

Final Technical Program and Presentation Abstracts

INTERNATIONAL CONFERENCE ON LONG-LIFE CONCRETE PAVEMENTS—2012

September 18–21, 2012 — Seattle, Washington



ORGANIZED BY

Federal Highway Administration
National Concrete Pavement Technology Center

CO-SPONSORED BY

American Association of State Highway and Transportation Officials
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Washington State Department of Transportation

ACPT *ADVANCED CONCRETE
PAVEMENT TECHNOLOGY*

INTERNATIONAL CONFERENCE ON LONG-LIFE CONCRETE PAVEMENTS

Seattle, Washington

September 18, 2012

Dear Conference Participants:

It is with great pleasure that we welcome you to the International Conference on Long-Life Concrete Pavements. We hope that you find the conference both technically and professionally rewarding, and trust that your stay at the conference hotel and your visit to the Seattle area will be a pleasurable one. We have attendees from several countries and more than 170 registrants. A few items to note:

1. Proceedings CD—The bag contains the proceedings CD.
2. Badges—*Please wear your conference badge for all conference activities—conference sessions, breakfast, lunch, breaks, and reception.* You may be asked to leave the activity if you are not wearing your badge. Also, please note that admission to the Tuesday reception is for *registered attendees* only.
3. Reception—The conference will commence with a reception held at 6 p.m. on Tuesday. The reception will feature a good variety of food items, so you may not need to plan for dinner.
4. Breakfast/Lunch/Breaks—Breakfast will be provided on Wednesday, Thursday, and Friday between 7 and 8:30 a.m. Lunch will be provided on Wednesday and Thursday, between noon and 1:30 pm, and on Friday from 12:30 to 1:30 p.m. Breaks will also be provided in the morning and afternoon. These activities are *open only to attendees who have registered.*
5. Drink Tickets—Each registered attendee will be provided with two drink tickets for the reception. A cash bar will also be available.
6. Internet access in the guest rooms is free for conference attendees. Free internet access is also available in the hotel lobby.
7. Extra copies of the Proceedings CD will go on sale after noon on Wednesday for \$50 (US) per CD.
8. The Proceedings CD will be available after noon on Wednesday for university and college libraries at no charge.

Enjoy the Conference and the Seattle Area! Please contact us if we can be of assistance.

Shiraz Tayabji
*Co-Chair,
Conference
Steering Committee*

Tom Cackler
*Co-Chair,
Conference
Steering Committee*

Kurt Smith
*Member,
Conference
Steering Committee*

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- The Sponsors—FHWA, NCPTC, AASHTO, ACPA, CRSI, ISCP, NRMCA, PCA, TRB, the University of Washington, and the Washington State Department of Transportation.
- University of Northern Illinois for conference support (Ms. Jeanne Burau and her staff).
- Exhibitors (for support of the reception).
- The presenters, the reviewers, the moderators, and all of you—the attendees!

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PROGRAM AT A GLANCE—September 18–21, 2012

TIME	TUESDAY SEPTEMBER 18	WEDNESDAY SEPTEMBER 19	THURSDAY SEPTEMBER 20	FRIDAY SEPTEMBER 21
7:00–8:30	NONE	BREAKFAST	BREAKFAST	BREAKFAST
8:30–10:00	FHWA Advanced Concrete Pavement Technology	1–Plenary Session	5–Considerations for LLCs	9–NCC Forum
10:00–10:30	Expert Task Group Meeting (ETG members)	BREAK	BREAK	BREAK
10:30–12:00	8 a.m.–4 p.m., Ballard Room	2–U.S. LLC Practices	6–Long-Life Repairs and Rehabilitation	10–Concrete Pavement Durability I
12:00–1:30	National Concrete Consortium Meeting (NCC)	LUNCH	LUNCH	LUNCH
1:30–3:00	8 a.m.–4:30 p.m., Metropolitan A Room	3–Optimizing Design	7–SHRP 2 LLC Products	11–Concrete Pavement Durability II
3:00–3:30	Conference Registration opens at 3 p.m., Metropolitan A Room	BREAK	BREAK	END OF CONFERENCE
3:30–5:00		4–Optimizing Materials	8–Sustainable LLCs	—
6:00	RECEPTION	—	—	—

DISCLAIMER

The information presented at the Seattle Long-Life Concrete Pavement conference and contained in the Conference Proceedings does not represent any formal endorsement of techniques, materials, or processes by the sponsoring organizations. The information presented in these proceedings should be used judiciously by experienced concrete pavement technologists.

FOREWORD

Long-life concrete pavements (LLCPs) have been attainable for a long time as evidenced by the fact that a large mileage of very old pavements remains in service. In addition, continuing advances in design, construction, and concrete materials technology give us the knowledge and technology needed to achieve consistently what we already know to be attainable.

Many State highway agencies in the United States, in conjunction with industry, are implementing innovative features related to structural design, concrete mixtures, construction equipment, construction process management, and testing procedures to achieve LLCPs that are economical and sustainable. To achieve long life, pavements must not exhibit premature failures and must have a reduced potential for cracking, faulting, spalling, and materials-related distress. To be sustainable, pavement design and construction practices must reduce the carbon footprint due to construction, maintenance, repair, and rehabilitation. Finally, the life cycle impact of concrete pavements, considering life cycle costs and environmental and societal impacts, must be better than other pavement systems.

The 3-day Seattle LLCP conference was organized by the Federal Highway Administration (FHWA) as part of technology transfer activities under the Advanced Concrete Pavement Technology (ACPT) Program that operates within FHWA. The conference provides an international forum to address various aspects of concrete pavement design, construction, and materials technologies that result in long life for concrete pavements and are sustainable.

The editors would like to thank the authors for supporting the objective of this conference by developing comprehensive papers on all aspects of long-life concrete pavements, including materials, design, construction, and maintenance/ rehabilitation. The papers included in the proceedings were peer-reviewed for technical content, and the editors would also like to thank the conference steering committee members and the many reviewers who participated in the paper review process.

Shiraz Tayabji, Ph.D., P.E.
Co-Editor and Co-Chair,
Conference Steering Committee

Peter Taylor, Ph.D.
Co-Editor and Co-Chair,
Conference Technical Program
Committee

Kurt Smith, P.E.
Co-Editor and Member,
Conference Steering Committee

Technology Transfer to Develop and Manage Safer, Smoother, Longer Lasting Concrete Pavements That Incorporate Sustainable Technologies

Much work is in progress to create sustainable concrete pavement technologies that are cost effective and meet the user's needs for safer, smoother, quieter, and longer lasting pavements. The findings from these ongoing and completed studies will be disseminated at the conference, and directions for future work will be defined.

TECHNICAL PROGRAM

TUESDAY, SEPTEMBER 18, 2012		
8 a.m.–4 p.m.	FHWA Advanced Concrete Pavement Technology Program Expert Task Group Meeting (ETG members)	
8 a.m.–4:30 p.m.	National Concrete Consortium Meeting (separate registration required)	
3 p.m.	CONFERENCE REGISTRATION BEGINS	
6–8 p.m.	RECEPTION	
WEDNESDAY, SEPTEMBER 19, 2012		
7–8:30 a.m.	BREAKFAST	
8:30 a.m.	SESSION 1: PLENARY SESSION	<p>Welcome</p> <ul style="list-style-type: none"> • Butch Wlaschin, Federal Highway Administration (FHWA) • Tom Baker, Washington State Department of Transportation (DOT) • Tom Cackler, National Concrete Pavement Technology Center (NCPTC) • Gerald Voigt, American Concrete Pavement Association (ACPA) <p>Long-Life Concrete Pavements in Washington State—Past and Present. Steve Muench, University of Washington; Jeff Uhlmeier, David Luhr, Jianhua Li, and Mark Russell, Washington State DOT</p>
	Moderators: Kurt Smith, Applied Pavement Technology, Inc., and Sam Tyson, FHWA	
10–10:30 a.m.	BREAK	
10:30 a.m.	SESSION 2: U.S. LLCP PRACTICES	<p>Efforts to Improve the Life of Concrete Pavements in Virginia. Celik Ozyildirim, Mohamed Elfino, and Shabbir Hossain, Virginia DOT</p> <p>California’s Endeavors for Longer Life Concrete Pavements. William K. Farnbach, California DOT; Craig Hennings, Southwest Concrete Pavement Association</p> <p>Moving Trucks From Savannah to Atlanta for the Next 40+ Years. Georgene M. Geary and Myron Banks, Georgia DOT; Wouter Gulden, Southeast Chapter, ACPA</p> <p>Sustainable Long-Life Composite Concrete Pavement for the Illinois Tollway. Steven L. Gillen, Illinois State Toll Highway Authority; Alexander S. Brand and Jeffery R. Roesler, University of Illinois at Urbana-Champaign; William R. Vavrik, Applied Research Associates, Inc.</p>
	Moderator: Suneel Vanikar, FHWA	
NOON	LUNCH	
1:30 p.m.	SESSION 3: OPTIMIZING DESIGN FOR LLCPs	<p>Long-Term Performance and Rehabilitation Strategy of Portland Cement Concrete Pavement on US-290 in Houston, Texas. Moon Won, Texas Tech University</p> <p>Early Performance of Two Test Sections on I-90, Syracuse, New York. Luis Julian Bendaña, Engineering Consultant; Issam S Khoury and Shad M. Sargand, Ohio University; Drew C. Hatton, Structural Design Group</p> <p>Prediction of Transverse Cracking in JPCP Considering Design Features and Material Properties. Shervin Jahangirnejad and Dennis Morian, Quality Engineering Solutions, Inc.</p> <p>Concrete Coefficient of Thermal Expansion Test for Quality Assurance. Jagan M Gudimetla, Global Consulting Inc.; Mehdi Parvini, California DOT; Gary L. Crawford, FHWA</p>
	Moderator: John Staton, Michigan DOT	
3 p.m.	BREAK	
3:30 p.m.	SESSION 4: OPTIMIZING MATERIALS FOR LLCPs	<p>Evaluation of High-Volume Fly Ash Mixtures (Paste and Mortar Components) Using a Dynamic Shear Rheometer and an Isothermal Calorimeter (Interim Results). Jussara Tanesi, Global Consulting, Inc.; Ahmad A. Ardani and Richard Meininger, FHWA; Mihai Nicolaescu, Global Consulting, Inc.</p> <p>Design and Specification of Durable Pavements Using Slag Cement Concrete. Peter Bohme, Holcim (US) Inc.; Gordon McLellan, Hanson Slag Cement; Henry B. Prenger, Lafarge North America; Anthony E. Fiorato, Slag Cement Association</p> <p>Development of a Protocol to Assess Integral Waterproofing Admixtures. Ezgi Yurdakul, Iowa State University; Peter C. Taylor, NCPTC; Halil Ceylan, Iowa State University; Fatih Bektas, NCPTC</p> <p>Achieving Long-Life Concrete Pavements by Preventing Alkali–Silica Reactivity. Gina Ahlstrom, FHWA; Jim Pappas, Delaware DOT</p>
	Moderator: Tony Zander, Indiana DOT	

TECHNICAL PROGRAM

THURSDAY, SEPTEMBER 20, 2012		
7–8:30 a.m.	BREAKFAST	
8:30 a.m.	<p>SESSION 5: CONSIDERATIONS FOR LLCPS</p> <p>Moderator: Kenny Seward, Oklahoma DOT</p>	<p>Investigation of the Effect of the Interfacial Zone on Joint Deterioration of Concrete Pavements. Jiake Zhang and Peter C. Taylor, NCPTC</p> <p>Condition of Field-Exhumed Dowel Bars. Kurt D. Smith and Roger M. Larson, Applied Pavement Technology, Inc.; Roger L. Green, Ohio DOT; Barry C. Paye, Wisconsin DOT</p> <p>Character, Extent, and Severity of Corrosion in Continuously Reinforced Concrete Pavements in South Dakota. Allen L. Jones and Nadim Wehbe, South Dakota State University; Stephanie Klay, Barr Engineering Co.</p> <p>Trends in Specifications and Costs of Subbases for Concrete Pavement Structures. Robert A. Rodden and Gerald F. Voigt, ACPA</p>
10 a.m.	BREAK	
10:30 a.m.	<p>SESSION 6: LONG-LIFE REPAIRS AND REHABILITATION</p> <p>Moderator: Julie Vandebossche, University of Pittsburgh</p>	<p>Full-Depth Replacement of Concrete Pavements With Rapid-Strength Concrete. Boris Stein and Brian Kramer, Twining, Inc.; Robert Ryan, CMT Research Associates; Shakir Shatnawi, Shatec Engineering</p> <p>A Comparison of Three Rehabilitated Sections on I-86 in New York. Issam Khoury and Shad M. Sargand, Ohio University; Luis Julian Bendaña, Engineering Consultant; David A. Padilla, Virginia Tech</p> <p>Virginia’s Efforts in Developing Effective Concrete Pavement Patching Specifications. Mohamed Elfino, Affan Habib, and Larry Lundy, Virginia DOT; Syed Haider, Michigan State University</p> <p>Pervious Concrete Shoulders for Stormwater Management. John T. Kevern, University of Missouri–Kansas City</p>
NOON	LUNCH	
1:30 p.m.	<p>SESSION 7: SHRP 2 LLCP PRODUCTS</p> <p>Moderator: James Bryant, SHRP 2</p>	<p>SHRP 2 Project R23—Guidelines for Long-Life Pavement Renewal Using Bonded and Unbonded PCC Overlays. Newton Jackson, Nichols Consulting Engineers Chtd.; Joe Mahoney, University of Washington; Mark Snyder, Engineering Consultant; Neeraj Buch, Michigan State University</p> <p>Long-Life Composite Pavement Systems. Michael I. Darter and Shree Rao, Applied Research Associates, Inc.; Lev Khazanovich and Derek Tompkins, University of Minnesota; John Harvey and James Signore, University of California at Davis; Julie Vandebossche, University of Pittsburgh</p> <p>SHRP 2 Project R05: Precast Concrete Pavements for Long-Life Repair and Rehabilitation of Existing Pavements. Shiraz Tayabji and Dan Ye, Fugro Consultants, Inc.; Neeraj Buch, Michigan State University</p> <p>The Evolution of Precast Concrete Pavement in California. Tinu Mishra, California DOT</p>
3 p.m.	BREAK	
3:30 p.m.	<p>SESSION 8: SUSTAINABILITY CONSIDERATIONS</p> <p>Moderator: Jerry Voigt, ACPA</p>	<p>Relative Cost of Concrete Pavement Design Features for Conventional and Long-Life Performance Consideration. Gerald F. Voigt, Larry Scofield, and Robert A. Rodden, ACPA</p> <p>Designing Sustainable Concrete Pavements Using the Mechanistic–Empirical Pavement Design Guide and Life Cycle Analysis. James W. Mack, CEMEX; Mehdi Akbarian, Franz-Josef Ulm, Jeremy Gregory, Randolph E. Kirchain, Margaret Wildnauer, and Omar Abdullah Swei, Massachusetts Institute of Technology</p> <p>Photocatalytic Concrete Pavements: Decrease in NO_x Removal Due to Reaction Product Blinding. Joel K. Sikkema, James E. Alleman, Say Kee Ong, and Jacek A. Koziel, Iowa State University; Peter C. Taylor, NCPTC; Haotian Bai, Iowa State University</p> <p>Sustainable and Long-Life Precast Prestressed Concrete Pavements. Samuel S. Tyson, FHWA; David K. Merritt, The Transtec Group</p>

TECHNICAL PROGRAM

FRIDAY, SEPTEMBER 21, 2012		
7:00–8:30 a.m.	BREAKFAST	
8:30 a.m.	SESSION 9: NATIONAL CONCRETE CONSORTIUM FORUM	<p>High-Performance Concrete Pavement in Indiana. Tommy Nantung, Indiana DOT</p> <p>Constructing Long-Life Pavements—How Will We Know If We Were Successful? Heather McLeod, Kansas DOT</p> <p>Moderator: Tom Cackler, NCPTC</p> <p>Louisiana’s Experience With Surface Resistivity Measurements and Implementation Efforts. Tyson D. Rupnow and Patrick J. Icenogle, Louisiana Transportation Research Center</p> <p>Minnesota’s Experience With Low W/C Ratio Pavements. Maria Masten, Minnesota DOT</p> <p>Striving for Long-Life Concrete Pavements—Missouri’s Direction. Brett Trautman, Missouri DOT</p> <p>North Carolina's Experience With QA Systems and New Technologies. Nilesh Surti, North Carolina DOT</p>
10:30 a.m.	BREAK	
11 a.m.	SESSION 10: CONCRETE PAVEMENT DURABILITY SYMPOSIUM (PART I)	<p>Long-Life Low-Temperature Concrete Mixtures Using Moderate Dosages of Chemical Admixtures. Lynette A. Barna, Cold Regions Research and Engineering Laboratory; Charles J. Korhonen, ARCTIKOR</p> <p>Effect of Joint-Cutting Method on the Durability of Concrete Pavements. John T. Kevern, University of Missouri–Kansas City; Heather McLeod, Kansas DOT; Feras El Ghussein, University of Missouri–Kansas City</p> <p>Moderator: Peter Taylor, NCPTC</p> <p>State of the Practice: Freeze-Thaw Durability. Matt Sheehan, CTLGroup, Inc.</p> <p>State of the Practice: Alkali–Silica Reactivity Prevention and Mitigation. Thanos Drimalas, University of Texas</p>
12:30 p.m.	LUNCH	
1:30 p.m.	SESSION 11: CONCRETE PAVEMENT DURABILITY SYMPOSIUM (PART II)	<p>Joint Distress in Portland Cement Concrete Pavements. Lawrence Sutter, Michigan Technological University; Jan Olek, Jason Weiss, and Nancy Whiting, Purdue University; Peter Taylor, Iowa State University</p> <p>State of the Practice: Joint Sawing and Sealing. Kurt D. Smith, Applied Pavement Technology, Inc.</p> <p>Moderator: Jeff Uhlmeyer, Washington State DOT</p> <p>State of the Practice: Deicer Damage Prevention. Peter C. Taylor, NCPTC</p>
3 p.m.	CLOSURE	Kurt Smith, Applied Pavement Technology, Inc.

PRESENTATION ABSTRACTS

SESSION 1: PLENARY Wednesday, 8:30 a.m.

Long-Life Concrete Pavements in Washington State—Past and Present. Steve Muench, Jeff Uhlmeyer, David Luhr, Jianhua Li, and Mark Russell

The Washington State Department of Transportation (WSDOT) is responsible for about 2,360 lane-miles (3,800 lane-km) of concrete pavement. It is generally old but has performed

remarkably well since the majority of it was constructed in the 1950s to 1970s. The performance of these pavements combined with what WSDOT has learned in the intervening 40–50 years gives a high level of confidence that future concrete pavements have strong potential to perform for 50 years or more. However, the greatest current issue is not with performance, but rather funding. WSDOT estimates \$1.1 billion worth of concrete pavement rehabilitation and reconstruction needs in the next 10 years but is facing a typical biennial budget of \$50 million to \$70 million (i.e., about 25 percent of the needed

PRESENTATION ABSTRACTS

funding). This large shortfall has resulted in WSDOT engaging in a triage effort to keep its concrete network in serviceable condition. It may also serve as an indicator that future issues regarding long-lasting concrete are likely to be more financial and less performance-related. This may indicate the future research needs could involve (1) a better way to finance major concrete pavement reconstruction, and (2) development of a concrete pavement that can be resurfaced periodically without needing major reconstruction.

SESSION 2: U.S. LLCP PRACTICES Wednesday, 10:30 a.m.

Efforts to Improve the Life of Concrete Pavements in Virginia.

Celik Ozyildirim, Mohamed Elfino, and Shabbir Hossain

The Virginia Department of Transportation has been active in improving the service life of concrete pavements in new construction and repairs. Several new technologies and practices have been successfully tried in the past decade. This paper addresses recent developments in design, materials, and construction practices and provides examples from newly constructed and repaired pavements. Some of these advancement areas are attention to foundation support, use of continuously reinforced concrete pavement (CRCP) along with its thickness and steel amount, new innovative construction practice using precast and prestressed slabs, use of wider slabs (truck lanes) to reduce edge stresses, use of large-size aggregate and pozzolanic materials in the mixture, implementation of trial batches and trial pavement sections, and attention to consolidation and curing during construction. These practices are expected to provide longer life. Recent projects have incorporated these practices. Examples included are the Route 288, Madison Heights Bypass, and Battlefield Boulevard interchange for CRCP projects for new construction and the precast and precast prestressed pavements from I-66 for rehabilitation.

California's Endeavors for Longer Life Concrete Pavements.

William K. Farnbach and Craig Hennings

The California Department of Transportation (Caltrans) has an ever striving effort to continually improve its pavement designs and materials to achieve longer lives. This paper describes the history of Caltrans' efforts to date, current efforts, and future prospects. In particular, this paper covers the following topics:

Efforts and performance (successes and lessons learned) moving from 20-year to 40-year design-life standards.

- Analyzing what is needed to build beyond 40-year pavements.
- Building a better concrete.
- Increasing use of continuously reinforced concrete pavement.
- Improving concrete design details and value.

- Improving construction.
- Rebuilding an existing system.
- Using life cycle cost analysis as a tool.

This paper also discusses the remaining challenges.

Moving Trucks From Savannah to Atlanta for the Next 40+ Years. Georgene M. Geary, Myron Banks, and Wouter Gulden

Combining the use of long-life rehabilitation strategies and new pavement techniques can lead to the extension in life of already long-life pavements. During the 2011/2012 construction season, the Georgia Department of Transportation performed a major rehabilitation on a section of Interstate 16 that was originally constructed in the late 1960s as an undoweled pavement with joint spacing of greater than 15 ft (4.6 m). I-16 is the main truck route from the port of Savannah to the freight hub of Atlanta and the main tourist route from the Atlanta area to the beaches of historic Savannah. I-16 carries over 22,000 vehicles per day, more than 30 percent of which are trucks. For this 15.7-mi (25.3 km) section of I-16, two processes were used that had not been used on Georgia interstate highways previously. The first was full-depth reclamation (FDR) in place of the existing soil-cement subbase and soil subgrade using cement. The second was the placement of a special nonwoven geotextile fabric as an interlayer between the cement FDR and the new portland cement concrete slab. The fabric specifications were based on a pavement fabric first identified in Germany during the 2006 Long Life Concrete Pavement Scan. The decisions leading to the chosen design, the construction experiences, and, the lessons learned, are documented for this recent project.

Sustainable Long-Life Composite Concrete Pavement for the Illinois Tollway. Steven L. Gillen, Alexander S. Brand, Jeffery R. Roesler, and William R. Vavrik

The Illinois State Toll Highway Authority (Tollway) has begun the 15-year, multi-billion-dollar, Move Illinois program for roadway reconstruction, rehabilitation, and expansion. To improve sustainability efforts, the Tollway initiated a study conducted at the University of Illinois to investigate the changes in fresh and hardened properties when using coarse, fractionated (separated by size) reclaimed asphalt pavement (FRAP) as a partial replacement of virgin coarse aggregate in a ternary blended concrete for rigid pavement. The coarse FRAP replacement levels were 0, 20, 35, and 50 percent of the coarse aggregate content in a mix. The results indicated that acceptable strength properties can be attained with up to 50 percent FRAP addition, and extra processing of the "dirty" FRAP by washing to produce a "clean" FRAP did not significantly improve these properties. Additionally, matching the clean FRAP gradation to the typical virgin coarse aggregate gradation yielded statistically insignificant differences in strength properties. Another part of this study demonstrated that concrete with FRAP can have suitable durability properties.

From these preliminary findings, and to enhance sustainability efforts, the Tollway developed performance-based

PRESENTATION ABSTRACTS

specifications for ternary concrete mixes with a coarse aggregate content containing between 20 percent and 50 percent dirty FRAP, as well as specifications for the construction of two-lift concrete pavements for the use of such mixtures in the bottom lift. Based on the FRAP concrete properties, a two-lift concrete pavement section was designed using DARWin-ME. Additional design inputs included the expected local climate, traffic, materials, and pavement structure specific to the Illinois Tollway. The resultant 12- to 14-inch (305 to 355 mm) dowelled concrete pavement design consists of a 9.0- to 11.0-inch (288 to 279 mm) bottom lift containing FRAP and a 3.0-inch (76 mm) top lift of virgin aggregate concrete and 15-ft (4.6 m) joint spacing. A life cycle cost analysis of the two-lift composite concrete shows no difference from a standard jointed plain concrete section due to the engineering properties of the two-lift concrete and the construction cost estimates.

SESSION 3: OPTIMIZING DESIGN FOR LLCPS Wednesday, 1:30 p.m.

Long-Term Performance and Rehabilitation Strategy of Portland Cement Concrete Pavement on US-290 in Houston, Texas. Moon Won

The 27-mi (43.5 km) section of US-290 between Loop 610 and Badtke Road consists of portland cement concrete (PCC) pavement built at various times with different pavement structures (10-inch and 13-inch-thick (250 mm and 330 mm) slabs). There are two pavement types (continuously reinforced concrete pavement (CRCP) and jointed reinforced concrete pavement (JRCP). As of 2012, the age of the pavement varies from 7 to 52 years.

Over the years, the traffic on US-290 has increased steadily, and the highway capacity has been exceeded in some parts of the section, resulting in traffic delays and high user costs. The Houston District of the Texas Department of Transportation is planning to increase the highway capacity of this section. Detailed evaluations were made to develop optimum short-term and long-term strategies.

All the sections are in good structural condition with no punchouts in the 27-mi-long (43.5 km) roadway, regardless of the age of the pavement and slab thickness. However, major functional distresses exist in the 10-inch (250 mm) sections, all built with siliceous river gravel as the coarse aggregate. Primary distress type present is severe spalling. However, from a structural standpoint, all the four sections outperformed design traffic by 3 to 10 times. All of the 13-inch (330 mm) CRCP sections used crushed limestone as the coarse aggregate, and spalling distress is almost nonexistent. Based on the performance of CRCP built with crushed limestone coarse aggregate with a stabilized base and tied concrete shoulder, it is believed that the 13-inch CRCP sections will provide excellent long-term performance with minimal maintenance required.

The recommended short-term strategy is to place a 4-inch (100 mm) bonded concrete overlay on the 10-inch (250 mm) CRCP sections built prior to 1985, and an 8-inch (200 mm) unbonded concrete overlay with a 2-inch (50 mm) asphalt interlayer on the 10-inch JRCP built in 1973 through 1977. Recommended long-term strategies include removal and replacement of all the current 10-inch PCC pavements with 13-inch (330 mm) CRCP, and widening the existing 13-inch CRCP.

Early Performance of Two Test Sections on I-90, Syracuse, New York. Luis Julián Bendaña, Issam S Khoury, Shad M. Sargand, and Drew C. Hatton

This paper presents the evaluation and comparison of two portland-cement concrete pavement test sections placed on cement-treated permeable base (CTPB) or dense-graded aggregate bases (DGAB) on the I-90 Thruway in New York. The first test section had full-depth DGAB layer only, while the second section had a half-depth of CTPB layer placed above a half-depth DGAB layer. Environmental data were collected and dynamic testing was conducted to evaluate the load response of each test section.

Each test section included instrumentation: embedded strain gauges to measure environmental and dynamic response, linear variable differential transformers to measure the edge deflection of the slabs, pressure cells to measure the interface pressure between the base and subbase, strain gauges on instrumented tie bars to measure the forces between two adjacent slabs, and soil moisture probes underneath.

The results from the environmental monitoring show that the section placed on CTPB had higher strains and began to experience higher edge deflections after a year of service. The moisture probes indicated the CTPB did not affect subgrade moisture content. Dynamic truck load tests indicated the CTPB section had higher mid-slab strains and greater transverse joint deflections. The higher strains and deflections in the environmental and dynamic tests were attributed to the rigid CTPB layer, which caused loss of support at the slab edges. Early performance data show that there were no benefits from the CTPB, and that the rigid base layer had a negative impact on early-age pavement performance.

Prediction of Transverse Cracking in JPCP Considering Design Features and Material Properties. Shervin Jahangirnejad and Dennis Morian

To achieve long service life in jointed plain concrete pavements it is important that the full potential of the pavement section be realized. One approach to achieving this objective is to evaluate the potential for pavement distresses such as cracking, faulting, spalling, and materials-related distress at the design stage. Mechanistic and mechanistic-empirical performance models can be used to identify the potential development of such anticipated distresses, with the objective of eliminating or decreasing their presence during the design life of the pavement.

PRESENTATION ABSTRACTS

SESSION 4: OPTIMIZING MATERIALS FOR LLCPS Wednesday, 3:30 p.m.

One primary distress mechanism in plain doweled jointed pavement is cracking. This paper demonstrates the use of mechanistic and mechanistic-empirical tools to evaluate the significance of factors including slab thickness, joint spacing, material properties such as concrete coefficient of thermal expansion, and load type and magnitude in the development of mid-panel cracks in pavement slabs. Such cracking is known to develop when the tensile stress exerted on the slab exceeds the tensile strength of the concrete. Tensile stresses can be the result of mechanical loading, thermal loading, or a combination of the two. The ultimate design objective is to identify and eliminate conditions which could be expected to produce cracking.

Slab thickness, joint spacing, material properties, and loading conditions typically used by highway agencies in their designs were considered in this analysis. Factorials were developed to assess the role of these factors in crack development. Combinations of different levels of design variables resulting in satisfactory performance were then identified based on cracking potential and predicted cracking performance for the pavements modeled. This paper provides two separate approaches that States can use to incrementally improve pavement performance by taking advantage of minimal changes in design parameters which can be identified using these approaches.

Concrete Coefficient of Thermal Expansion Test for Quality Assurance. Jagan M Gudimettla, Mehdi Parvini, and Gary L. Crawford

Coefficient of thermal expansion (CTE) is a parameter that quantifies the extent with which a material changes length in response to changes in temperature. Numerous sensitivity studies over the past decade have shown CTE to have a significant impact on pavement performance. This is reflected in the new DARWin-ME™ pavement design software by high sensitivity of performance results to this input parameter. The most widely used method to measure CTE is AASHTO T 336, Standard Test Method for the Coefficient of Thermal Expansion of Hydraulic Cement Concrete.

Recently, there is a growing interest in using CTE test values as a quality assurance tool during concrete production to ensure that CTE does not exceed the design input. This paper presents CTE test data (per AASHTO T 336) collected by the California Department of Transportation and the Federal Highway Administration's Mobile Concrete Laboratory from various concrete paving projects constructed in 2011. The paper evaluates the variability of CTE test results as a function of variability in material, production, test equipment, and testing labs. In addition, correlation analysis is performed to identify if any relationships exist between routine quality control/quality assurance test data and CTE values. Finally, the paper discusses the importance of measuring the CTE during construction to ensure the pavement meets or exceeds its expected design life.

Evaluation of High-Volume Fly Ash Mixtures (Paste and Mortar Components) Using a Dynamic Shear Rheometer and an Isothermal Calorimeter (Interim Results). Jussara Tanesi, Ahmad A. Ardani, Richard Meininger, and Mihai Nicolaescu

Physical, chemical, and mineralogical characteristics of fly ash change from one source to another and sometimes within the same source. These changes in fly ash properties could have a profound impact on concrete performance. Delayed setting and slower early-age strength development could be the result of incompatibilities between the cementitious materials and the admixtures. This paper documents the use of a dynamic shear rheometer (DSR) and an isothermal calorimeter as scanning tools to predict possible materials incompatibilities, to assess early-age behavior of high-volume fly ash (HVFA) mixtures, and, most importantly, to ensure that concrete performance is not compromised. Additionally, this project aims to incorporate these tools as future quality assurance/quality control procedures in properly evaluating and qualifying fly ashes and other supplementary cementitious materials used in concrete mixtures for the highway infrastructure.

A series of paste and mortar mixtures containing different fly ashes (one Class C fly ash and one Class F fly ash), with replacement levels ranging from 20 percent to 60 percent, with high- and low-alkali cement, were evaluated. Materials testing included ASTM C109, compressive strength of mortar cubes at different ages; ASTM C1437, flow; ASTM C403, time of setting; and ASTM C1679, isothermal calorimetry and rheological properties using the DSR. In most cases, for the same water-binder ratio (0.40) and replacement level, Class C fly ash mixtures exhibited higher strength but delayed setting when compared with Class F fly ash mixtures. Class C fly ash mixtures presented lower plastic viscosity and lower yield stress, as well as higher flow. Plastic viscosity and yield stress increased with the increase of fly ash content for both fly ashes. Isothermal calorimetry proved to be a good scanning tool for prediction of setting time, early-age compressive strength, and materials incompatibility. Rheological properties provided an indication of setting delays. The ultimate goal of this study is to foster the prudent use of HVFA concrete mixtures in building a sustainable concrete infrastructure, while reducing the CO₂ footprint associated with the production of portland cement and maintaining standards for durability, workability, and strength.

Design and Specification of Durable Pavements Using Slag Cement Concrete. Peter Bohme, Gordon McLellan, Henry B. Prenger, and Anthony E. Fiorato

The use of slag cement and portland cement with fly ash and silica fume in binary, ternary, and quaternary blends has fundamentally changed concrete technology for paving and transportation structures. These cementitious blends provide broader options for engineering the properties of concrete and

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designing for durability, sustainability, and economy. Properly used, they can contribute to the goal of designing U.S. interstate and primary pavements to provide a service life of at least 40 years without requiring significant repair or rehabilitation treatments. These options for cementitious systems have also led to the need to update concrete design approaches, applicable test methods, and construction specifications. This paper provides data on properties of binary and ternary slag cement systems for paving and transportation applications, highlights some case studies, and reviews some issues related to test methods and construction specifications.

Development of a Protocol to Assess Integral Waterproofing Admixtures. Ezgi Yurdakul, Peter C. Taylor, Halil Ceylan, and Fatih Bektas

Concrete durability is a direct function of permeability, therefore reducing permeability will improve the potential durability of a given mixture. One approach to improving permeability of a mixture is to add chemical compounds, known as integral waterproofing admixtures, which help to fill and block capillary pores.

Currently there are no standard approaches to evaluate the effectiveness of integral waterproofing admixtures or to compare them in the United States. A review of manufacturers' data sheets shows that a wide range of test methods have been used, and rarely are the same tests used on more than one product.

This study investigated the fresh and hardened properties of mixtures containing commercially available integral waterproofing admixtures. The aim was to develop a protocol that would help owners and specifiers compare different products and to evaluate their effects on concrete mixtures.

In this experimental program, concrete mixtures were prepared with a fixed water-to-cement ratio and cement content. One mixture was prepared as a control mixture, five mixtures were prepared using the recommended dosage of different waterproofing admixtures, and five mixtures were prepared using double the recommended dosages. Fresh and hardened properties were assessed at various ages. The data are presented and recommendations for a testing protocol provided.

Achieving Long-Life Concrete Pavements by Preventing Alkali-Silica Reactivity. Gina Ahlstrom and Jim Pappas

Alkali-silica reactivity (ASR) is a materials-related distress that causes deleterious expansion in concrete through a reaction of alkalis found in portland cement and reactive silica found in the aggregates that creates an expansive gel in the presence of moisture. The expansive force of this gel is typically greater than the tensile strength of concrete, and therefore cracking occurs, allowing the penetration of water and salts that cause deterioration of reinforcing steel and loss of service of the concrete asset.

Numerous research projects, programs, and initiatives have been aimed at addressing ASR worldwide since Thomas Stanton first documented ASR in 1942. In 2010, the American Association of State Highway Transportation Officials (AASHTO) published a specification to minimize the risk of ASR from developing in new concrete assets including pavements and structures.

This paper highlights the necessary steps to design a new concrete mixture that is resistant to ASR. A brief discussion of the ASR mechanism and previous efforts related to ASR is provided. We have an increasing amount of knowledge today to design concrete that is resistant to ASR. However, pavements and structures are still being designed and constructed that do not meet their design life because of ASR. This paper discusses the need for a specification to address this materials-related distress.

The paper discusses AASHTO Specification PP 65-11, "Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction." The paper also discusses the current methods and tests necessary to determine the reactivity potential of aggregates and outlines two methods to design a new concrete mixture that provides a reasonable level of resistance to ASR: a performance-based approach for determining appropriate preventative measures and the prescriptive-based approach. By eliminating materials-related distresses, such as ASR, we can design long-life concrete pavements and structures that meet the long-term needs of the agency and the public.

SESSION 5: CONSIDERATIONS FOR LLCPs Thursday, 8:30 a.m.

Investigation of the Effect of the Interfacial Zone on Joint Deterioration of Concrete Pavements. Jiake Zhang and Peter C. Taylor

Some sawn joints in concrete pavements are deteriorating faster than desired in the midwestern region of the United States. It is becoming clear that a significant factor causing the distress is the freezing and thawing of saturated concrete that contains a marginal air system and a high water-to-cementitious materials ratio (w/cm), combined with the effects of non-NaCl deicing salts.

Typically, freeze-thaw damage is evidenced in the form of layers of small flakes, as water cyclically penetrates a few millimeters into the surface, then freezes and expands. However, the distress in pavements is sometimes exhibited in the form of cracks that appear and grow about 1 in. (25 mm) from the free surface. These cracks are observed to go around the coarse aggregate, leaving it clean with little or no cement paste adhering to it.

It is hypothesized that a mechanism for this observation is that when joints are saw cut, the cut aggregate face exposes the

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interfacial transition zone (ITZ) around the particle. If water is held in the saw-cuts, it can be wicked around the coarse aggregate particles through the ITZ. Subsequent freezing and dissolution of the soluble calcium hydroxide in the ITZ will cause cracking around the coarse aggregate particles until the stress field drives a vertical crack up to the surface about 1 in. from the sawn edge. Once the now-loose piece is removed by traffic loading, the cycle is repeated.

This paper describes an experimental program aimed at investigating this hypothesis. Factors influencing concrete ITZ evaluated in this study include w/cm, aggregate type, and addition of silica fume. A significant increase of both absorption and air permeability were observed with higher w/cm. Concrete mixtures with limestone provide better durability than mixtures with gravel, which results in reduced ITZ on limestone mixture. However, the addition of silica fume increases the bonding between aggregate and paste, causing the gravel mixture to have higher material loss and the limestone mixture to be more brittle during freezing and thawing.

Condition of Field-Exhumed Dowel Bars. Kurt D. Smith, Roger M. Larson, Roger L. Green, and Barry C. Paye

Many highway agencies have adopted long-life concrete pavements designs for their heavily trafficked roadways and urban corridors. As part of these designs, epoxy-coated dowel bars are commonly used to provide positive load transfer across the transverse joints. However, there is currently limited information regarding the long-term effectiveness of epoxy coatings in preventing or minimizing the corrosion of dowel bars in highway pavements.

This paper reports on a program implemented by two highway agencies to investigate the condition of epoxy-coated dowel bars and several alternative dowel bars in older concrete pavement projects. A total of 18 projects (10 projects in Ohio and 8 projects in Wisconsin) were evaluated, which included the retrieval of dowel bar cores from each in-service project and the visual examination of the dowel's condition and surrounding concrete integrity. In addition, chloride content testing was performed on the retrieved core. Together, these data were analyzed to assess the effectiveness of the epoxy coating in providing corrosion protection. Overall, the epoxy coating was judged to provide an effective performance of 20 to 30 years on these projects located in Ohio and Wisconsin. As part of the program, several older projects with plastic-coated dowels were evaluated, which were performing very well after 33 years of service.

Character, Extent, and Severity of Corrosion in Continuously Reinforced Pavements in South Dakota. Allen L. Jones, Nadim Wehbe, and Stephanie Klay

A major drawback of CRC pavement is the potential for the steel reinforcement to corrode. The corrosion process is initiated and accelerated when deicing chemicals, used extensively during winter maintenance, penetrate through the cracks and reach the steel reinforcement. The expansion of the corroded

reinforcement leads to spalling of concrete and rapid degradation of the pavement section.

CRC pavements constructed in South Dakota as part of the original Interstate Highway System (pre-1995) have performed well with little to no observed corrosion of steel reinforcement. However, recent surveys conducted by the South Dakota Department of Transportation (SDDOT) indicate a strong likelihood of potential future problems in newer CRC pavements (post 1995) with corrosion of the reinforcing steel. SDDOT is interested in determining cost-effective maintenance and rehabilitation strategies to maintain and extend the life of in-service CRC pavements exhibiting unexpected levels of cracking and distress for the post 1995 CRC pavements.

An extensive field and laboratory testing program was initiated to define the character, extent, and severity of corrosion in CRC pavements constructed in South Dakota since 1995 and to identify factors and interactions among factors that contribute to observed levels of corrosion. Field evaluations included detailed crack mapping, half-cell potential measurements, dust sample profiling, and core sampling. Dust samples were tested for chloride content and the core samples were examined under a scanning electron microscope for imaging, X-ray spectrum, semi-quantitative analysis of the X-ray spectrum, and elemental mapping. The results of the field and laboratory testing were used to evaluate the reinforcement condition of eight representative sites across South Dakota.

The results of this study show that the distress in CRCP is not necessarily the results of reinforcement corrosion. Corrosion of the reinforcement occurred only at locations of cracks in the CRCP where chlorides could penetrate and reach the reinforcement. In intact (uncracked) concrete, the chloride content from deicing salts was insignificant and was below the threshold for corrosion at the level of the reinforcement. The half-cell potential Numeric Magnitude Technique was not a good indicator of the probability of corrosion in CRCP. However, in general, a strong correlation was observed between the crack density in the pavement and elevated half-cell potential readings.

Trends in Specifications and Costs of Subbases for Concrete Pavement Structures. Robert A. Rodden and Gerald F. Voigt

Roadbed design and construction are key to long-term performance and smoothness of any pavement structure. For concrete pavement, the roadbed foundation typically comprises a subbase layer on top of the subgrade soil. A variety of engineered subbase materials and gradations exist for use under concrete pavement. This paper presents results from four surveys conducted between 1995 and 2010 that investigated subbase specifications and costs in the United States. The findings show that, because of construction and performance issues and a resultant lack of long-term cost-effectiveness, permeable subbases have fallen out of favor. Permeable subbases were at one time thought to be the preferred alternative for long-life concrete pavement structures and were specified by most State agencies. However, the U.S. concrete

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pavement industry has been on record as not in favor of permeable subbases, and as a result, State agencies have been shifting their engineering approach. The recent trend shows more States requiring both a minimum and maximum permeability in the specifications for drainable subbases, resulting in the emergence of a new classification of subbase, typically termed a “free-draining” subbase. Other notable results reveal a decrease in the number of subbase options typically allowed by a State agency and about a 25 percent decrease in the specification of asphalt-treated and lean concrete subbases from 2005 to 2010. These engineering changes have generally provided for more cost-effective design sections, as industry cost surveys also show a significant initial cost savings with free-draining materials over permeable asphalt-treated or cement-treated subbases.

SESSION 6: LONG-LIFE REPAIRS AND REHABILITATION Thursday, 10:30 a.m.

Full-Depth Replacement of Concrete Pavements With Rapid-Strength Concrete. B. Stein, B. Kramer, R. Ryan, and S. Shatnawi

Full-depth replacement of individual panels and sections of lanes with rapid-strength concrete (RSC) is a frequently used pavement rehabilitation strategy. Caltrans has implemented this strategy for hundreds of projects in California for extending service life of concrete pavements.

Project experience demonstrates that performance and properties of RSC used for replacement of pavements during short-duration lane closures that allow for 1 to 4 hours of curing prior to opening highway lanes to traffic, are uniform and predictable, provided the ambient conditions (and specifically ambient temperature) are accounted for.

The paper discusses elements of pavement rehabilitation strategies, elaborates on production and construction practices, and illustrates recommended approaches with examples of projects built in California. Authors discuss principles of design (proportioning) of RSC with consideration for constructability and durability. The paper also analyzes other aspects of RSC performance defining quality of pavements and their service life.

Finally, the authors provide their view of the needs of future research and development in the field of RSC materials science and technology, design of replacement pavements, and rehabilitation practices.

A Comparison of Three Rehabilitated Sections on I-86 in New York. Issam Khoury, Shad M. Sargand, Luis Julian Bendaña, and David A. Padilla

An evaluation of the performance of three experimental rehabilitated sections on I-86 in New York State is presented in this paper. Three experimental sections were built to evaluate the effectiveness of different fracturing methods for

rehabilitating rigid pavements before applying unbonded concrete overlays. Each section consists of an unbonded jointed plain concrete pavement (JPCP) overlay over a broken and seated (B&S), rubblized, or untreated jointed reinforced concrete pavement (JRCP).

Sensors to measure strain, temperature, deflection, and pressure were installed in the three sections prior to reconstruction in June 2006, and environmental response data as well as data due to falling-weight deflectometer (FWD) loading was collected continuously since placement of the concrete. In addition, pavement condition surveys were conducted on an annual basis.

Performance of these test sections was significantly influenced by environmental response. Results suggest that a JPCP overlay over untreated JRCP would exhibit a more severe environmental response compared to the same overlay over B&S or rubblized JRCP. The B&S section experienced a more severe dynamic response to the FWD tests and exhibited loss of support but provided better load-transfer efficiencies (LTE) than the other sections. The rubblized section showed fair LTE values but provided better support than the other two sections. The untreated section showed the lowest LTE values. From field observations and FWD testing, this study suggests that top-down cracking could be the primary distress mechanism leading to failure.

Virginia's Efforts in Developing Effective Concrete Pavement Patching Specifications. Mohamed Elfino, Affan Habib, Larry Lundy, and Syed Haider

To achieve quality and longevity for rigid pavements with limited resources (funds and work force), full-depth and partial-depth patches are used to repair transverse cracks, joints with excessive faulting, spalling, and punchouts in Virginia.

The Virginia Department of Transportation (VDOT) has worked extensively over many years to have a cost- and time-efficient methodology for repairing concrete pavements through patching. As a result, VDOT moved from a strict method and means specification to a “quasi performance” specification with a mandatory warranty period of 1 year for concrete patches. The warranty covered any premature failure related to material and workmanship. The historical performance data, though not formally documented, for these concrete patches revealed only a few patch failures before 1 year (typical warranty period). However, in spite of having a low risk of failure, the impact of even limited failure is very significant in terms of traffic delays during the repair, especially on highways with high traffic volumes. Also, over time, the department felt that in case of premature failures, it was hard to resolve the warranty issues with the contractors. In addition, there were concerns regarding the fresh concrete strength gain and minimum time before the concrete patch could be opened to traffic. Therefore, construction provisions have been revised to improve pavement performance and resolve construction-related issues.

The new provisions for patching address three aspects: (a) no-excuse warranty, (b) minimum compressive strength before a

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concrete patch can be opened to traffic, and (c) quality assurance of the concrete mix design along with the use of maturity meters during construction. The HIPERPAV® software was used to assess some performance aspects of the concrete patches based on the available materials and climatic conditions in Virginia.

This paper highlights the evolution of the concrete pavement patching specifications. Several concerns and solutions adopted for patching are documented. Several hypothetical scenarios were analyzed using HIPERPAV software to provide a general idea about the sensitivity of the parameters that impact concrete performance. In addition, the impact of these maintenance practices in achieving long-life pavement in Virginia is discussed.

Pervious Concrete Shoulders for Stormwater Management, John T. Kevern

This paper discusses the requirements for using pervious concrete shoulders in roadway applications and the mixture development for the first pervious concrete shoulder section in the United States. Roadway stormwater management techniques that do not require additional right-of-way are attractive retrofit options for roadway owners. This paper presents the mixture development and project goals of a unique, comprehensive, demonstration project in St. Louis, Missouri, that utilizes photocatalytic cement for air quality improvements and pervious concrete shoulders for stormwater management. Mixture proportioning development included internal curing to eliminate curing under plastic and photocatalytic pervious concrete. As part of the project, pervious concrete shoulders were installed and instrumented to determine the potential for pervious concrete shoulders to be installed as linear stormwater best management practices. Four test locations are instrumented to determine stormwater volume reduction and pollutant removal capacity.

SESSION 7: SHRP 2 LLCP PRODUCTS Thursday, 1:30 p.m.

SHRP 2 Project R23—Guidelines for Long-Life Pavement Renewal Using Bonded and Unbonded PCC Overlays. Newton Jackson, Joe Mahoney, Mark Snyder, and Neeraj Buch

Guidelines for long-life pavement renewal were produced under SHRP 2 Project R23, entitled “Using Existing Pavements in Place and Achieving Long Life,” which is in the SHRP 2 Renewal emphasis area. How bonded and unbonded PCC overlays are treated in the study is the subject of this paper.

As part of the project, the performance of bonded and unbonded PCC overlays was investigated by surveying the States and several countries, reviewing national and international literature, and analyzing data in the Long Term Pavement Performance data base. This analysis showed that unbonded PCC overlays can provide 40- to 50-year service lives, and that

bonded PCC overlays could provide 30-plus years of service when placed over structurally sound pavements.

This paper summarizes the performance information collected for bonded and unbonded PCC overlays and the guidance developed for the design and construction of long-life PCC overlays. This guidance, along with that for flexible paving approaches, is provided in the SHRP 2 Guidelines for Long-Life Pavement Renewal. The guidelines are available through a Web-based program that provides selection guidance, as well as resource documents, including information concerning pavement assessment, best practices for rigid and flexible pavements, guide specifications, traffic considerations, life cycle assessment, and life cycle cost analysis for approach selection.

Long-Life Composite Pavement Systems. Michael I. Darter, Shree Rao, Lev Khazanovich, Derek Tompkins, John Harvey, James Signore, and Julie Vandebossche

The Strategic Highway Research Program 2 (SHRP 2) R21 project on Composite Pavement Systems is under the Renewal area of SHRP 2, the goal of which is to develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities. Two composite pavement design strategies were determined to reflect the SHRP 2 Renewal philosophy of “get in, get out, stay out”:

- High-quality, thin, hot-mixed asphalt (HMA) surfacing (e.g., dense HMA, stone matrix asphalt, porous HMA, asphalt rubber friction course (e.g., Nova Chip)) over a new, less expensive, portland cement concrete (PCC) structural layer (e.g., jointed plain concrete (JPCP)), continuous reinforced concrete pavement (CRCP), and jointed roller-compacted concrete.
- High-quality, thin, PCC surfacing (e.g., exposed aggregate concrete, diamond grinding, conventional texturing) atop a thicker, less expensive structural PCC layer (e.g., JPCP, CRCP).

Both types of composite pavements have strong technical, sustainable, and economic merits in fulfilling the key goals of the SHRP 2 program including long lived pavements, rapid renewal, and sustainable pavements. These merits exist because the upper surface requires higher durability materials (which cost more) than the lower PCC portion, which does not require the same quality (or cost). This research investigated the design and construction of new composite pavement systems for all levels of highway and urban streets. The behavior, material properties, and performance for each type of composite pavement under varying climate and traffic conditions were determined. The AASHTO MEPDG and other structural, climatic, material, performance prediction models, and design algorithms were evaluated, and some were improved as needed. Practical recommendations for construction specifications and techniques, life cycle costing, and training materials were prepared.

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SHRP 2 Project R05: Precast Concrete Pavements for Long-Life Repair and Rehabilitation of Existing Pavements. Shiraz Tayabji, Dan Ye, and Neeraj Buch

Historically, highway agencies have been searching for strategies for pavement rehabilitation and reconstruction that are faster and can produce longer lasting pavements. Expedient rehabilitation that results in a shorter pavement lifespan is no longer considered acceptable by most highway agencies. A promising alternative rehabilitation strategy is the effective use of precast concrete pavement (PCP) technology, which provides for rapid repair and rehabilitation of pavements and also results in durable, longer-lasting pavements. Rapid construction techniques can significantly minimize the impact on the driving public, as lane closures and traffic congestion are kept to a minimum. Road user and worker safety is also improved by reducing road users' and workers' exposure to construction traffic.

The "Renewal" focus area under the Strategic Highway Research Program 2 (SHRP 2) emphasizes the need to complete highway pavement projects rapidly, with minimal disruption to highway users and local communities, and to produce pavements that are long-lasting. A goal of this focus area includes applying new methods and materials to preserve, rehabilitate, and reconstruct roadways. The effective use of PCP technologies for rapid repair, rehabilitation, and reconstruction of pavements addresses this goal. One of the projects funded under SHRP 2 is Project R05, Modular Pavement Technology. The objective of Project R05 was to develop better guidance for use by highway agencies to design, construct, install, maintain, and evaluate modular pavement systems, principally precast concrete pavement (PCP) systems. This paper presents the findings from Project R05 and summarizes recommended guidelines for PCP project selection, system acceptance, design, precast panel fabrication, and installation.

The Evolution of Precast Concrete Pavement in California.
Tinu Mishra

California's first precast concrete pavement project was constructed in 2004 and entailed replacing a small stretch of concrete roadway in the Los Angeles area. Since then, the California Department of Transportation (Caltrans) has gradually pursued different precast concrete pavement projects in other parts of the State, each one increasing in size and scope. The most recent undertaking was done on a full scale, incorporating almost 5 mi (8 km) of precast concrete pavement in the San Francisco Bay Area. The project was innovative in its integration of different precast systems including a new design of post-tensioned and jointed panels under different rapid rehabilitation conditions, including installations under structures and on curves. In the end, the project set the standard for large-scale rehabilitation of concrete roadways under live traffic conditions.

Now, Caltrans, in partnership with industry, is in the process of developing statewide standards in the form of design plans and specifications for use on any precast project. The ultimate goal

is to provide another "tool" that engineers can use for concrete pavement rehabilitation.

This paper discusses the success of precast concrete at Caltrans, specifically on its most recent project in Northern California, the challenges in developing statewide standards, and the future of this innovative concept of long-life rehabilitation in the Golden State.

SESSION 8: SUSTAINABILITY CONSIDERATIONS Thursday, 3:30 p.m.

Relative Cost of Concrete Pavement Design Features for Conventional and Long-Life Performance Consideration.
Gerald F. Voigt, Larry Scofield, and Robert A. Rodden

A survey of American Concrete Pavement Association (ACPA) contractors was conducted in 2010 to determine the relative cost of selected design features. This work was used to create a relative cost Web application available at <http://apps.acpa.org/apps/RCpass.aspx>. The application is useful to assist owners in determining the best value achieved from design features. Three different surveys were used: a General Survey evaluating nine design features, a Saw and Seal Survey evaluating four sealant types and four reservoir widths, and a Dowel Bar and Tiebar Module evaluating different dowel configurations. To complete the surveys required 117 cost inputs to be developed by estimators from ACPA contractor member companies. This paper and the referenced Web application evaluate the initial construction cost of a national "average" project and isolate the relative cost of individual feature items. As evident in this work, several features considered for standard and long-life concrete pavements have significant cost impacts that should be considered in determining when and where to incorporate specific design options/features to enhance concrete pavement performance and cost effectiveness.

Designing Sustainable Concrete Pavements Using the Mechanistic-Empirical Pavement Design Guide and Life Cycle Analysis. James W. Mack, Mehdi Akbarian, Franz-Josef Ulm, Jeremy Gregory, Randolph E. Kirchain, Margaret Wildnauer, and Omar Abdullah Swei

Increasing the sustainability of our infrastructure is accomplished in ways other than just developing better materials and using recycled materials: it is also about employing the right designs. For concrete pavements, overdesign causes excess materials to be used during construction, leading to higher economic costs and environmental impacts. Optimizing pavement designs for prescribed service lives, climates, and traffic conditions allows pavement engineers to create structures that have low initial costs and CO₂ emissions as well as low life cycle costs and CO₂ emissions.

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This paper shows how design optimization can lower costs and CO₂ emissions by balancing two types of costs: (1) the initial costs and CO₂ emissions of a pavement, which are primarily a function of the thickness and specific design features used, and (2) the rehabilitation costs and CO₂ emissions, which are a function of the pavement's estimated service life and required rehabilitation activities.

To do this, a case study for a medium-volume highway in California is analyzed where the conventional designs are compared against optimized designs from the recently adopted AASHTO *Mechanistic-Empirical Pavement Design Guide*. Life cycle cost analysis and life cycle assessment are used to quantify the costs and environmental impacts of the different alternative pavement scenarios and to compare the trade-off between the initial costs and CO₂ emissions and successive rehabilitation activities to find the "optimized design."

Photocatalytic Concrete Pavements: Decrease in NO_x Removal Due to Reaction Product Blinding. Joel K. Sikkema, James E. Alleman, Say Kee Ong, Jacek A. Koziel, Peter C. Taylor, and Haotian Bai

On-road motor vehicles account for approximately 34 percent of nitrogen oxides (NO_x) emitted in the United States. The 35 million people who live within 100 m (300 ft) of major sources of on-road vehicle emissions are exposed to higher than average concentrations of NO_x and experience multiple adverse health effects. Recent changes to air quality regulations for nitrogen dioxide (NO₂) may identify new areas of nonattainment, which in turn would intensify efforts to mitigate pollution from the transportation sector. The recent development of photocatalytic concrete pavements presents a novel option to abate NO_x emissions from motor vehicles. However, over time the rate of NO_x photocatalytic oxidation decreases because interfering substances (e.g., roadway contaminants, fine dust, organisms, and reaction products) blind the pavement surface. NO_x removal by photocatalytic mortar slabs was tracked over 5-hour and 20-hour periods in a bench-scale photoreactor within which environmental conditions could be controlled. Although percent removal initially decreased in comparison to a reference measurement, as time progressed removal stabilized asymptotically. Hence, it is probable that reaction product formation will not result in the complete loss of the pavement's air-cleaning property. Analysis by scanning electron microscope—energy-dispersive spectroscopy found that immersion in water did not remove the reaction products from the surface. Therefore, strategies to regenerate photocatalytic activity must be developed.

Sustainable and Long-Life Precast Prestressed Concrete Pavements. Samuel S. Tyson and David K. Merritt

Significant advancements have been made during the last 12 years in the application of precast concrete panels for rehabilitation of highway pavements in high-volume traffic corridors. The use of precast pavement technology typically is justified on the basis of two important advantages over

alternative rehabilitation procedures: precast construction can be completed during short lane closures with all lanes immediately opened to traffic, and the precast panels offer enhanced concrete quality, durability, and long-life performance. The use of prestressing and other design features result in a thinner pavement slab, thereby reducing concrete quantities by up to 30 percent compared to conventional jointed concrete pavement alternatives. Additionally, with a small number of working joints, the prestressed concrete pavement offers reductions in anticipated maintenance activities.

This paper provides a qualitative assessment of how construction costs, lane closure requirements, anticipated maintenance activities, and life cycle cost considerations can impact the choice of precast prestressed concrete pavement (PPCP) over conventional construction. A section of Interstate Route 66 in Fairfax County, Virginia, constructed in 2009 using PPCP (Virginia DOT 2010), is utilized to demonstrate how such factors can be documented and anticipated to serve as a starting point for considering the enhanced sustainability and reduced life cycle cost for PPCP. Additionally, factors associated with life cycle assessment are described as they relate to the use of PPCP.

The information presented in this paper was previously presented in 2011 at an international conference on sustainability of concrete pavements in Boston, Massachusetts.

SESSION 9: NATIONAL CONCRETE CONSORTIUM FORUM Friday, 8:30 a.m.

High-Performance Concrete Pavement in Indiana. Tommy Nantung, Indiana DOT

Until the early 1990s, curling and warping of portland cement concrete pavement (PCCP) did not concern pavement engineers in many transportation agencies. Since beginning construction of the Interstate system in the United States in the late 1950s through the late 1980s, the performance of PCCP has been associated with properties of concrete as a pavement material. In those years, developed standards and design guidelines emphasized better concrete materials and construction control. At the time, combining curling and loading stresses was quite controversial due to the nature of the load-carrying capacity of concrete pavement and the occurrence of types of loads. Arguments developed that the types of loads (traffic and curling) rarely occurred at the same time of day. The concrete pavement design principle did not include the effects of curling and warping of concrete pavement as determining design factors in pavement performance.

This research project was initiated as a response from the INDOT Pavement Steering Committee related to the joint spacing of jointed plain concrete pavement (JPCP) in Indiana. There was an initiative in the Committee to reduce the joint

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spacing from 18 ft (5.5 m) to 15 ft (4.6 m) as a way to reduce premature concrete pavement deterioration. There was an indication that some newly paved JPCP had transverse cracks even before the pavement section was opened to traffic.

The objective of this study is to answer the questions from the INDOT Pavement Steering Committee and provide data to justify any decision to change the INDOT Pavement Design Manual. As the research study progresses, the new Mechanistic-Empirical Pavement Design Guide is released by the Transportation Research Board that supports the important phenomenon of curling stress. In this experimental study, several important conclusions were drawn from temperature analysis, stress-strain analysis, and tiltmeter data analysis.

Constructing Long-Life Pavements—How Will We Know If We Were Successful? Heather McLeod, Kansas DOT

Short-life pavement has never been the goal for a DOT and transportation owner. The Kansas DOT has a long history of constructing successful long-life concrete pavements and continuous efforts to improve the life of concrete. Some successful long-life concrete pavements constructed in Kansas are the result of intentional efforts to implement innovative ideas and technologies, a strategy KDOT has always embraced through research. However, some of the longest-lived pavements constructed in Kansas were constructed with KDOT standard practices, achieving up to a 90-year life quite by accident. It almost goes without saying that “achieving long-life” will be evaluated at a future date when the pavement fails or achieves the intended design (long) life. Accurate and thorough documentation is required at the time of construction to properly evaluate the performance in the future, particularly for the implementation of new and innovative ideas.

Recent research aimed at evaluating concrete pavement life in Kansas has revealed an important question: Do DOTs routinely keep adequate construction records to evaluate our current methods and materials in the future? Questions as simple as “Where exactly is this pavement located?” were found to not be elementary. However, the answer is clearly critical to performing accurate field survey. Thousands of hours were invested in mining more than 20 agency and nonagency sources to determine what was thought to be simple historical information for approximately 150 pavements that were only 10 to 30 years old. At times the meaning of the available information needed to be interpreted by personnel involved during construction or in the development of the data source. These challenges will only increase when evaluating long-life pavements, such as those exceeding 30 years. Construction management systems (CMS) are often cited as the source of historical documentation. The purpose of a CMS is often to pay the contractor, not for historical recordkeeping purposes, and therefore it may not lend itself to accurate or accessible historical records. Towards the goal of knowing in the future whether our efforts at constructing long-life concrete pavements are successful, current CMS systems and other agency sources should be evaluated and methods to improve the accuracy and possibly the robustness these systems should be considered.

Louisiana’s Experience With Surface Resistivity Measurements and Implementation Efforts. Tyson D. Rupnow and Patrick J. Icenogle, Louisiana Transportation Research Center

Many entities currently use permeability specifications in portland cement concrete (PCC) pavements and structures. Recent studies have shown surface resistivity testing correlates well with rapid chloride penetration (RCP) testing. A precision statement has been developed for use of the meter. The success of this research has led to implementation in Louisiana of surface resistivity testing on PCC cylinders. A total of 17 surface resistivity meters and operators participated in round-robin testing conducted at the Louisiana Transportation Research Center over the course of 2 days. The tests were conducted side by side, and the individual meter results were compared. Eight mixtures representing multiple permeability classes were tested with two replicates for each mixture. A precision statement was developed for use with Louisiana Department of Transportation and Development’s Test Requirements Procedure TR 233, “Surface Resistivity Indication of Concrete’s Ability to Resist Chloride Ion Penetration.” The single operator coefficient of variation of a single test result was found to be 2.2 percent. Therefore the results of two properly conducted tests by the same operator on concrete samples from the same batch and of the same diameter should not differ by more than 6.2 percent. The multilaboratory coefficient of variation of a single test result was found to be 3.9 percent. Therefore, the results of two properly conducted tests in different laboratories on the same material should not differ by more than 11 percent.

A ruggedness factorial using many of the factors in question to determine the level of impact of each factor was developed. A partial factorial consisting of 35 combinations of factors was developed using 11 factors and 16 mixtures. Some factors were mixture-dependent, so RCP testing was also performed on a portion of the factorial to determine if factors influence the surface resistivity meter or permeability in general. The ruggedness study showed age and aggregate type as significant factors for surface resistivity. Additional comparisons against a control suggested age, calcium nitrite, aggregate size, and aggregate type as significant factors for surface resistivity. However, comparative RCP testing on the same sample sets concluded that all significant factors determined either affect the permeability of the sample in general or will influence rapid chloride permeability as well.

This presentation also details the implementation efforts of Louisiana Department of Transportation and Development. Cost benefit analysis results for an actual bridge project is detailed showing about \$10,000 in savings over 3 months.

Minnesota’s Experience With Low W/C Ratio Pavements. Maria Masten, Minnesota DOT

In 1995, MnDOT decided to move away from strength as the primary method of acceptance for concrete pavements and transition to the use of a low w/c ratio specification for acceptance to achieve more durable and longer lasting pavements.

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With the change to a low w/c ratio specification, MnDOT focused on the use of incentives to encourage contractors to look for new and different ways to build durable concrete pavements. The specifications used incentives for w/c ratios less than 0.40, well-graded aggregates (8–18 gradation band), and enhanced aggregate quality. Several changes evolved with the move to lower w/c ratios, which included the use of 1 ½-inch (38 mm) coarse aggregate, reduced total cementitious content, increased SCMs, and the use of water reducers.

Since some of the first low w/c pavements have now been in place more than 15 years, MnDOT has undertaken research to evaluate the cost effectiveness of producing these lower w/c ratio pavements. Selected cores from concrete pavements constructed both before and after 1995 are being examined for rapid chloride permeability, chloride ion penetration, and petrography. This presentation focuses on the preliminary results of this ongoing project.

Striving for Long-Life Concrete Pavements—Missouri's Direction. Brett Trautman, Missouri DOT

The Missouri DOT (MoDOT), like so many other State agencies, has seen revenue remain flat for the last few years, putting a tremendous strain on our ability to meet the transportation needs of our citizens. To meet the challenges of the future, agencies must try new technologies, materials, or construction techniques to maximize concrete pavement performance and at the same time address fiscal, social, and environmental concerns. In recent years, senior management at MoDOT has encouraged employees to try new ways to improve concrete performance or reduce cost without reducing service life. This presentation discusses some of the changes MoDOT has implemented over the past 20 years to improve the performance of our concrete pavements.

Reducing Transverse Joint Spacing. From pavement surveys, MoDOT found that 75 percent of its 30-ft (9.1 m) slabs had a crack developing in the center of the slab, while the 61.5-ft (18.7 m) slabs had two to three cracks developing between the joints, with many cracks experiencing significant faulting and a large amount of spalling. In 1993, MoDOT reduced the transverse joint spacing to 15 ft (4.6 m), which has eliminated the transverse cracking.

Removing Reinforcement. In the 1930s, MoDOT started utilizing steel fabric in concrete pavements to help hold concrete together when transverse cracks developed in the concrete. Problems with faulting, corrosion, and delamination were investigated, and in 1993, MoDOT stopped utilizing reinforcement and started constructing jointed plain concrete pavements.

Determining Air Content Behind Paver. In 2004, MoDOT started requiring that the air content be determined on concrete sampled from behind the paver to ensure that the proper air content was being achieved due to reports from other States that the air content behind the paver was lower than the air content in front of the paver. MoDOT currently requires concrete placed behind the paver to have an air content of 5.0 percent or higher. Testing has validated MoDOT's decision to determine the air content behind the paver.

Using Cementitious Materials. In 1990, MoDOT started allowing 15 percent of hydraulic cement to be replaced with fly ash to reduce cost without affecting concrete quality, and has increased

the replacement rate incrementally to the current 25 percent. MoDOT has also allowed other cementitious materials such as slag, silica fume, and metakaolin to be used in concrete. Use of cementitious materials can improve the quality of concrete by increasing strength and decreasing permeability, offer safe disposal of industrial waste, and help to reduce CO₂ emissions.

Allowing Optimized Concrete Mix. In 2004, MoDOT started allowing optimized concrete mixtures. MoDOT has seen optimized mixes improve workability and finishing characteristics of concrete, helping contractors receive incentive pay for smoothness. Optimized mixes produce a more consistent concrete, which is key when utilizing percent within limits to determine pay factors.

QC/QA Inspection. Since 2004, when MoDOT implemented new quality control/quality acceptance (QC/QA) inspection procedures, the quality of concrete has improved. QC/QA has required contractors to have a much better understanding of aggregates, admixtures, portland cement, and cementitious materials and their effect on fresh and hardened concrete properties.

The Future. To continue improving concrete pavements, MoDOT is considering the following: 1) surface resistivity testing; 2) increasing replacement rates for fly ash and slag; 3) increasing replacement rate for ternary mixes; 4) the use of recycled concrete aggregates in new concrete. As MoDOT moves forward, it will be important to be open to new ideas to meet Missouri's transportation needs.

NCDOT'S Experience With QA Systems and New Technologies. Nilesh Surti

This presentation discusses the North Carolina Department of Transportation (NCDOT) acceptance and verification program for concrete pavements, recent changes, and testing and adoption of new quality assurance technology. NCDOT conducts all the sampling and testing for acceptance, which is based on concrete strength, concrete thickness, and pavement smoothness.

Strength is accepted on a minimum 4,500 lbf/in² (31 MPa) compressive strength based on 28-day cylinder tests. The contractor uses the maturity method (ASTM C 1074) to check concrete strength, with maturity meter readings witnessed and verified by NCDOT.

Thickness has been accepted based on 4-inch (100 mm) cores taken at random locations in a lot within 30 days of concrete placement. However, in July 2012, NCDOT received a MIT-SCAN-T2, a pulse-induction technology that can nondestructively measure the thickness of asphalt or concrete pavements. The State will compare thickness readings from the MIT-SCAN-T2 with cores taken in the same location to determine the accuracy of the device.

Final surface testing for *pavement smoothness* has been determined on concrete pavements and bridges using the Rainhart profilograph. The 2012 NCDOT *Standard Specifications* calls for surface smoothness to be measured with an inertial profiler using line laser technology. NCDOT also performs a post-construction check of the macrotexture of the finished surface of concrete pavement in accordance with ASTM E 965 (sand patch) test, and is exploring the use of a flow meter (ASTM E 2380) as an

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option. Testing is being conducted to compare both methods and establish a correlation.

Other innovations at NCDOT include use of the MIT SCAN-2 to verify dowel bar location and alignment; Shilstone design mix and diamond grinding for noise reduction; longitudinal tining on pilot project; pavement drainage fabric in lieu of asphalt drainage; implementing use of DARwin-ME™ on major projects.

SESSION 10: CONCRETE PAVEMENT DURABILITY SYMPOSIUM (PART I) Friday, 11 a.m.

Long-Life Low-Temperature Concrete Mixtures Using Moderate Dosages of Chemical Admixtures. Lynette A. Barna and Charles J. Korhonen

Combinations of chemical admixtures at moderate dosage levels have been successfully used in concrete formulations for low-temperature applications. The admixture combinations depressed the freezing point of the mix water, reduced the amount of water needed, and self-protected the concrete to an internal temperature of -5°C (23°F). No artificial heat was needed. The admixtures are available commercially, and the dosage rates used were within the manufacturer's recommendations. Eight candidate low-temperature concrete formulations containing moderate levels of admixture dosages were tested for freeze-thaw durability for air-entrained and non-air-entrained prisms in the laboratory following a standard test method. The laboratory results showed variability in the durability of the mixtures. Yet, the durability testing indicated that moderate dosages of chemical admixtures used in the concrete formulations was not harmful and may have a positive effect on durability, even without entrained air. Full-scale field demonstrations successfully used the low-temperature formulations. One field site, a bridge repair located in West Lebanon, New Hampshire, conducted a side-by-side comparison between a typical winter concrete mixture and a low-temperature mixture. This location has been exposed to freeze-thaw cycling for nearly decade. The condition of the low-temperature concrete shows minimal cracking and spalling compared to normal concrete. To further build on this intriguing finding, additional understanding is needed on adding moderate dosages of chemical admixtures to produce long life, high performance concrete mixtures for use in environments exposed to deicing chemicals and freeze-thaw cycling.

Effect of Joint-Cutting Method on the Durability of Concrete Pavements. John T. Kevern, Heather McLeod, and Feras El Ghussein

This paper presents ongoing results from an investigation into the early- and later-age impacts of saw-cutting methods on near-joint concrete. A Kansas Department of Transportation concrete paving project was selected that utilized primarily limestone coarse aggregate. Concrete slabs were instrumented

prior to early-entry and conventional saw cutting. The concrete was then allowed to cure in the field before samples were transferred to the lab for durability testing. Temperature of the concrete during placement and sawing procedures, relative humidity, saw temperature, air system, and concrete microstructure were used to correlate performance against a variety of traditional durability measures. The samples were evaluated in the lab for ASTM C457 air, freeze-thaw performance, deicer scaling, absorption, resistivity, permeability, and SEM microstructure. The concrete was placed September 16, 2011, and the durability testing is ongoing.

State of the Practice: Freeze-Thaw Durability. Matt Sheehan, CTLGroup, Inc.

Concrete used in pavements constructed in climatic conditions where freezing occurs must be resistant to physical degradation that can result due to cyclic freezing and thawing in a saturated state. In addition, application of chemical deicers in cold regions may not only exacerbate the physical degradation mechanism, but some deicers may also result in a form of chemical attack. The state of the practice to protect concrete against harsh winter conditions requires that durable aggregates be used with low permeability paste that includes an effective entrained air-void system. In some cases, sealants have been used to extend pavement life, but concrete mixture material properties typically have the greatest impact on durability and are established upon paving completion. Designing and constructing a durable concrete pavement thus requires concrete mixture testing to be conducted during the materials selection, mixture design, and construction phases to ensure that the constructed concrete pavement will provide decades of service by remaining resistant to damage from freezing and thawing. This presentation describes the freeze-thaw damage mechanism and provides the state of the practice to promote freeze-thaw durability of concrete pavements.

State of the Practice: Alkali-Silica Reactivity Prevention and Mitigation. Thanu Drimalas, University of Texas

This presentation describes the current practice for identifying potentially deleterious reactive aggregates and selecting appropriate measures. In the current practice, prescriptive and performance-based approaches are provided for the prevention of deleterious alkali-silica reaction in concrete. The prescriptive approach is based on levels of prevention based on the reactivity of the aggregate, exposure conditions, structure type, and the available alkalis in the system. Preventative measures include controlling the alkali content, using supplementary cementing materials, using lithium nitrate as an admixture, or a combination of these measures. The performance-based approach allows for conventional testing to determine the required mitigation needed to prevent expansion from deleterious aggregates. These approaches were recently adopted as a provisional practice by the American Association of State Highways and Transportation Officials.

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SESSION 11: CONCRETE PAVEMENT DURABILITY SYMPOSIUM (PART II) Friday, 1:30 p.m.

Joint Distress in Portland Cement Concrete Pavements.

Lawrence Sutter, Jan Olek, Jason Weiss, Nancy Whiting, and Peter Taylor

Over the past 7 to 10 years, there has been a steady increase in the level of materials-related distress reported in portland cement concrete pavements where the distress is concentrated at both the longitudinal and transverse joints. The distress tends to be occurring in wet-freeze climates, but not exclusively. In cooperation with industry and State highway agency stakeholders, research is ongoing to identify the cause of the distress and help identify design changes or mitigation strategies. The purpose of this presentation is to provide an update on this research and summarize what is known to date regarding this premature deterioration. Preliminary indications are that design, construction, and maintenance practices combined contribute to the distress.

State of the Practice: Joint Sawing and Sealing. Kurt D. Smith, Applied Pavement Technology, Inc.

The sawing of contraction joints in the construction of portland cement concrete (PCC) pavements is a critical construction element. The joint sawing creates a weakened plane that forces a crack to develop below the saw cut, which prevents random, or uncontrolled, cracking and helps accommodate slab movement in response to temperature and moisture changes.

This presentation summarizes the current practices employed by State highway agencies in the timely and effective sawing of contraction joints in PCC pavements. The importance of joint saw-cut timing and depth of sawing are described, along with the types of sawing equipment that are commonly used. The emergence of early-entry saw-cutting technology in PCC pavement construction is also briefly discussed. Finally, the current practices associated with sealing contraction joints are presented, including the adoption of nonsealed joints by a few agencies and the movement towards narrower contraction joints, a characteristic that minimizes wheel slap, allows for additional future widenings, and reduces the required quantity of joint sealant material.

State of the Practice: Deicer Damage Prevention. Peter C. Taylor, NCPTC

This presentation will discuss the effects that various deicing and anti-icing salts can have on concrete pavements and the mechanisms behind them. Recommendations will be made on how distress can be minimized in new and existing pavements.

POSTER PROGRAM IN THE EXHIBIT AREA

Highway Agency Practices and Future Directions

Representatives of State DOTs, members of NCC, report on their agency practices related to sustainability and on trends and changes they anticipate in the future.

Salt Frost Deterioration in Concrete Pavement—Causes and Mitigation. Andy Bennett, Michigan DOT

Designing Pavements for Long-Term Stability in Expansive Clays. Jeff Dean, Oklahoma DOT

Improvement Revisions to Specifications to Extend the Life of Concrete Pavements. Shannon Golden, Alabama DOT

Nebraska Department of Roads Evaluation of Statewide Aggregate Reactivity—Phase I. Lieska Halsey, Nebraska DOR

Indication of Chloride Permeability in Pavement Cores at Various Ages. Todd Hanson, Iowa DOT

Nebraska Department of Roads Evaluation of Statewide Aggregate Reactivity—Phase II. Wally Heyen, Nebraska DOR

Long-Life Concrete Pavement Applied to I-95 Corridor in Philadelphia, PA. Steven Koser, Pennsylvania DOT

Sustainability of Concrete Pavement: I-225—Mississippi to 6th Avenue. Patrick Kropp, Colorado DOT

Evaluation of Alternative Dowel Bar Materials and Coatings. Craig Landefeld, Ohio DOT

Long-Lasting Concrete Repair: Maximizing UDOT's Investment. Bryan Lee, Utah DOT

Recycling of Iowa Pavements. Kevin Merryman, Iowa DOT

Determining CoTE for Concrete. Andy Naranjo, Texas DOT

Long-Life Concrete Pavement. James Page, Georgia DOT

Caltrans Experience With Ternary Mix for Long-Performing Concrete. Mehdi Parvini, California DOT

Preserving the Long-Life Concrete Pavement Network of the Washington State Department of Transportation. Mark Russell, Washington State DOT

Tie Bar Inspections Using Ground-Penetrating Radar. Jason Smith, South Dakota DOT

Academia Posters

Characterizing Recycled Concrete Fines for Re-Use. N. Dufalla, D. Janssen, and J. Vandenbossche, University of Pittsburgh

Revised Bonded Whitetopping Design Procedure. Z. Li, J. Vandenbossche, and N. Dufalla, University of Pittsburgh