, such as geotextile layers, for use as bond separators.

5. Evaluate the feasibility of overlaying multi-lane roads a single lane at a time while maintaining traffic through the work area.

6. Investigate methods to reduce paving train length and width and reduce the time of construction operations.

7. Determine the opening strength required to allow access by local traffic and construction equipment.

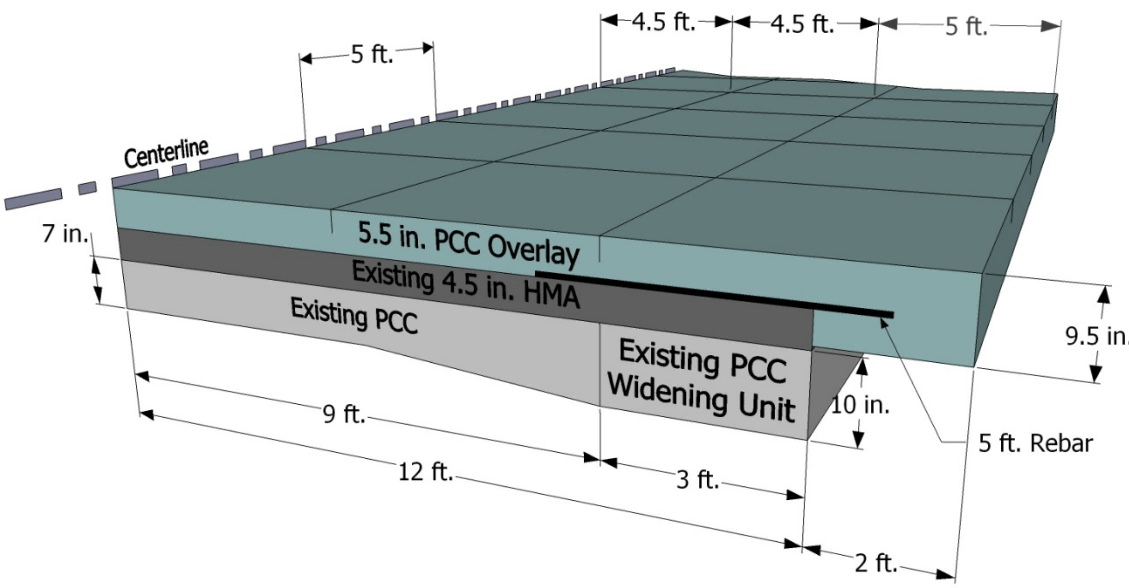
Research Plan

In order to investigate the needs and concerns noted above, four concrete overlay projects were selected. These projects were already under development by the Iowa DOT and Osceola, Poweshiek, Worth, and Johnson counties. A portion of the research objectives was implemented on each of the projects. A description of each project is provided below:

Project Details:

- Constructed from IA 60, east 8.8 miles to the east junction of County Road L-58.
- Existing 18-foot wide PCC pavement with 4 to 8 foot shoulders; widened to 24-foot roadway with 4.5-inch HMA overlay.
- Constructed a 5.5 inch PCC Overlay; including a 2-foot widening section on each side (final pavement width of 28 feet).
- 5 ft. tie bars were installed over the widening units.
- Traffic was detoured off-site during construction.

Typical Pavement Cross Section and Jointing



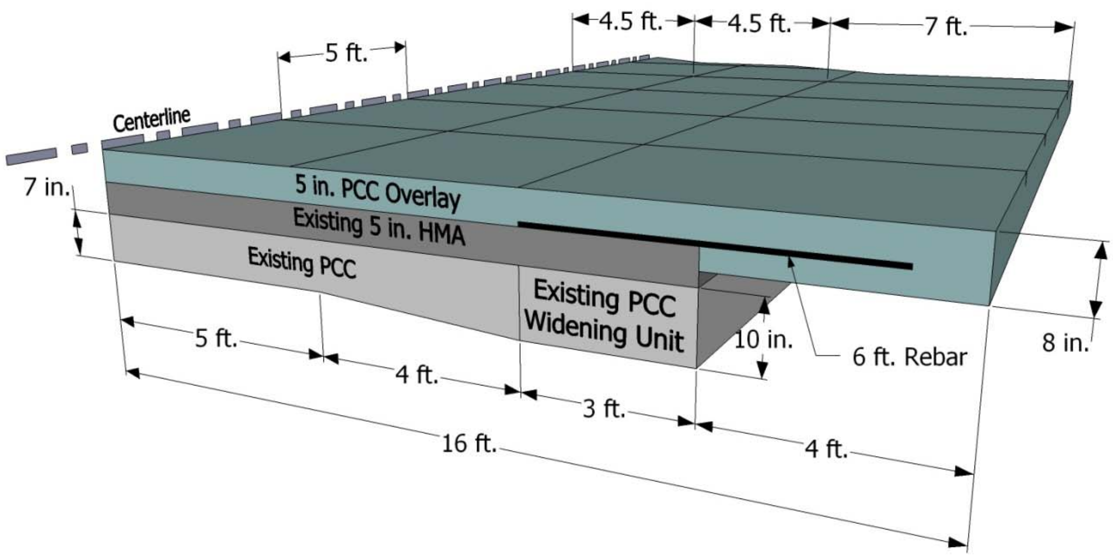
Before

After

Project Details:

- Constructed from Manly, north 10.5 miles to the southern corporate limits of Northwood.
- Existing 24-foot wide pavement consisting of 7.5 inch PCC with a 5-inch HMA overlay.
- Proposed 5-inch PCC overlay including a 4-foot widening section on each side (final pavement width of 32 feet).
- 6 ft. tie bars were installed over the widening units.
- Through traffic was detoured off-site during construction. The project was staged to maintain cross traffic at multiple intersections.
- Stringless paving was utilized to construct one lane of the overlay.

Typical Pavement Cross Section and Jointing



Before

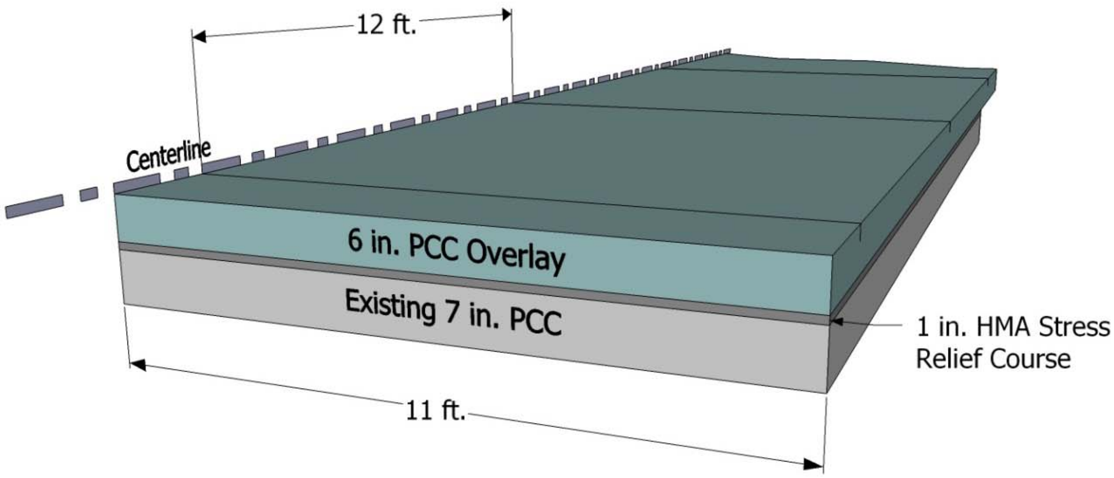
After

County Road V18 in Poweshiek County

Project Details:

- Constructed from IA 85 north 9.6 miles to the southern corporate limits of Brooklyn, IA.
- Existing roadway is 22-feet wide with a 2 to 4 foot shoulder and is 30-35 years old.
- Existing pavement is 7 inch PCC and shows signs of joint deterioration.
- Proposed a 6-inch unbonded PCC overlay.
- Traffic was detoured off-site during construction.
- Stringless paving was utilized for placement of the overlay.
- Geotextile Fabric Bond Breaker was substituted for HMA at four locations.

Typical Pavement Cross Section and Jointing



Before

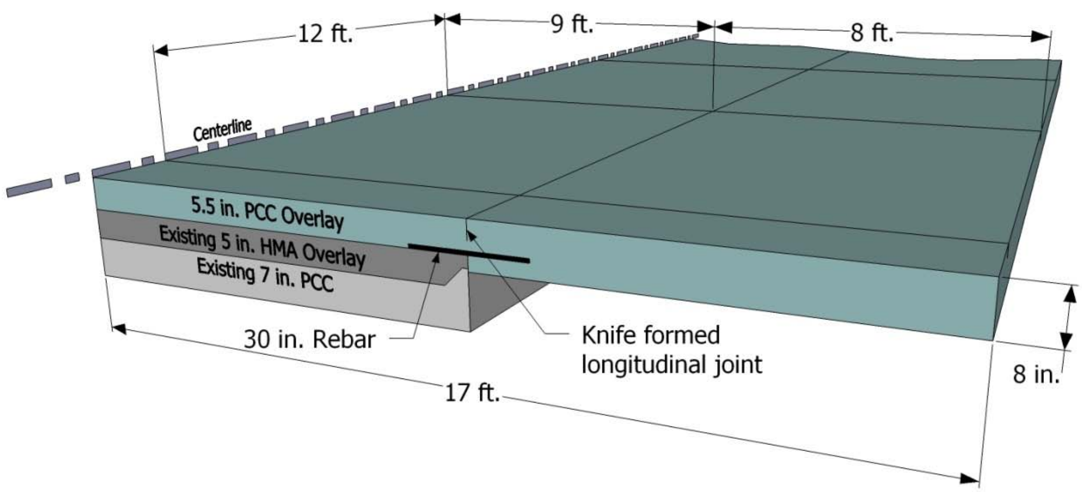
After

County Road W-62 (Oak Crest Hill Road) in Johnson County

Project Details:

- Constructed from a point one-half mile south of the town of Hills, north 4.7 miles to the IA 921 connection with US 218 (Avenue of the Saints).
- Existing 18-foot wide PCC pavement with lip curbs (constructed in 1929).
- Pavement was previously resurfaced with HMA to fill in the height of the curbs and widened with a 3-inch HMA surface (removed).
- Proposed a 5.5 inch PCC overlay of the 18 foot section with an 8-inch by 8-foot widening section (final pavement width of 34 feet).
- All construction was contained within the existing 66-foot right-of-way.
- A redesigned paving “knife” was used to form the longitudinal joints.

Typical Pavement Cross Section and Jointing



Before

After

Project Approach and Conclusions

<u>Objective #1:</u> Evaluate the feasibility, benefits, and limitations of GPS mapping of the existing roadway surface prior to construction, and the use of machine control systems for slipform pavers.

Rationale: This objective addressed two concerns. The first regards the ability to estimate the quantity of concrete required for an overlay project and establishing desired profile grades for the finished overlay surface. Wheel ruts, deviations in the existing cross slope, and other roadway imperfections affect the thickness of the overlay across the slab, thereby affecting the volume of concrete required for the overlay. High spots in the pavement cross section can also result in thin spots in the concrete overlay. A more detailed method of mapping the surface of the existing roadway is required to accurately calculate concrete volumes and identify thin spots in the concrete overlay.

The second concern is the width of a typical paving train and the inconvenience of a stringline. A typical slipform paver requires the installation of a stringline and support posts adjacent to the roadway to establish the correct pavement alignment and profile. This requirement adds several additional feet (6' – 8') of required clearance to the paving envelope, which is already wider than the pavement due to the tracks of the slipform paver. In addition, the stringline becomes an obstacle for equipment, concrete delivery trucks, and finishing crews. If equipment access across the stringline is required, the stringline must be lowered and reset, resulting in delays and introducing the potential for errors. While the width of the paving train and the inconvenience of a stringline create difficulties on new construction projects, these problems are magnified on concrete overlays. On most new construction projects, side obstacles such as mailboxes, power pole, and signs are moved or removed to accommodate grading operations, and therefore do not impact the paving operation. On overlay projects, these obstacles must be worked around or removed. Establishing a method to eliminate the stringline could result in increased production, decreased construction time, and a reduction in errors.

Approach: In order to map the existing roadway surface, a utility vehicle was equipped with a laser profiler and GPS rover unit. The utility vehicle was driven along the pavement at 5 mph, recording the existing pavement profile at 25-foot intervals along the pavement edges, wheel paths, lane quarter points, and centerline. The data collected was used to produce a 3D plot of the pavement surface utilizing readily available CADD software.

Stringless paving was utilized on two of the four overlay projects. The 3D model provided the design surface of the proposed overlay. The stringless paving method selected utilized multiple total stations with prisms mounted on the paving machine. Vertical control points were established at 250-foot intervals on alternating sides of the roadway. This kept the paving equipment, crews, and terrain from interfering with the line of sight between the paving machine and at least three vertical control points. Modifications to the paving machines were required to add electronic/hydraulic controls. A five-day training course on the operation of the total stations and modified slipform paver was provided to construction crews.

Conclusions: The results of the roadway mapping indicate that current "off the shelf" GPS technology does not provide adequate vertical accuracy for mapping the pavement surface when measured with a rapidly moving device. Slow moving (< 5mph) GPS data collection and other proprietary software and systems do have the potential for mapping the pavement surface with an accuracy adequate for paving machine control at speeds up to 35 mph.

Stringless paving systems can be retrofit to most modern slipform pavers. The keys to a successful stringless paving project include development of accurate existing and proposed pavement surface models and establishment of tight vertical control on the ground during paving. The stringless paving equipment evaluated accurately replicated the line, grade, and cross-slope indicated in the design model of the finished pavement surface and met smoothness incentives.

Figure 1. Utility Vehicle Equipped with GPS Receiver and Laser Profiler

Figure 2. Slipform Paver Utilizing Stringless Paving

Figure 3. Dual Lane Stringless Paving Operation

Objective #2: Develop methods to ensure that the longitudinal joints in the overlay match underlying joints in the existing pavement.

Rationale: Positioning longitudinal joints directly over the existing longitudinal joints is critical to prevent reflective cracking in bonded (PCC over PCC) concrete overlays. Locating these joints accurately has proven difficult in the past. A more accurate method of locating existing joints and placing new joints is needed.

Approach: Although these projects were unbonded overlays, investigation of methods to replicate the longitudinal joints were still undertaken. Prior to construction, the existing centerline joint was located at 10-foot intervals with GPS equipment. Two different methods were used to locate and place longitudinal joints in the overlays. The first method utilized GPS equipment to re-establish the centerline joint surveyed prior to placement of the overlay. These points were marked on the pavement surface. The concrete saw followed the line created by connecting these points. The second method utilized a saw equipped with a GPS unit. The data from the original longitudinal joint survey was loaded into the GPS unit on the saw. A screen mounted on the saw allowed the contractor to visualize the location of the saw blade in relation to the existing longitudinal joint line and make adjustments as necessary.

Conclusions: A conventional saw can be outfitted with a GPS receiver, allowing the operator to saw a joint in the overlay that is within 1 inch horizontally from the existing joint in the underlying pavement. Concrete cores verified that this method is more precise than measuring the centerline offset from paving hubs, which are often destroyed during construction.

Figures 4 & 5. Standard Concrete Saw Outfitted with GPS Unit

Objective #3: Establish methods to determine the level of milling required for existing asphalt surfaces to reduce project overruns.

Rationale: Existing asphalt surfaces often have tire ruts and other distortions that can cause uneven concrete overlay thicknesses across the pavement. In addition, these deformations can cause overruns in concrete volumes as a result of the additional material required to fill in the depressions. On some roadways, the existing cross slope also needs to be increased to provide adequate drainage. Standard methods for milling pavement surfaces prior to concrete overlays need to be developed.

Approach: In one project, an existing HMA surface was milled to achieve a 2% cross-slope in each lane and reduce the amount of PCC overlay overrun due to wheel ruts. A 12-foot wide milling machine was set to just scratch the surface at the centerline and mill to a 2% cross slope across the driving lane. For roadways that included shoulder widening, a milling machine was used to remove the existing granular surfacing to the required depth.

Conclusions: A 12-foot wide milling head with closely spaced teeth provided a very consistent cross-slope and minimized the additional concrete required to fill ruts and depressions, improving overlay concrete yield values. In addition, over-width milling can be used to remove shoulder material to accommodate pavement widening and provide an improved pad line for the paver, resulting in an improved ride in the final surface. The economics of milling versus anticipated overruns due to filling ruts and depressions with additional concrete should be evaluated during the project design phase.

Figure 6. Mainline Pavement Milling

Figure 7. Shoulder Milling for Pavement Widening

Objective #4: Evaluate the use of innovative materials, such as geotextile layers, for use as bond separators.

Rationale: Unbonded concrete overlays make use of a bond breaker between the existing pavement and the concrete overlay to prevent reflective cracking from the underlying pavement. Typically, the bond breaker consists of a one-inch lift of HMA. A variety of geotextile fabrics are currently available that are marketed as less costly alternatives to HMA overlays. An analysis of these products is required to determine the cost effectiveness of these products.

Approach: A geotextile fabric, meeting a national interim specification, was installed at four locations on the Poweshiek County project in lieu of the 1-inch lift of HMA. The fabric was provided to the contractor and the contractor unrolled and installed the material and fasteners. At some locations, the material was unrolled between the paving machine and the ready mix truck. At other locations, the material was unrolled and secured prior to paving, and the ready mix trucks backed up over the material.

Conclusions: Pavement cores verified that the fabric did prevent a bond from forming between the overlay and the existing pavement. The fabric was easily installed and ready mix trucks were able to operate on top of the fabric. On some up-grade sections, minor movement in the fabric was observed, but no ruptures were noted and extra nails were installed where bubbles in the fabric formed.

The cost of the fabric is estimated to provide a 67% cost savings over a 1-inch HMA bond breaker course. Because the quantities of fabric utilized on this project were limited, it is anticipated that cost savings could be even greater if larger quantities of material were installed.

Long-term performance for prevention of reflective cracking is not yet available. The results of this project will continue to be monitored.

Figure 8. Geotextile Bond Breaker between Paver and Ready Mix Trucks

Figure 9. Equipment Operating over Geotextile Bond Breaker

Objective #5: Evaluate the feasibility of overlaying multi-lane roads a single lane at a time while maintaining traffic through the work area.

Rationale: A perceived drawback to concrete overlays is the combination of equipment and construction methods require completely closing roadways to traffic. On long roadways, this can create a significant problem for residents who may have no other access to their property. Proving that traffic can be maintained during construction is a major benefit to promoting increased use of concrete overlays.

Approach: On one of the overlay projects studied, the contractor was required to maintain access for local traffic during construction. This was accomplished by constructing the overlay a single lane at a time. The existing roadway cross section had wider shoulders allowing local, two-way traffic to be maintained on the remainder of the adjacent lane and shoulder. During pavement construction, adjacent property owners were asked to park across the street to avoid conflicts with the stringline and paving train.

Conclusions: Depending on the width of the existing roadway and shoulder, local traffic can be maintained during construction with only minor inconvenience to adjacent property owners. On the study project, a stringline was utilized for the paver. The use of stringless paving could expand the number of roadways where local traffic can be maintained during construction.

Figure 10. Construction on W-62 in Johnson County while maintaining local traffic

Objective #6: Investigate methods to reduce the time of construction operations using both existing and new paving trains.

Rationale: A significant obstacle to widespread adoption of concrete overlays as a viable alternative to HMA overlays is the perception that concrete overlays require complete road closures for a considerable amount of time. Identifying construction operations that can be completed under traffic, prior to the overlay and reducing the amount of time required for actual paving operations could minimize the total roadway closure time and minimize inconvenience to motorists and residents.

Approach: During construction, the research team observed the process to identify the best ways to minimize the time of road closure.

Conclusions: The research team identified a number of potential areas to reduce the time and inconvenience of road closure. Work such as drainage improvements outside the pavement area, pipe extensions, relocating utilities, establishing survey control, and conducting roadway surface mapping can be completed with minimal impact on traffic. These preliminary construction items should be completed prior to charging working days or as part of a separate project.

Improvements that require more substantial traffic control, but not complete road closure, such as subdrain improvements, patching, pavement surface milling, bridge approach repair, and intersection or shoulder work should be completed utilizing flaggers or other traffic control as required.

Utilizing total roadway closures with detours, in conjunction with two-lane overlay construction, improves paving efficiency and reduces total closure time.

Figure 11. Typical Road Closure

Figure 12. Dual Lane Paving with a Stringline Requires Complete Road Closure

<u>Objective #7:</u> Determine the PCC overlay opening strength required to allow access by local traffic and construction equipment.

Rationale: While improvements in the roadway preparation and paving operation for a concrete overlay can increase the speed and efficiency of construction, the road must remain closed after paving until sufficient strength is achieved in the slab. A minimum level of strength is required prior to sawing to support sawing equipment and prevent raveling of the joint. Additional strength is required before allowing access for local traffic. A higher level of flexural strength is required prior to allowing construction traffic on the slab to complete shouldering and other finishing operations prior to fully opening the road to through traffic. Determining the minimum timing for each of these key events is critical in minimizing road closure times and establishing concrete overlays as a rehabilitation method with a minimum inconvenience to the traveling public.

Approach: Previous research has indicated that local traffic can access a slab after achieving flexural strength of 350 psi. Current specifications require a minimum flexural strength of 500 psi prior to opening the roadway to heavy construction traffic and through traffic. To determine the time required to achieve these key values, maturity meters were installed at 1,000-foot intervals on each project. The sensors were read at 15-minute intervals until the achieving a minimum estimated flexural strength of 500 psi.

Joint sawing was completed as soon as the slab could support the operation without producing excessive raveling. The time of sawing for each joint was recorded and correlated with the maturity meter measurements to determine the flexural strength of the slab at the time of sawing.

Conclusions: A flexural strength of 350 psi was achieved within 24-hours after paving on each of the projects using standard concrete mixes. This would allow construction of temporary access points for residents one day after paving. Residents would only be inconvenienced on the day of paving, rather than for multiple days. A flexural strength of 500 psi, required for construction equipment and through traffic access, was achieved in less than 48 hours.

The time of joint sawing ranged from five to nine hours after paving. The flexural strength of the pavement at the time of sawing varied based upon the coarse aggregate and cement utilized in the concrete mix. Careful selection of mix materials and saw blade type can reduce sawing time to five hours without excessive raveling.

<u>Additional Research and Conclusions:</u> Some additional research, that was not included as part of the original research concept was completed with this project.

Longitudinal Joints Formed with Paving Knife: A paving “knife” can be used to form a longitudinal joint during paving operations, eliminating the need for sawing. This concept was employed on numerous projects in Iowa before its use was prohibited due to concerns with premature cracking. A redesigned version of the “knife” was used on one overlay project to form the pavement joint between the through lane and the paved shoulder. Results from this project indicate that the "knife" successfully formed the longitudinal joint.

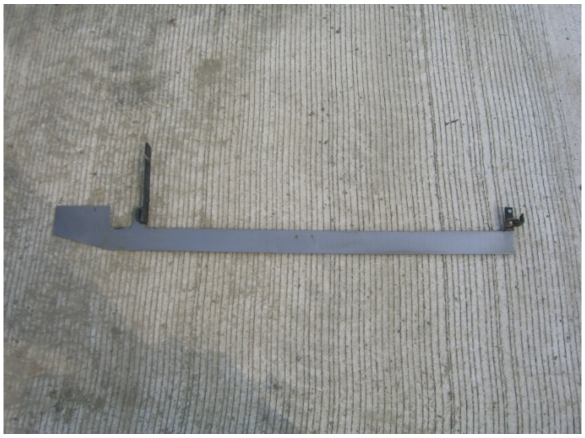


Figure 13. Longitudinal Joint "Knife"

Figure 14. Longitudinal Joint "Knife" Installed on Slipform Paver

Falling Weight Deflectometer Analysis: To properly design a concrete overlay, some information on the structural adequacy of the existing pavement is required. One method for analyzing this capacity is through Falling Weight Deflectometer (FWD) testing. FWD testing was conducted on three of the concrete overlay projects to determine what frequency of FWD testing is necessary to characterize the structural capacity of the existing surface.

The results indicated that FWD testing should be carried out on a frequency of at least 1.0-mile increments in each lane. For pavements with severe distress, intervals should be reduced to 0.1 to 0.5 miles to identify areas for consideration of strengthening or replacement. FWD testing at 9 kip loading is recommended.

Figures 15 & 16. Falling Weight Deflectometer Testing

Summary of Recommendations

GPS Pavement Surface Mapping

- At a minimum, existing surface profile information should be gathered prior to final design along pavement edges and at the centerline. Additional surveys should be conducted at the quarter points and in each wheel path if the existing surface is badly rutted.
- Utilize GPS in conjunction with lasers, ultrasonic, radar and other technologies to map the surface of existing pavements prior to concrete overlays.

Longitudinal Joint Formation with GPS Controlled Saws

- Contractors should consider the use of GPS-guided saws to accurately match new longitudinal joints in concrete overlays to those in the underlying pavement.

Milling

- Analyze the additional cost of milling versus the savings in concrete yield during the design phase.
- Use a 12-foot wide milling machine with closely spaced teeth to improve the overall cross slope of the finished surface and improve the yield of the concrete.
- Use a mill head that is wider than the pavement widening unit to develop an improved paver pad line, better drainage, and improved ride of the final product.

Slipform Paver Machine Control

- Look at ways to improve concrete yield with prior planning of highway agency goals, mapping of the existing surface, and development of tight vertical control point systems along the pavement prior to design and construction
- Consider the opportunity to demonstrate stringless controls with a combination of GPS, lasers, and total stations.

Geotextile Bond Breaker

- Consider the use of a geotextile bond breaker as an economical alternative to HMA for unbonded concrete overlays.
- Install bond within one day prior to paving to reduce potential for wind and traffic damage.

Concrete Opening Strength for Local Traffic Use

- Consider using maturity measurements to open local resident access points less than 24 hours after paving with flexural strengths of 350 psi.
- Consider using maturity measurements to begin shouldering operations less than 48 hours after paving with flexural strengths of 500 psi.
- Maturity curves specific to the concrete mix materials being used should be developed for each project.

Traffic Control for One- and Two-Lane Overlay Construction

- Analyze the additional costs for maintaining through traffic and building the overlay in stages verses the additional inconvenience of closing the roadway and placing a single or dual lane overlay.

Overlay Construction Operation Timing

- Perform utility relocations, drainage improvements, and pavement survey activities prior to the overlay project to minimize road closure times.
- Maintain through traffic with flaggers during initial improvements such as subdrain installation, pavement milling, and pavement patching.
- A total road closure with detours and two-lane overlay construction should be considered to minimize the overall duration of the project.

FWD Testing

- Perform FWD testing before and after the overlay to measure deflection reduction and to verify the adequacy of the overlay depth.

Future Research

Longitudinal Joint Formation for Bonded Overlays

- Consider manual measurements from hub lines to existing centerlines prior to overlay and re-establishment of those points on the surface prior to the centerline sawing of the overlay.

Surface Mapping

- Consider the use of LiDAR, slow moving GPS units, or robotic total station work to accurately map the road surface prior to overlay design.

Surface Milling

- Investigate the amount of concrete required to fill the milled surface from a single lane with coarse or widely spaced cutting head and a narrowly spaced cutting head.
- Compare the yield in overlay concrete of a surface milled from the paving grade line to one that is independent of the paving grade line. The same comparison can be made between a milling unit using only GPS control to one with total station control.

Machine Control

- Investigate the potential for a survey of the actual pavement overlay surface elevations at the centerline and pavement edges of the finished product to ensure quality compliance with the paving model.
- Investigate the potential of using a combination of lasers, total stations, and GPS for machine control of the slipform paver.
- Consider the use of the ski or moving stringline to achieve overlays and still maintain smoothness specifications.

Opening Strength

- Evaluate the effect of shouldering activities at varying concrete flexural strengths (350, 400, 500 psi) to determine the impact on the durability of concrete overlay pavement edges.