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Whitetopping Performance and Mechanistic Design

Prepared for
Wisconsin Highway Research Program
Rigid Pavements Technical Oversight Committee

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Transportation Literature Searches are prepared for WisDOT staff and principal investigators to heighten awareness of completed research in areas of current interest. The citations below are representative, rather than exhaustive, of available English-language studies on the topic. Primary online resources for the literature searches are OCLC's WorldCat and TLCat, U.S. DOT's TRIS Online, the National Transportation Library (NTL), TRB's Research in Progress (RiP) and other academic, engineering and scientific databases as appropriate. Links to online copies of cited literature are noted when available. Hard copies may be obtained through the WisDOT Library at library@dot.state.wi.us or 608-264-8142.

SUMMARY

Our search produced 46 citations pertaining to whitetopping performance, mechanistic design, the linkage of performance with design, and life-cycle cost analysis. Of these documents, 19 were conference presentations; 14 were state DOT or state research institution reports, representing eight states overall; 11 originated from Transportation Research Board, Federal Highway Administration, or other federal sources; and two were found in engineering journals. Many of the conference papers refer to specific state efforts in Minnesota, Colorado or Iowa. Of the 14 state-issued reports, four came from Iowa, two each from Colorado, Florida and Illinois, and one each from Indiana, Minnesota, Missouri and Ohio.

Of the 46 citations, two are of an **Overview** nature, including an NCHRP Synthesis Report and a conference paper on the same report. Sixteen citations are devoted to the linkage of **Performance and Design**, while 21 citations focus strictly on whitetopping **Performance**, five focus on mechanistic **Design** issues alone, and two address **Life-Cycle Cost Analysis**. Of the 46 citations, two were published in 2006, 16 in 2005, two in 2004, six in 2003, seven in 2002, 11 in 2001, and two in 2000.

We also found three **Research in Progress** efforts.

KEYWORDS

Whitetopping, mechanistic, performance.

CITATIONS – Overview (2)

Title: Key Findings from NCHRP Synthesis of Highway Practice 338: Thin and Ultrathin Whitetopping
Author(s): Robert Otto Rasmussen, Dan K. Rozycki
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 194-196.
Description: 3 pp.
Contents: The National Cooperative Highway Research Program (NCHRP) has recently published a Synthesis of Highway Practice entitled "Thin and Ultra-thin Whitetopping." The purpose of this synthesis is to summarize available information and to document how departments of transportation and other agencies and owners are currently using thin whitetopping and ultrathin whitetopping overlays among their various pavement rehabilitation alternatives. This presentation serves to highlight key findings from this comprehensive and cooperative effort.

Title: Thin and Ultra-Thin Whitetopping
Author(s): R.O. Rasmussen, D.K. Rozycki
Date: 2004
Doc ID/URL: *NCHRP Synthesis of Highway Practice No. 338*. http://trb.org/publications/nchrp/nchrp_syn_338.pdf
Description: 95 pp.
Contents: This report summarizes available information to document how departments of transportation and other agencies and owners are currently using thin and ultra-thin whitetopping (TWT and UTW) overlays among various pavement rehabilitation alternatives. This study covered all stages of the proper application of whitetopping overlays, including project selection, design, materials selection, construction, maintenance, and eventual rehabilitation or replacement. This synthesis provides the practitioner with a comprehensive source for the state of the practice, as well as the state of the art in TWT and UTW overlay application. It is designed to serve as a quick reference guide and as a training aid. The report includes a review of published literature related to all stages of the proper application of whitetopping overlays and a broad range of citations has been gathered, from practical case studies to reports of theoretical modeling. In addition, a survey of the highway community was undertaken that provided first-hand results of experiences with TWT and UTW. Responses were received from both the public and private sectors.

CITATIONS – Performance and Design (16)

Title: UTW behavior on asphalt pavements tested with HWLS
Author(s): Yoon-Ho Cho, Han-Mo Koo
Date: November 2006
Doc ID/URL: *Journal of Transportation Engineering*, Vol. 132 (11): 880-887.
Description: 8 pp.
Contents: The objective of this research is to evaluate how the physical properties and thickness of asphalt pavements influence behaviors of ultra thin whitetopping (UTW). The results of the three-dimensional finite-element method reveal that properties of asphalt and concrete layers, bonding between the two layers, and temperature strongly affect the distress of UTW. Based on results of FEM analysis, a wheel tracking device called the "heart wheel load simulator (HWLS)" was developed and used to perform an experiment to observe behavior variation in accordance with asphalt and concrete layer thicknesses as well as temperature. The results of HWLS simulation show that the effect of temperature is not significant and the increase of the tensile strain with the increase of a load is relatively small for a 100mm concrete layer, as compared to a 50mm concrete layer. In addition, for a 50mm concrete layer with a less than 150mm asphalt layer, the increased ratio of the tensile strain at the bottom of the concrete slab is significantly higher. Therefore, this research recommends that an at least 150mm asphalt layer after milling be required in order to apply UTW safely. © 2006 ASCE.

Title: Evaluation of Composite Pavement Unbonded Overlays: Phase III
Author(s): James K. Cable, Jennifer L. Morud, Toni R. Tabbert
Date: August 2006
Doc ID/URL: DTFH61-01-X-00042 (CTRE Project 01-95), Final Report.
http://www.ctre.iastate.edu/reports/composite_unbonded_overlay.pdf
Description: 37 pp.
Contents: In recent years, thin whitetopping has evolved as a viable rehabilitation technique for deteriorated asphalt cement concrete (ACC) pavements. Numerous projects have been constructed and tested, allowing researchers to identify the important elements contributing to the projects' successes. These elements include surface preparation, overlay thickness, synthetic fiber reinforcement usage, joint spacing, and joint sealing. Although the main factors affecting thin whitetopping performance have been identified by previous research, questions still existed as to the optimum design incorporating these variables. The objective of this research is to investigate the interaction between these variables over time. Laboratory testing and field testing were conducted to achieve the research objectives. Laboratory testing involved shear testing of the bond between the portland cement concrete (PCC) overlay and the ACC surface. Field testing involved falling weight deflectometer deflection responses, measurement of joint faulting and joint opening, and visual distress surveys on the 9.6-mile project. The project was located on Iowa Highway 13 extending north from the city of Manchester, Iowa, to Iowa Highway 3 in Delaware County. Variables investigated include ACC surface preparation, PCC thickness, slab size, synthetic fiber reinforcement usage, and joint spacing. This report documents the planning, construction, and performance of each variable in the time period from summer 2002 through spring 2006. The project has performed well with only minor distress identification since its construction.

Title: Ultrathin Whitetopping in California and Nevada: A 13-Year Performance Perspective of Performance Based on Joint Spacing, Thickness, and Traffic Loading
Author(s): David J. Akers, Rich Warren
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 59-70.
Description: 12 pp.
Contents: Since the first California ultrathin whitetopping (UTW) was constructed at a mortuary, UTW has proven not to be a dead concept but a steadily growing process providing low-maintenance pavements for streets, bus pads, intersections, and parking lots. A Pavement Condition Index (PCI) survey of 18 projects using the Micropaver protocol yielded ratings of excellent to very good for 2- to 13-year old pavements located from coastal southern California to Reno, Nevada. A constant in considering UTW for pavement rehabilitation has been the cost of saw-cutting joints at the close spacings recommended by the American Concrete Pavement Association (ACPA). Based on the finding that 90% of projects constructed with joint spacings larger than those recommended by ACPA have PCIs > 85 (excellent), UTW subjected to car-only traffic can have larger spacings.

Title: Performance of Florida's First Whitetopping Project
Author(s): Jamshid Armaghani, Roger Schmitt
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 71-76.
Description: 6 pp.
Contents: In 1988, the Florida Department of Transportation constructed the first whitetopping project on US-1, south of Daytona Beach. This was an experimental project constructed on milled asphalt pavement on the southbound side of the four-lane, divided US-1. The 3.1 km (1.9 mi) whitetopping project was designed to evaluate the performance of various thicknesses, joint spacings, doweled and undoweled joints, and standard and special dowel patterns. This summary discusses the design, construction, and overall condition of the project. The primary issues addressed are the performance of the 152-mm (6-in.) whitetopping section relative to the 178-mm (7-in.) and 203-mm (8-in.) sections, the performance of special dowels compared to standard dowels and doweled joints versus undoweled joints, the condition of the bond between the concrete overlay and the asphalt surface, and lessons learned.

Title: The Illinois Whitetopping Experience: A Practical Approach
Author(s): Thomas J. Winkelman
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 77-105
Description: 29 pp.
Contents: Between 1998 and 2004, eight experimental whitetopping projects were constructed in Illinois. Four of these projects rehabilitated highway intersections, and the remaining four rehabilitated mainline pavements. The projects included the use of ultrathin whitetopping, thin whitetopping, and bonded concrete overlays. This paper explores the construction and performance of all eight projects. Details of the design, construction methods, construction costs, traffic loadings, and performance are addressed. Detailed traffic counts, visual distress surveys, and soundings of the whitetopping projects were used as performance measures. The performance of the thin whitetopping rehabilitations on the four mainline pavements and the ultrathin whitetopping sections of the intersection rehabilitations has been excellent to date. The performance of the bonded concrete sections of the intersection rehabilitations has been poor.

Title: Thin Concrete Overlays of Composite Pavements in Southeast Michigan
Author(s): Kerry Sutton
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 106-113.
Description: 8 pp.
Contents: A thin concrete overlay, or whitetopping, is a widely used technique to rehabilitate deteriorated full-depth asphalt pavements. Across Michigan, as well as other parts of the United States, agencies are faced with choosing an appropriate rehabilitation option to address old concrete pavements or even composite pavement sections, old concrete with a deteriorated asphalt overlay on top. Local agencies in Michigan as well as the Michigan Department of Transportation (DOT) have developed and constructed a separated concrete overlay that involves constructing a

102-mm (4-in.) or less concrete pavement section and a 25-mm (1-in.) asphalt separator on the old pavement or composite pavement sections. This paper outlines several projects constructed in the Detroit metro area including one constructed over 20 years ago and several more recent projects constructed in Wayne County. Details of project scoping, design, and construction are provided as well as recent information on pavement performance. The Michigan DOT will also be constructing a large, separated concrete overlay project in the City of Detroit during summer 2005. This project will consist of over 167,226 m(squared) (200,000 yd(squared)) of 10-mm (4-in.) separated concrete overlay. Details of this project are also discussed.

Title: Best Practices for the Design and Repair of Thin and Ultrathin Whitetopping Based on Mn/ROAD Findings
Author(s): Julie M. Vandenbossche
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 242-261.
Description: 20 pp.
Contents: Thin and ultrathin whitetopping (TWT and UTW) overlays are becoming a more common method of pavement rehabilitation. It is important to gain information on the types of distress that occur in the overlays and effective repair techniques. In 1997, the Minnesota Department of Transportation constructed several TWT and UTW test sections at the Minnesota Road Research (Mn/ROAD) facility and at intersections in US-169 in Elk River, MN. Many different overlay designs were represented at the test sections. This allowed the opportunity to determine which design parameters help to optimize performance and to identify the type of failures that can occur. Different techniques for repairing UTW were also investigated. Various techniques were used to deter reflective cracking. This included the use of various bond-breaking materials and full-depth sawing at strategic locations along the longitudinal joint to prevent cracks from propagating into adjacent panels at misaligned transverse joints. The TWT and UTW test sections have shown that whitetopping is a viable rehabilitation alternative for asphalt pavements. The importance of evaluating the existing pavement before placing the overlay and choosing an optimum panel size was exhibited. It has also been shown that, when necessary, it is easy to repair UTW sections. Various techniques for repairing each type of distress have been summarized.

Title: Incorporation of Probabilistic Concepts Into Fatigue Analysis of Ultrathin Whitetopping as Developed for the American Concrete Pavement Association
Author(s): Randell C. Riley, Leslie Titus-Glover, Jagannath Mallela, Steve Waalkes, Michael Darter
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 288-317.
Description: 30 pp.
Contents: Fatigue analysis for the design of ultrathin whitetopping (UTW) pavements as used in the design procedures published by ACPA is based on fatigue models that have been in existence for pavement design for decades. The underlying assumptions in the fatigue models result in an unstated, conservative factor of safety in all UTW designs developed using the procedure. Checking the performance of UTW projects against the design calculations reflects this conservatism. Recent efforts in the revision of the existing fatigue models to incorporate probabilistic concepts are reviewed and approximate comparisons are made with several existing projects constructed in Illinois as a base of reference for the revised models. Possible extension of the models into thicker designs is also discussed.

Title: Evaluation of Applicability of Ultrathin Whitetopping in Florida
Author(s): Wasantha Kumara, Mang Tia, Chung-Lung Wu, Bouzid Choubane
Date: 2003
Doc ID/URL: *Transportation Research Record 1823* (2003), 39-46.
Description: 8 pp.
Contents: A three-dimensional (3-D) finite element model for stress analysis of pavements with ultrathin whitetopping (UTW) under critical loading conditions was developed. The 3-D model developed was used to analyze the UTW test pavement sections at the Ellaville Weigh Station in Florida, which had less than satisfactory performance. The poorly performing UTW sections at the Ellaville Weigh Station were found to have relatively higher maximum computed stresses under critical loading conditions, which appeared to explain their poor performance and high percentages of cracked slabs. The 3-D model developed was also used to perform a parametric analysis to determine the effects of asphalt thickness, asphalt modulus, concrete thickness, concrete modulus, base stiffness, subgrade stiffness, slab dimension, temperature differential in the concrete, and applied load on the maximum stresses in UTW pavements under typical Florida conditions.

Title: Mechanical Behavior of Ultrathin Whitetopping Structure Under Stationary and Moving Loads
Author(s): T. Nishizawa, Y. Murata, K. Kokubun
Date: 2003
Doc ID/URL: *Transportation Research Record 1823* (2003), 102-110.
Description: 9 pp.
Contents: The structural design of ultrathin whitetopping (UTW) requires precise predictions of the loading stresses in the concrete slabs. A plate finite element model (FEM) is not used for structures with UTW because the model is not able to account for the asphalt subbase behaviors and the mechanical interaction between the concrete slab and asphalt subbase. A three-dimensional FEM (3DFEM) was used for the stress calculation of UTW. To take into account the mechanical interaction at the interface between the concrete slab and asphalt subbase as well as the load transfer across the joint, a general interface element was developed and incorporated into 3DFEM. Also, the viscosities of asphalt materials were considered by the viscoelastic formulation in the 3DFEM. A loading test was conducted on a test pavement. Stationary and moving loads were applied to the concrete slabs, and the strains in the slabs and the asphalt subbase were measured. By comparing the strains computed by 3DFEM with the measured strains, it was found that the viscosity of the asphalt subbase and the interface condition significantly affect the stresses in the concrete slab.

Title: Forensic Investigation of the Ellaville Weight Station UTW Pavements
Author(s): M. Tia, C-L Wu, W. Kumara
Date: June 2002
Doc ID/URL: UF PN 49104504831-12, Final Report.
http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_SMO/FDOT_BC354_43rpt.pdf
Description: 310 pp.
Contents: To evaluate the applicability of ultra-thin whitetopping (UTW) in Florida, the Florida Department of Transportation constructed a UTW test pavement at the Ellaville weigh station along I-10 in North Florida in 1997. This UTW pavement consisted of 6 test sections with varying panel dimensions and slab thickness. The performance of these test sections, however, was less than ideal, with the observation of some early cracking on the concrete surface. These pavement sections are scheduled for rehabilitation in 2002. This study was conducted to determine the causes of the problems of the UTW sections, so that lessons could be learned from this experimental project, the use of UTW under Florida's conditions can be adequately assessed, and UTW technology may be properly applied in the future. This investigation was performed through a literature and document review, field evaluation, laboratory testing, and a design assessment.

Title: Portland Cement Concrete Overlays: State of the Technology Synthesis
Author(s): K.D. Smith, H.T. Yu, D.G. Peshkin
Date: April 2002
Doc ID/URL: FHWA-IF-02-045, Final Report.
Description: 190 pp.
Contents: This report presents the latest information on the design, construction and performance of portland cement concrete (PCC) overlays. It describes the four types of PCC overlays that are commonly used in highway pavement applications: bonded PCC overlays, unbonded PCC overlays, conventional whitetopping and ultra-thin whitetopping. Recommended applications, critical design elements, current overlay design methodologies, recommended construction practices, and performance highlights are described for each overlay type. Information is also provided on the selection of PCC overlays as possible rehabilitation alternatives for existing pavements. Taken together, this document addresses the current "state of the technology" of PCC overlays placed on both existing PCC pavements and on existing hot-mix asphalt pavements. As described in this document, there has been significant progress over last decade in improving the performance of PCC overlays. However, there remain several critical design and construction areas that are currently not adequately addressed, and these suggested future research needs are listed in this report.

Title: Instrumentation and Field Testing of Whitetopping Pavements in Colorado and Revision of the TWT Design Procedure
Author(s): C. Wu, M. Sheehan
Date: March 2002
Doc ID/URL: Report No. CDOT-DTD-R-2002-3, Interim Report, March 2002.
http://www.dot.state.co.us/Publications/PDFFiles/AirVoids.pdf
Description: 60 pp.
Contents: Whitetopping has recently been generating considerable interest and greater acceptance as an approach to asphalt pavement rehabilitation. A number of thin whitetopping (TWT) and ultra-thin-whitetopping (UTW)

pavement test sections have been constructed during the past 10 years, and the pavements have demonstrated considerable advantages as a rehabilitation technique. In 1996 the Colorado Department of Transportation (CDOT) sponsored a research project to develop a mechanistic design procedure for TWT pavements. Construction Technology Laboratories, Inc., installed the instrumentation, conducted the load testing on the instrumented test section, performed a theoretical analysis, and developed a TWT design procedure for CDOT. Many variables were considered in the construction of the test sections, including concrete overlay thickness, slab dimension, existing asphalt layer thickness, different asphalt surface preparation techniques, and the use of dowel bars and tie bars. Based on the original design procedure development, there are several observations and conclusions regarding the use of TWT pavements for rehabilitation that should be examined more extensively with a supplemental investigation. The items include subgrade support conditions, required thickness of asphalt beneath the concrete layer, and effects of variable joint spacings. New TWT pavement test sections were constructed during 2001 in conjunction with a TWT project constructed by CDOT on SH 121 near Denver, Colorado. This provided an opportunity to instrument and load best additional TWT test sections and use the data to calibrate and verify the existing observations and design procedure. Therefore, the objective of this project is to instrument, load test, and monitor the new and original TWT test section performances to supplement and confirm the results of the 1996 study.

Title: Design and Quality Control of Concrete Overlays
Author(s): N. Delatte, S. Chen, J. Davidson, A. Sehdev, N. Amer, M. Endfinger
Date: December 2001
Doc ID/URL: UTCA Report 01220, Final Report. http://ntl.bts.gov/lib/19000/19400/19409/PB2002106729.pdf
Description: 56 pp.
Contents: The United States has a significant investment in civil infrastructure, which is deteriorating under heavy use, age, and environmental attack. A large proportion of this infrastructure consists of plain and reinforced concrete pavements and bridge decks. Concrete overlays have been used for pavement and bridge deck rehabilitation for many years. Concrete overlays on pavements or bridge decks can fulfill three design functions - they can strengthen the structure against further deterioration due to fatigue cracking (or rutting, with whitetopping overlays), they can improve smoothness and restore ride quality, and they can add skid resistance. This research developed and tested a range of plain and fiber reinforced concrete overlay mixes that allow reliable, economic, and durable overlay construction as well as early opening to traffic. This report documents the benefits of using nondestructive testing technologies, including spectral analysis of surface waves, in overlay investigation, planning, construction, and quality control. Analytical modeling using the HIPERBOND module of the program HIPERPAVE was used to investigate behavior and performance prediction for the eight overlay concrete designs investigated in the laboratory testing program. So far, two ultrathin whitetopping overlays have been constructed in Alabama, on heavily traveled asphalt pavements in Selma and Jasper. Both projects were constructed in the outside lanes at intersections, where stopped trucks caused considerable rutting over the years. Performance of the two overlays to date has been very good. Recommendations are made in this report for materials selection, design, and construction controls for overlay construction.

Title: Analysis of Performance of the Ultra-Thin Whitetopping Subjected to Slow Moving Loads in an Accelerated Pavement Testing Facility
Author(s): Sudarshan Rajan, Jan Olek, Thomas L. Robertson, Khaled Galal, Tommy Nantung, and W. Jason Weiss
Date: September 2001
Doc ID/URL: *7th International Conference on Concrete Pavements*, Orlando, Florida, September 9-13, 2001. http://rebar.ecn.purdue.edu/APT/Research/S16-P4-Rajan.pdf
Description: 11 pp.
Contents: Ultra-Thin Whitetopping (UTW) is rapidly emerging as a technology that can be used for the rehabilitation of deteriorated pavements. To investigate the performance of UTW when they are placed over flexible pavements and subjected to a slow moving load, four whitetopping mixtures were placed over a milled asphalt surface in the Accelerated Pavement Testing (APT) facility of the Indiana Department of Transportation (INDOT) Research Division in West Lafayette, Indiana in the Fall of 1999. This paper presents the response of the UTW to repeated loading, including analysis of stresses and strains, with the goal of identifying the factors influencing the performance of UTW. The data was analyzed to determine the maximum strains and their location, the degree of bonding between the UTW and the existing pavement, and the pavement performance under repeated loading. The study described in this paper is a part of a larger effort to develop preliminary design guidelines for UTW construction in Indiana including development of the semi-empirical model for performance prediction of UTW.

Title: The Ultrathin Whitetopping Option
Author(s): J.K. Cable, J. Hart
Date: 2001
Doc ID/URL: *7th International Conference on Concrete Pavements: The Use of Concrete in Developing Long-Lasting Pavement Solutions for the 21st Century*, International Society for Concrete Pavements, 2001: 969-975.
Description: 7 pp.
Contents: This paper describes how an 11.6-km (7.2-mile) of ultrathin whitetopping was constructed on a highway in Iowa in 1994. Research was carried out under Iowa Highway Research Board Project Number HR-559 for five years and TR-432 for an additional five years. When considering ultrathin as an overlay option, the question to be asked is how long is the performance life and what are the rehabilitation options? Some 41 sections of pavement including three overlay depths, four joint patterns, three surface preparations, and fiber usage were constructed. The paper discusses the methods used in the rehabilitation and the success of each method. Deflection testing, visual surveys, coring, and direct shear testing have continued over the seven years. Analyses of the data have identified ways to accurately estimate the overlay performance in terms of bond strength retained.

CITATIONS – Performance (21)

Title: Forensic Investigation Report for Mn/ROAD Ultrathin Whitetopping Test Cells 93, 94, and 95
Author(s): Thomas R. Burnham
Date: September 2005
Doc ID/URL: MN/RC 2005-45, T9PR2004, Final Report. http://www.lrrb.org/PDF/200545.pdf
Description: 116 pp.
Contents: Three instrumented ultra-thin whitetopping (UTW) pavement test sections were constructed in 1997 at the Minnesota Road Research facility (MnROAD). The sections were installed on the interstate highway portion of MnROAD to accelerate the traffic loadings compared to typical applications of UTW. By spring 2004, significant deterioration of the sections had occurred. Prior to replacement of the three test sections in fall 2004, a forensic investigation of the distresses was carried out. The focus of this report was to describe the forensic investigation procedures carried out, and to summarize findings from the investigation. The investigation revealed that the performance of ultra-thin whitetopping test cells at the MnROAD project was related to traffic volume, wheel placement, and layer bonding. Distresses were more frequent and severe in the higher-volume driving lane. Panel sizes that place wheelpaths near the edges of UTW slabs resulted in accelerated distress and poor performance. Bonding of UTW to the underlying asphalt layer was essential for long-term performance. Reflective cracking occurs in bonded concrete overlays for thicknesses less than 5 in. (over 6 in. minimum asphalt layer). Large polyolefin fibers did provide some benefit to crack containment in UTW, but added significant cost to the concrete mix.

Title: Forensic investigation of ultra-thin whitetopping failures in Taiwan
Author(s): Deng-Fong Lin, Her-Yuan Wang
Date: May 2005
Doc ID/URL: *Journal of Performance of Constructed Facilities*, Vol. 19 (2), May 2005: 165-171.
Description: 7 pp.
Contents: This paper addresses the causes of the premature failures observed on newly constructed ultra-thin whitetopping (UTW) sections. The key factors contributing to premature failure were high pouring temperature and an insufficient underlying asphalt layer. Severe cracking and deep rutting were observed on sections placed during the daytime when the weather was hot and dry. Pouring temperature was even more critical when river gravel aggregate was used because it has a high thermal coefficient of expansion. Also, a low water-cement ratio magnified the effect of thermal cracking at high pouring temperature. On the basis of field results, it was found that the use of high-strength concrete should be discouraged when the pour temperature is high, since high shrinkage and premature cracking can result. It was concluded that the deep rutting was caused by the pumping of fines from the underlying base layer, in locations where there was no erosion-resistant asphalt layer. Sections poured at temperatures below 30°C with 100 mm of underlying asphalt performed well, and those two criteria are recommended for future UTW application. © ASCE.

Title: Ultrathin Overlays: Standing the Test of Time
Author(s): James K. Cable
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 45-58.
Description: 14 pp.

Contents: In 1994, the Iowa Department of Transportation, in conjunction with the Federal Highway Administration, constructed an 11.6-km (7.2 mi) segment of ultrathin overlay on a section of portland cement concrete pavement in central Iowa. The project included variations in base preparation, slab depth and size, use of fibers, and consideration for joint sealing. The project was developed for 5 years of research monitoring, at the end of which the department decided to extend the evaluation for 5 years and to investigate the potential for repair methods of damaged panels. The project has survived the 10-year research window, and continues to perform well. The attributes that make this a good design are included in the paper for others to apply in the consideration of ultrathin surface restoration projects.

Title: Results of Forensics Evaluation of the Ultrathin Whitetopping Overlays at the FHWA ALF Conducted Under Concrete Pavement Technology Program Task 5
Author(s): Robert Otto Rasmussen, J. Mauricio Ruiz, James A. Sherwood
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 321-322.
Description: 2 pp.
Contents: In 1998 eight test lanes of ultrathin whitetopping (UTW) were constructed over existing hot-mix asphalt (HMA) pavements at the Federal Highway Administration's (FHWA's) Accelerated Loading Facility (ALF) located at the Turner-Fairbank Highway Research Center in McLean, Virginia. Various combinations of thickness, joint spacing, fiber reinforcement, and HMA base-type were used. In this presentation synopsis, the various failure mechanisms at the ALF UTW are identified and summarized.

Title: Ultra-Thin Portland Cement Concrete Overlay Extended Evaluation
Author(s): James K. Cable, L.E. Edgar, D.R. Anderson
Date: January 2005
Doc ID/URL: Iowa DOT Project TR-432, Final Report.
http://publications.iowa.gov/archive/00003441/01/tr432.pdf
Description: 104 pp.
Contents: In this day of the mature highway systems, a new set of problems is facing the highway engineer. The existing infrastructure has aged to or past the design life of the original pavement design. In many cases, increased commercial traffic is creating the need for additional load carrying capacity, causing state highway engineers to consider new alternatives for rehabilitation of existing surfaces. Alternative surface materials, thicknesses, and methods of installation must be identified to meet the needs of individual pavements and budgets. With overlays being one of the most frequently used rehabilitation alternatives, it is important to learn more about the limitations and potential performance of thin bonded portland cement overlays and subsequent rehabilitation. The Iowa ultra-thin project demonstrated the application of thin portland cement concrete (PCC) overlays as a rehabilitation technique. It combined the variables of base preparation, overlay thickness, slab size, and fiber enhancement into a series of test sections over a 7.2-mi length. This report identifies the performance of the overlays in terms of deflection reduction, reduced cracking, and improved bonding between the PCC and asphalt cement concrete (ACC) base layers. The original research project was designed to evaluate the variables over a 5-year period of time. A second project provided the opportunity to test overlay rehabilitation techniques and continue measurement of the original overlay performance for 5 additional years. All performance indicators identified exceptional performance over the 10-year evaluation period for each of the variable combinations considered. The report summarizes the research methods, results, and identifies future research ideas to aid the pavement overlay designer in the successful implementation of ultra-thin PCC overlays as an alternative pavement rehabilitation technique.

Title: Whitetopping Performance in Illinois
Author(s): Thomas Winkelman
Date: January 2005
Doc ID/URL: Final Report, Physical Research Report No. 148, January 2005, Illinois Department of Transportation. http://www.dot.il.gov/materials/research/pdf/148.pdf
Description: 61 pp.
Contents: Between 1998 and 2004, nine experimental whitetopping projects were constructed in Illinois and their field performance was evaluated. Five of these projects involved the rehabilitation of highway intersections and the remaining four were a rehabilitation of mainline pavements. The projects were constructed on U.S. Highways, Illinois State Routes, and County Highways. These projects included the use of ultrathin whitetopping, thin whitetopping, and bonded concrete overlays of brick pavers and concrete. This report explores the performance for all nine projects through the end of 2004. A summary of the construction methods has been included for each project as a quick reference. Detailed traffic volumes, visual distress surveys, and soundings of the whitetopping projects

were used as performance measures. These values and tests were collected or performed on an annual basis where applicable. The performance of the mainline pavement rehabilitations has been excellent to date except for a few minor distresses in one of the projects. The performance of the whitetopping sections of the intersection rehabilitations has also been excellent. The performance of the bonded concrete sections at the intersection rehabilitations has been satisfactory.

Title: Evaluation of Composite Pavement Unbonded Overlays: Phases I and II
Author(s): J. K. Cable, M.L. Anthony, F.S. Fanous, B.M. Phares
Date: April 2003
Doc ID/URL: IDOT HR-1093, TR-478, FHWA DRFH6101X00042.
http://www.ctre.iastate.edu/reports/hr1093construction.pdf
Description: 28 pp.
Contents: In recent years, thin whitetopping has evolved as a viable rehabilitation technique for deteriorated asphalt cement concrete (ACC) pavements. Numerous projects have been constructed and tested. These projects allow researchers to identify the important elements contributing to the projects' successes. These elements include surface preparation, overlay thickness, synthetic fiber reinforcement usage, joint spacing and joint sealing. Although the main factors affecting thin whitetopping performance have been identified by previous research, questions still existed as to the optimum design incorporating these variables. The objective of this research is to investigate the interaction between these variables over time. Laboratory testing and field-testing were planned in order to accomplish the research objective. Laboratory testing involved shear testing of the bond between the portland cement concrete (PCC) overlay and the ACC surface. Field testing involved falling weight deflectometer deflection responded, measurement of joint faulting and joint opening, and visual distress surveys on the 9.6 mile project. The project was located on Iowa Highway 13 extending north from the city of Manchester, Iowa, to Iowa Highway 3 in Delaware County. Variables investigated included ACC surface preparation, PCC thickness, synthetic fiber reinforcement usage and joint spacing. This report documents the planning, equipment selection, construction, field changes and construction concerns of the project built in 2002. The data from this research could be combined with historical to develop a design specification for the construction of thin, unbonded overlays.

Title: Mechanical Properties and Durability of Bonded-Concrete Overlays and Ultrathin Whitetopping Concrete
Author(s): N. Delatte, A. Sehdev
Date: 2003
Doc ID/URL: *Transportation Research Record 1834* (2003): 16-23.
Description: 8 pp.
Contents: Concrete overlays have been used for pavement and bridge-deck rehabilitation for many years. The mechanical properties and durability of several plain and fiber-reinforced concrete-overlay mixes were analyzed. Eight different concrete-overlay mix designs were investigated. The materials properties investigated were compressive and splitting tensile strength, modulus of elasticity, bond to concrete (with three different surface roughness characteristics), and durability. Freeze-thaw tests were performed to determine the durability of the concrete mixtures used. Strength and stiffness were investigated from 1, 3, 7, and 14 days. Laboratory tests on the strength and stiffness development of eight candidate concrete-overlay designs showed that high-strength concrete was appropriate for opening overlays to traffic in 24 h or less, but normal-strength concrete may be used if traffic loading may be delayed for 48 or 72 h. For larger projects, where paving continues over several days, normal-strength mixtures may be used when 48 to 72 h or more of curing can be achieved before traffic loading begins, with high-strength mixtures used for the last day's construction. All the high-strength concrete overlay-mixture designs tested appear to have satisfactory strength, stiffness, bond properties, and durability for use in bonded overlay construction. The normal-strength concrete is more economical than the high-strength concrete but develops its design properties more slowly.

Title: Whitetopping and Hot-Mix Asphalt Overlay Treatments for Flexible Pavement: Minnesota Case History
Author(s): T. Burnham and D. Rettner
Date: 2003
Doc ID/URL: *Transportation Research Record 1823* (2003), 3-10.
Description: 8 pp.
Contents: In 1993, two hot-mix asphalt and four whitetopping overlay test sections were constructed on low-volume road TH 30 in southern Minnesota. A study was undertaken to examine the performance and costs associated with the test sections after 9 years of service. The field testing and evaluation are described, and the costs incurred through 2001 are tabulated. The hot-mix asphalt overlay test sections are performing up to their design expectations. Routine preventive maintenance has been applied to both hot-mix asphalt test sections, adding to their long-term cost of operation and ownership. The whitetopping test sections are performing very well at the midpoint

of their design lives of 20 years. Most distresses to date are related to poor construction and materials rather than inherent design features. Some random longitudinal cracking has occurred in areas of the whitetopping control section. The doweled test section has numerous distressed transverse joints caused by dowels near the surface of the slabs. There is virtually no faulting of the transverse joints, and the ride quality has stabilized. No maintenance has been performed on the whitetopping sections through 2001. As of 2002, the most economical overlay design in this study is a 6-in.-thick bonded whitetopping. On the basis of recent observations, it appears that whitetopping performs well and is an economical option for rehabilitation of low-volume roads in Minnesota.

Title: Performance Analysis of Ultrathin Whitetopping Intersections on US-169: Elk River, Minnesota
Author(s): Julie M. Vandenbossche
Date: 2003
Doc ID/URL: *Transportation Research Record 1823* (2003), 18-27.
Description: 10 pp.
Contents: The Minnesota Department of Transportation constructed an ultrathin whitetopping (UTW) project at three consecutive intersections on US-169 at Elk River, Minnesota, to gain more experience with both the design and the performance of UTW. Distinct cracking patterns developed within each test section. The UTW test sections with a 1.2- × 1.2-m (4- × 4-ft) joint pattern included corner breaks and transverse cracks. Corner breaks were the primary distress in the test section with a 1.8- × 1.8-m (6- × 6-ft) joint pattern, although very little cracking was exhibited. The Minnesota Road Research Facility UTW test sections on I-94 allow comparisons of the same UTW design on hot-mix asphalt (HMA) pavements with different structural capacities to be made. The strain and deflection measurements emphasize the importance of the support provided by the HMA layer. A reduction in this support occurs when the temperature of the HMA is increased or when the HMA begins to ravel. During evaluations of whether UTW is a viable rehabilitation alternative, cores should be pulled from the pavement to determine if the asphalt is stripping and if the asphalt layer has adequate thickness. UTW can be successfully placed on as little as 76 mm (3 in.) of asphalt, if the quality of the asphalt is good. The cores should also reveal whether the asphalt layer is of uniform thickness and whether stripping and raveling have occurred. If the asphalt layer is of uniform thickness and stripping and raveling have not occurred, UTW is a good option for use in the rehabilitation of asphalt pavements.

Title: Whitetopping construction and early performance in Illinois
Author(s): Thomas J. Winkelman
Date: June 2002
Doc ID/URL: FHWA/IL/PRR 144, Technical Report. http://ntl.bts.gov/lib/23000/23200/23217/144.pdf
Description: 73 pp.
Contents: Seven experimental whitetopping projects were constructed in Illinois between 1998 and 2001. Three of these projects included the rehabilitation of intersections, while the remaining four were a rehabilitation of mainline pavement. The three intersection projects include whitetopping of both existing bituminous pavements and existing concrete pavements (thin bonded concrete overlay). All four of the mainline pavement projects were a rehabilitation of an existing bituminous pavement. This report summarizes the construction and early performance of all seven projects. Details of the design, construction methods, construction costs, and early performance are addressed. Visual distress surveys and sounding of the overlay for delaminations have been conducted on an annual basis for performance. Initial performance reviews for the four mainline pavement projects indicate excellent results. Performance reviews for the whitetopping portions of the intersection projects indicate good performance. Performance reviews for the thin bonded concrete overlay portions of the intersection projects indicate poor performance.

Title: Ultra-thin whitetopping in Canada: State-of-practice
Author(s): Scott Murison, Ahmed Shalaby, Tim Smith
Date: June 2002
Doc ID/URL: *Procedures of the Annual Conference of the Canadian Society of Civil Engineering*, Vol. 2002, June 5-8, 2002, Montreal, Quebec, Canada: 2631-2639.
Description: 9 pp.
Contents: Ultra-thin whitetopping is the technology to construct thin (50-100mm) Portland cement concrete overlays on distressed asphalt pavements. There have been several UTW projects completed in Canada, the first in Mississauga ON, with others in Brampton, Markham, Ottawa, Hamilton, and Vancouver. All projects have shown good to excellent performance thus far, indicating that this rehabilitation strategy can stand up to the harsh Canadian climate. The suitability of UTW rehabilitation for a particular site is dependent on several factors including existing asphalt thickness, volume of truck traffic, base and subgrade support, and pavement condition. UTW is beneficial in several ways especially for repairing roads and intersections experiencing problems with rutting or washboarding.

This paper outlines the state-of-practice in Canada for UTW construction, with respect to traffic, materials, design, construction, and repair. The determination of load carrying capacity and measurement of performance of a UTW project is discussed as well as issues related to life cycle cost analysis. Several case studies on UTW projects in Canada are presented.

Title: Identification of pavement failure mechanisms at FHWA accelerated loading facility ultrathin whitetopping project
Author(s): Robert Otto Rasmussen, Frank B. McCullough, J. Mauricio Ruiz, James Mack, James A. Sherwood
Date: 2002
Doc ID/URL: *Transportation Research Record 1816* (2002): 148-155.
Description: 8 pp.
Contents: In 1998 eight test lanes of ultrathin whitetopping (UTW) were constructed over existing hot-mix asphalt (HMA) pavements at FHWA's Accelerated Loading Facility (ALF) located at the Turner-Fairbank Highway Research Center in McLean, Virginia. Various combinations of thicknesses, joint spacings, fiber reinforcement, and types of HMA base were used. In spring 2000 the loading experiment of these pavements was completed, and the analysis of behavior and performance was begun. A summary of some of the pavement distresses observed at the ALF Is presented, and hypothesized failure mechanisms are identified, providing an addition to the state of the knowledge with respect to the actual life cycle of UTW pavements.

Title: Performance, Analysis, and Repair of Ultrathin and Thin Whitetopping at Minnesota Road Research Facility
Author(s): Julie M. Vandenbossche, Aaron J. Fagerness
Date: 2002
Doc ID/URL: *Transportation Research Record 1809* (2002), 191-198.
Description: 8 pp.
Contents: Thin and ultrathin whitetopping overlays are becoming a more common method of pavement rehabilitation. It is important to gain information on the types of distresses that occur in the overlays and effective repair techniques. In 1997 the Minnesota Department of Transportation constructed several thin and ultrathin whitetopping test cells at the Minnesota Road Research (Mn/ROAD) facility. Typical distresses included corner breaks, transverse cracks, and reflective cracks. The finite element program ISLAB2000 was used to investigate stress patterns and their relation to the distresses. Different techniques for repairing ultrathin whitetopping were investigated. Various techniques were also used to deter reflective cracking, including various bond-breaking materials and full-depth sawing at strategic locations along the longitudinal joint to prevent cracks from propagating into adjacent panels at misaligned transverse joints. Four of the six sections had present serviceability indexes (PSIs) greater than 3.5 before the repairs, showing that a good level of performance has been maintained after 4.7 million equivalent single-axle loads. The two sections that exhibited the largest drop in PSI were the overlays with 1.2- × 1.2-m (4- × 4-ft) panels. The repairs made in sections containing these panels have brought the PSI back up to an acceptable level (PSI > 3). The thin and ultrathin whitetopping test sections at Mn/ROAD have shown that whitetopping is a viable rehabilitation alternative for asphalt pavements. The importance of choosing an optimum panel size was exhibited. It has also been shown that when necessary, it is easy to repair ultrathin whitetopping sections. Various techniques for repairing each type of distress have been summarized.

Title: Concrete Overlay as a Rehabilitation Option for Distressed Asphalt Pavements
Author(s): S. Rajan, J. Olek
Date: December 2001
Doc ID/URL: FHWA/IN/JTRP-2001/06, Final Report.
http://rebar.ecn.purdue.edu/JTRP_Completed_Project_Documents/SPR_2340/FinalReport/spr_2340_final_form1700.pdf
Description: 149 pp.
Contents: Ultrathin Whitetopping (UTW) involves placing a very thin concrete overlay 50 mm to 100 mm thick (2"-4") on the milled surface of a distressed asphalt pavement. To investigate the performance of UTW placed over a flexible pavement subjected to slow and heavy moving wheel loads, whitetopping mixes were placed over a milled pavement surface in the accelerated pavement testing (APT) facility of the Indiana Department of Transportation (INDOT) Research Division in West Lafayette Indiana in the fall of 1999. The UTW installation experiment consisted of four test 'lanes' of two different thickness; each utilizing plain and fiber reinforced concrete. The test 'lanes' were instrumented using strain gages, Variable Differential Transducers (LVDTs) and thermocouples to measure the strains, deflections, and to monitor the pavement temperatures respectively. The test 'lanes' were subjected to both static and dynamic tandem wheel loads of varying magnitudes. In addition, one of the test 'lanes' was also exposed to thermal load by applying a temperature gradient to the pavement. A mix design for the UTW was developed based on literature survey of previous UTW projects. The mechanical properties of concrete were

evaluated in the laboratory before the UTW pavements were constructed at the APT facility. The pavements were monitored continuously during the testing period and the dynamic load strains during the motion of the wheel, as well as the static strains due to the stationary wheel load were recorded. This data was analyzed to determine the maximum strains and their location, the degree of bonding between the UTW overlay and the underlying asphalt and the pavement performance under repeated loading. In addition, non-destructive test method was utilized to evaluate the pavement condition after the accelerated pavement testing was completed. In addition, cores obtained from the pavement were subjected to shear force to determine the quality of the bond.

Title: Evaluation of Ultra-Thin Whitetopping
Author(s): Dave Amos
Date: October 2001
Doc ID/URL: Missouri DOT Research Investigation RI99-012, October 2001.
http://168.166.124.22/RDT/reports/Ri99012/RDT01014.pdf
Description: 51 pp.
Contents: An asphalt intersection with a history of rutting and shoving problems was selected to determine whether Ultra-Thin Whitetopping (UTW) would be a viable alternative to placing a bituminous overlay. The project selected was the intersection at Route 169 (Belt Highway), Route YY, and Mitchell Avenue in St. Joseph, Mo. The UTW project consisted of coldmilling 3 inches of the old asphalt surface, placing a 3-inch concrete overlay, and sawing the concrete overlay into 3 foot by 3 foot squares using early entry saws. The project was completed during a 60-hour period using a high-early strength concrete mix, gradation "F" Bethany Falls limestone and fibrillated polypropylene fibers. The design strength of 3500 psi was monitored using a maturity curve and was achieved prior to 14 hours after placement. Construction practices were monitored, as well as performing concrete tests, molding concrete specimens for later testing, and drilling cores for bond strength tests. Visual surveys were performed prior to and immediately after coldmilling operations and after overlay placement. Falling Weight Deflectometer (FWD) testing was performed prior to asphalt milling and after overlay placement. The FWD testing indicated a dramatic decrease in both the radial strain and the vertical strain following the overlay. The freeze/thaw resistance was lower than expected, with an average durability factor between 60-65 after 300 cycles. Chloride permeability tests placed the UTW in the moderate range. The air void analysis demonstrated that the air void system contained proper sized and spaced air voids that were evenly distributed through the concrete overlay. The concrete bond to the milled asphalt surface was low, but all cores separated below the concrete and asphalt interface. Visual surveys found no cracking in the concrete overlay until the 3-month survey. Most of the cracking was found in an area where the concrete was less than 3 inches thick. Based on 6 months of service, the UTW overlay seems to be a viable alternative to an asphalt overlay on an intersection where rutting and shoving has become a problem.

Title: Thin Bonded Overlay Evaluation
Author(s): J.K. Cable, J.M. Hart, T.J. Ciha
Date: June 2001
Doc ID/URL: Iowa DOT Project HR-559, Final Report.
http://www.operationsresearch.dot.state.ia.us/reports/reports_pdf/hr_and_tr/reports/hr559.pdf
Description: 154 pp.
Contents: In 1994 the Iowa Department of Transportation constructed a 7.2-mile portland cement concrete overlay project in Iowa County on Iowa Highway 21. The project was constructed to evaluate the performance of an ultrathin concrete overlay (ultrathin whitetopping) during a 5-year period. The experiment included variables of base surface preparation, overlay depth, joint spacing, fiber reinforcement, and the sealed or non-sealed joints. The project was instrumented to measure overlay/base interface temperatures and strains. Visual distress surveys and deflection testing were also used to monitor performance. Coring and direct shear testing was accomplished 3 times during the research period. Results of the testing and monitoring are identified in the report. The experiment was very successful and the results provide an insight into construction and design needs to be considered in tailoring a portland cement concrete overlay to a performance need. The results also indicate a method to monitor bond with nondestructive methods.

Title: Field Assessment and Analytical Modeling of Ultra Thin Whitetopping
Author(s): K. Tawfiq
Date: May 2001
Doc ID/URL: WPI 0510779, State Job 00700-3346-119, Final Report.
http://ntl.bts.gov/lib/18000/18000/18068/PB2001106554.pdf
Description: 263 pp.
Contents: In this investigation the mechanical behavior of three test tracks of Ultra Thin Whitetopping (UTW) overlays was studied under different conditions of loading and material properties. The emphasis was on the

analytical modeling of these test tracks where various nonlinear finite element (FE) schemes were used. The full scale UTW test tracks were built at the Florida Department of Transportation (FDOT) Materials Office in Gainesville, and were subjected to repetitive truck loading over a period of 24 months. Along with the field testing it was decided to construct three similar FE models using geometrical and material properties similar to those in the field. The Test Track I, a 4-in. thick UTW was placed on an existing pavement composed of 1.5-in. asphalt pavement and 6-in. concrete base. Test Track II consisted of 3- and 4-in. thick sections. Test Track III was built with a 2-in. thick concrete overlay. Joint spacings ranged from 4 ft to 6 ft for Test Tracks I and II, and 3 ft x 3 ft to 12 ft for Test Track III. Fibrillated Polypropylene fibers were used in Tracks I and II. Monofilament Polyolefin fibers were used in Track III. High early strength concrete mixture was designed for the UTW. Bond strength at the concrete-asphalt interface was generally above 200 psi. The test tracks were subjected to approximately 50,000 (18-kip) ESALs using a truck loaded with concrete blocks. During the fate of this project, Falling Weight Deflectometer test results showed significant reduction in the surface deflection which indicated an improvement in the structural capacity of the pavement after the UTW placement. A reduction in the surface deflection of about 75% was experienced at Track I and about 78% at Track II. Surface deflection at Track III was reduced by about 46% when UTW was used. Also, frequent condition surveys exhibited good performance of the three test tracks. Structural cracking was noticed on Track III with 12 ft x 12 ft panel. In general, the good performance of the test tracks was attributed to the method of UTW preparation and to the good performance of the underlying pavement layers. The same conclusion was deduced from the analytical modeling. Reducing the bonding strength, increasing the panel size, and reducing the overlay thicknesses were among the main factors for crack development, and hence, the low performance of the UTW. Other contributing factors may include the existing layer stiffnesses, fatigue characteristics of the fiber reinforced concrete, and surrounding environmental conditions.

Title: The Measured Response of Ultra-thin and Thin Whitetopping to Environmental Loads
Author(s): Julie M. Vandenbossche
Date: 2001
Doc ID/URL: *7th International Conference on Concrete Pavements: The Use of Concrete in Developing Long-Lasting Pavement Solutions for the 21st Century*, International Society for Concrete Pavements, 2001: 807-823.
Description: 17 pp.
Contents: This paper discusses how the technique of whitetopping asphalt concrete pavements with a thin (102-mm to 152-mm thick) or ultra-thin (51-mm to 102-mm) thick concrete overlay is becoming more common. This increase in use of thin whitetopping (TW) and ultra-thin whitetopping (UTW) has amplified the need for a comprehensive design procedure. The objective of this paper is to develop a better understanding of the behavior of thin and ultra-thin whitetopping by measuring the responses of the pavements to various environmental loadings. A 345-mm asphalt concrete pavement on I-94, at the Minnesota Road Research (Mn/ROAD) facility was whitetopped with a fiber-reinforced concrete overlay in October 1997. The experimental design features six test cells with various thicknesses, joint patterns and types of fibers. Each cell is instrumented with dynamic and static strain, temperature and moisture sensors. Temperature, moisture and static strain data have been collected continuously since construction. Strain gages were used to measure the effects of moisture and temperature changes in the pavement. An evaluation of the data over time indicates seasonal changes occur in the quality of bond between layers, which has implications for changes in load-related stress over time. Both thermal and moisture changes in the overlay have a significant effect on the shape of the slab. Strain measurements revealed the complexity of the relationship between changes in temperature and/or moisture and slab deformation. This relationship must be clearly defined before an analysis of the response of the overlay to an applied load can begin.

Title: Behavior and Performance of UTW on Thin Asphalt Pavement
Author(s): J. Balbo, D. Pereira, A. Severi
Date: 2001
Doc ID/URL: *7th International Conference on Concrete Pavements: The Use of Concrete in Developing Long-Lasting Pavement Solutions for the 21st Century*, International Society for Concrete Pavements, 2001: 825-837.
Description: 13 pp.
Contents: This paper describes how, during the spring of 1999, two sections of ultra-thin whitetopping (UTW) were built over a thin 45-mm asphalt layer in urban Sao Paulo. The UTW was constructed at a bus stop within the University campus, defining two panels of squared 0.6 and 1.0-m and 95-mm slabs. A high strength concrete was applied and the test sections were fully instrumented with top and bottom thermal resistors and strain gages. The instrumentation allowed the analysis of temperatures and thermal gradients on slabs as well as the curling deformation induced by these gradients. Temperature measurements showed daytime thermal gradients up to 11.7 degrees Celsius and up to -4.2 degrees Celsius. Concrete stresses due uniquely to curling reached very low values in all seasons and were deemed negligible. Open to traffic since November 1999, 19 months later no cracks or faulting

were observed on UTW sections submitted to a daily traffic of 120 buses and trucks which make it possible using the basis of measuring flexural stresses on slabs, to predict the good performance of the UTW.

Title: Performance and Repair of UTW Pavements
Author(s): C-L Wu, S. Tayabji, M. Sheehan, J. Sherwood
Date: 2001
Doc ID/URL: *7th International Conference on Concrete Pavements: The Use of Concrete in Developing Long-Lasting Pavement Solutions for the 21st Century*, International Society for Concrete Pavements, 2001: 839-856.
Description: 18 pp.
Contents: Since its inception in the early 1990s, ultra-thin whitetopping (UTW) has rapidly developed into a viable pavement rehabilitation alternative for deteriorated asphalt pavements. The objective of this paper is to present the results of studies conducted dealing with UTW pavement performance reviews and repair and rehabilitation experiences. The paper explores the effectiveness of using currently available concrete pavement repair and rehabilitation procedures. The paper also includes detailed performance descriptions of several existing UTW pavements in Georgia and Tennessee and the UTW repair and rehabilitation projects conducted at the Federal Highway Administration's (FHWA) Pavement Testing Facility and in several states.

CITATIONS – Design (5)

Title: Results from the Concrete Pavement Technology Program Task 3 Project on the Performance and Design of Whitetopping Overlays on Heavily Loaded Pavements
Author(s): Robert Otto Rasmussen
Date: April 2005
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 318-320.
Description: 3 pp.
Contents: In 2000, the Innovative Pavement Research Foundation (IPRF) and Federal Highway Administration (FHWA) initiated a project under the Concrete Pavement Technology Program with the goal of developing guidelines for designing, constructing, and rehabilitating whitetopping overlays. The first goal was to summarize available information and document how the industry considers whitetopping overlays among various pavement rehabilitation alternatives. Although whitetopping overlays have been constructed for decades, their recent popularity has stemmed largely from a renewed demand for longer lasting but cost effective solutions for hot-mix asphalt (HMA) pavement rehabilitation. The second goal of the project was to extrapolate beyond this knowledge base and into the state of the art. To accomplish this, a comprehensive design and construction process was developed for whitetopping overlays that provides the industry with a practical and reliable means to further utilize this important overlay type. This presentation synopsis summarizes the key findings from this important effort.

Title: Evaluation of Formulae in PCA Design Approach for Ultra-Thin Whitetopping Over Composite Pavement Section Under Accelerated Loading
Author(s): Scott A. Newbolds, Khaled A. Galal, Jan Olek, Tommy Nantung
Date: 2005
Doc ID/URL: *8th International Conference on Concrete Pavements*, 2005: 883-899.
Description: 17 pp.
Contents: Ultra-thin whitetopping (UTW) is a popular pavement rehabilitation technique that involves the placement of a thin layer of portland cement concrete (PCC) over a distressed hot mixture asphalt (HMA) pavement. The new pavement is essentially a thin bonded concrete overlay. Thus, its composite performance depends on the stiffness of the underlying pavement layers. One objective of this project is to develop models that can be used for the mechanistic design of UTW pavements. Additionally, UTW performance models will be developed. To accomplish this task, a UTW pavement test section was constructed in the Indiana Department of Transportation -- Purdue University Accelerated Pavement Testing facility. The pavement section consisted of a UTW overlay of an existing composite pavement section (thin HMA layer over a PCC layer). The performance of the UTW overlay was monitored using destructive and non-destructive methods, including measurements of strain, strength, and pavement stiffness. Portland Cement Association (PCA) design guidelines were investigated to assess their applicability to cases of UTW placed over composite pavements. Preliminary results indicate that the equations may be able to be used if the concept of an equivalent thickness is employed. Further, the effective radius of relative stiffness calculated from falling weight deflectometer testing of in-situ pavements may be able to be modified to account for the proposed UTW overlay and input into the design equations.

Title: Instrumentation and Field Testing of Thin Whitetopping Pavement in Colorado and Revision of the Existing Colorado Thin Whitetopping Procedure
Author(s): Matthew J. Sheehan, Scott M. Tarr, Shiraz D. Tayabji
Date: August 2004
Doc ID/URL: Report No. CDOT-DTD-R-2004-12, Final Report, August 2004.
http://www.dot.state.co.us/publications/PDFFiles/whitetopping2.pdf
Description: 90 pp.
Contents: This report summarizes the verification and revision of a thin whitetopping pavement mechanistic design procedure developed for the Colorado Department of Transportation. The original whitetopping procedure and design guidelines were developed during a 1998 study on thin whitetopping pavements in Colorado. This report includes information on the installation and construction of the test sections, instrumentation, field and laboratory testing, data acquisition, and data analysis. The revised Colorado thin whitetopping pavement design procedure provides improved predictions of whitetopping load responses, and therefore should also provide more accurate insights into longer-term performance of thin whitetopping pavements for highway applications. The successful development and revision of a second-generation thin whitetopping design procedure provides an additional level of confidence for designers and highway agencies when considering this rehabilitation technique. Two different procedures were developed to calculate the thickness. One is a mechanistic approach incorporating finite element program, ILLI-SLAB to predict critical concrete stresses and asphalt strains. The second method is an empirical approach, incorporating the number of expected equivalent 18-kip single axle loads (ESALs).

Title: Characterization and modeling of axial slab-support restraint
Author(s): Robert Otto Rasmussen, Dan K. Rozycki
Date: 2001
Doc ID/URL: *Transportation Research Record 1778* (2001): 26-32.
Description: 7 pp.
Contents: Slab-support interaction has long been established as an important consideration in the design and construction of concrete pavements for streets, highways, and airfields. With the current interest in design features such as open-graded permeable bases, unbonded concrete overlays, and whitetopping pavements, the need for an accurate and standard means for characterizing this behavior is evident. With respect to conventional concrete pavements, previous studies have concluded that excessive restraint between the slab and the support layers of a pavement structure can lead to pavement distresses that are ultimately detrimental to the performance of the pavement. These studies have indicated that undesirable restraint characteristics typically are caused by improper subbase design or construction. The consequences of underestimating or neglecting the support restraint characteristics have been shown to result in uncontrolled slab cracking, excessive joint movements, and underdesigned reinforcement. However, in some cases a high degree of slab-support restraint is desired, such as for whitetopping pavements, especially ultrathin whitetopping. Recent developments in characterizing and modeling axial slab-support restraint characteristics of concrete pavements are presented. Test procedures that have been developed to accurately assess the level of axial slab-support restraint present are identified, as are future enhancements to characterization and modeling of this phenomenon.

Title: Mechanistic Design of Thin Whitetopping Pavements in Colorado
Author(s): Scott M. Tarr, Matthew J. Sheehan, Ahmad Ardani
Date: 2000
Doc ID/URL: *Transportation Research Record 1730* (2000), 64-72.
Description: 9 pp.
Contents: A mechanistic design procedure was developed for the state of Colorado to determine the required concrete thickness of thin [12.7 cm to 17.8 cm (5 in, to 7 in.)] whitetopping overlays on asphalt pavements. Field testing was conducted to evaluate critical load locations for whitetopping with joint spacing up to 3.66 m (12 ft). The load-induced flexural strains were used to calibrate fully bonded stresses computed by applying finite element analysis techniques to partially bonded stresses measured in the field. For each test section, load testing was conducted throughout the course of a day to develop a temperature correction for the critical stresses derived for zero temperature gradient (zero slab temperature curling). Equations predicting the critical concrete flexural stresses and asphalt concrete strains for use in whitetopping were developed. A mechanistic design procedure is described that allows the evaluation of trial whitetopping thicknesses and joint spacings. The procedure computes the concrete and asphalt fatigue life for specific material properties. Iterations are required to determine the appropriate parameters that provide the required design life for both concrete and asphalt layers. In addition to the design procedure, the effect of surface preparation during construction was studied by comparing identical slabs constructed on milled and unmilled asphalt. It was concluded that existing asphalt pavement should be milled and cleaned before concrete placement for an overall reduction of 25 percent in the critical load-induced stresses.

However, new asphalt, such as that placed in repair patches, should not be milled before concrete placement to avoid a 50 percent increase in critical load-induced stresses.

CITATIONS – Life-Cycle Cost Analysis (2)

Title: Author(s): Life-Cycle Cost Analysis of Thin Whitetopping
Date: April 2005
Author(s): Greg Lowery
Doc ID/URL: *Proceedings of the International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, Denver, Colo., April 12-15, 2005: 16-33.
Description: 8 pp.
Contents: This report summarizes experiences with thin whitetopping (TWT) in the state of Colorado and provides a model for an economic analysis that justifies selecting TWT for a pavement rehabilitation strategy. Whitetopping is a concrete paving process where new concrete pavement is placed over an existing asphalt pavement. The concrete bonds to the asphalt, resulting in a composite pavement. Properties of both materials are measured or estimated for design. Whereas a typical concrete pavement is placed no thinner than 203 mm (8 in.) in Colorado, TWT is typically place at 152 mm (6 in.) thickness because it derives some support from the asphalt layer. Colorado began experimenting with TWT in 1990. From 1990 to 2003, the Colorado Department of Transportation has placed over 627,095 m(squared) (750,000 yd(squared)) of TWT on 15 different roadways. In 2004, another project with 81,940 m(squared) (98,000 yd(squared)) was placed. This report provides a model for life-cycle cost analysis of the TWT process used in Colorado.

Title: Summary of performance and cost of Ohio ultra-thin whitetopping projects
Author(s): W.H. Fair
Date: 2000
Doc ID/URL: Columbus, Ohio: Flexible Pavements, 2000 (OCLC 49251486)
Description: unpaged book
Contents: Third interim report on Ohio's ultra-thin Whitetopping demonstrations, July 2, 1999; second interim report on Ohio's ultra-thin whitetopping demonstrations, October 26, 1998; first interim report on Ohio's ultra-thin whitetopping demonstrations, January 30, 1998.

RESEARCH IN PROGRESS

Title: Evaluation of Portland Cement Concrete as a Rehabilitation Option for Overlaying an Existing Asphalt Roadway
Principal Investigator(s): Bryon Fuchs, North Dakota DOT, 701-328-6903
Start Date: 6/30/1998
RIP URL: http://rip.trb.org/browse/dproject.asp?n=10174
Sponsor Organization: North Dakota Department of Transportation
Contents: Whitetopping is the process of placing concrete on an existing asphalt roadway. An advantage of whitetopping is the ability to resist rutting and shoving that can cause collection of water on the roadway. Whitetopping impedes structural related distresses such as loss of support, pumping, faulting and corner breaks when constructed on a strong base. Another advantage of this process is to bridge isolated problems that would be reflected through a flexible pavement. The concept behind whitetopping is that when PCC is bonded to an underlying layer of asphalt, the two form a composite layer forcing the neutral axis in the slab downward. This would cause more of the concrete to be acting in compression rather than tension. Whitetopping has not been a rehabilitation method used by the North Dakota Department of Transportation in the past. The objective of this experimental feature is to determine if whitetopping is a feasible option for rehabilitation of an asphalt roadway. In order to determine the effectiveness of whitetopping as possible rehabilitation technique, the North Dakota Department of Transportation (NDDOT) elected to set up a test section to collect and evaluate performance data on this type of project. The NDDOT has constructed three test sections of 5", 6", and 7" of PCC to be placed over an existing asphalt section. Each whitetopping test section was approximately 500' in length. The project is located on US Highway 52 between Pingree and Buchanan, ND. The project will be evaluated on visual distresses and ride for a period of ten-years with reports every two-years. Test sections 1 and 3 are showing the most distresses. The primary distress is longitudinal cracking. Test sections 1 and 3 are adjacent to hot bituminous pavement sections. Test section 1 had a 40’ longitudinal crack that appeared immediately after construction. Test section 2 is performing well with only minor distresses. The control section is performing well with minor rutting and two transverse cracks. The longitudinal cracking in test sections 1 and 3 are likely the result of poor subgrade conditions. The location of the longitudinal cracks is in the same area as the distresses shown in photo 1 prior to whitetopping

the asphalt. These distresses appeared to have reflected through the whitetopping sections. The ride remains good in all sections.

Title: Evaluation of UTW and Whitetopping Design Procedure
Principal Investigator(s): Anastasios Ioannides, University of Cincinatti, 513-556-3137, ioanniam@uc.edu
Start Date: 4/1/2006
RIP URL: http://rip.trb.org/browse/dproject.asp?n=12076
Sponsor Organization: Illinois Department of Transportation
Contents: This project is part of an effort to meld the current empirical and theoretical knowledge of pavements with UTW and conventional PCC overlay design with Illinois-specific experience to develop tools and guidelines to effectively design these overlay types for IDOT's use. Existing UTW design procedures will be critically reviewed for potential adoption for IDOT, and in collaboration with ICT personnel, a list will be compiled of all available whitetopping and UTW field sections located in Illinois. Recommendations will be formulated on the most viable UTW design procedure for IDOT's use and any needed changes.

Title: Ultra-thin Whitetopping of Pavements
Principal Investigator(s): Tessa Volle, Illinois DOT, 217-782-3547, volleth@nt.dot.state.il.us
Start Date: n/a
RIP URL: http://rip.trb.org/browse/dproject.asp?n=3832
Sponsor Organization: Illinois Department of Transportation
Contents: Illinois is continually looking for new and innovative methods for rehabilitating roadways. For pavements with high volumes of heavy traffic, asphalt overlays may not be strong enough to resist rutting and shoving. One method of eliminating these problems is to use a portland cement concrete overlay over the asphalt surface. This is known as "whitetopping." An ultra-thin whitetopping is less than four inches thick and is bonded to the underlying asphalt surface. The objective of this project is to evaluate and document the performance of an ultra-thin whitetopping. Since many Illinois pavements either have been widened or have had lanes added, some of the projects will include a bonded concrete overlay on some lanes and ultra-thin whitetopping on others. If ultra-thin whitetopping performs well and is cost effective, Illinois will have another alternative for pavement rehabilitation.