Year	Title	Author(s)
2009	Effect of Design and Site Factors on Fatigue Cracking of New Flexible Pavements in the LTPP SPS-1 Experiment	Haider, Syed Waqar; Chatti, Karim
2007	Performance of Drained and Undrained Rigid Pavements in Long-Term Pavement Performance SPS-2 Experiment	Hall, Kathleen Theresa; Crovetti, James A.
2007	Performance of Drained and Undrained Flexible Pavements in Long-Term Pavement Performance SPS-1 Experiment	Hall, Kathleen Theresa; Crovetti, James A.
2007	Statistical Analysis of In-Service Pavement Performance Data for LTPP SPS-1 and SPS-2 Experiments	Haider, Syed Waqar; Chatti, Karim; Buch, Neeraj; Lyles, Richard W; Pulipaka, Aswani S; Gilliland, Dennis
2007	Effect of Design and Site Factors on the Long-Term Performance of Flexible Pavements	Haider, Syed Waqar; Chatti, Karim; Buch, Neeraj; Lyles, Richard W; Pulipaka, Aswani S; Gilliland, Dennis
2007	Evaluation of Pavement Performance on DEL 23	Sargand, Shad M.
2007	Effects of Subsurface Drainage on Pavement Performance: Analysis of the SPS-1 and SPS-2 Field Sections	Hall, Kathleen Theresa; Crovetti, James A.
2006	Effect of Design and Site Factors on Long-Term Performance of Flexible Pavements in SPS-1 Experiment	Chatti, Karim
2006	Effects of Base Type on Modeling of Long-Term Pavement Performance Continuously Reinforced Concrete Sections	Johnston, Daniel P; Surdahl, Roger W.
2006	Effects of Design and Site Factors on Roughness of Flexible Pavements in the LTPP SPS-1 Experiment	Haider, Syed Waqar; Chatti, Karim
2006	Evaluation of Pavement Slab Rocking and Pumping with Elevation Profile Data	Byrum, Christopher Ronald
2006	Implementation of Proven PCCP Practices in Colorado	Ardani, Ahmad
2006	Long-Term Pavement Performance Maintenance and Rehabilitation Data Collection Guide	Simpson, Amy L; Thompson, Travis
2006	Network-Level Evaluation of Specific Pavement Study-2 Experiment: Using a Long-Term Pavement Performance Database	Buch, Neeraj, et al
2006	Truck/Pavement/Economic Modeling and In-	Sargand, Shad M; Wu,

	Situ Field Test Data Analysis Applications - Volume 1: Influence of Drainage on Selection of Base	Shin; Figueroa, J. Ludwig
2005	LTPP Data Analysis: Influence of Design and Construction Features on the Response and Performance of New Flexible and Rigid Pavements	Chatti, K., et al
2005	Performance of SPS-1 Project in Kansas	Onyango, Mbaki, et al
2005	Performance of SPS-2 Project in Kansas	Khanum, Taslima, et al
2005	Structural Factors of Jointed Plain Concrete Pavements: SPS-2--Initial Evaluation and Analysis	Jiang, Y. Jane; Darter, Michael I.
2004	Accelerated Testing of Ohio SHRP Sections 390101, 390102, 390105, and 390107	Sargand, S.M; Edwards, W.
2004	Defining the Attributes of Good In-Service Portland Cement Concrete Pavements	
2004	Effects of Base Type on the Performance of Jointed Plain Concrete Pavements	ERES Consultants
2004	Factors Affecting Rigid Pavement Performance: Evaluation of the LTPP SPS-2 Experiment	Jiang, Y; Darter, M. I.
2003	Evaluation of Joint and Crack Load Transfer Final Report	Khazanovich, L; Gotlif, A.
2003	An Evaluation of LTPP SPS-2 Sections in Michigan	Vongchusiri, K; Buch, N; Desaraju, P; Salama, H.
2003	Structural Factors for Flexible Pavements--Initial Evaluation of the SPS-1 Experiment	Von Quintus, H. L; Simpson, A. L.
2002	Effects of Various Design Features on Rigid Airfield Pavement Design	Lee, Y-H; Yen, S-T.
2002	Pavement Smoothness Specifications for LTPP WIM Locations	Rada, G. R; Karamihas, S; Perera, R.
2002	Site Characterization of LTPP SPS WIM Sites	Ostrom, B. K.
2002	Summary of CRCP Long-Term Performance	Tawfiq, K.
2001	Characterization of Mechanical Properties and Variability of PCC Materials for Rigid Pavement Design	Mallela, J; Titus-Glover, L; Ayers, M E; Wilson, T. P.
2000	Asphalt Overlay Cost-Effectiveness: Manitoba TBS and Minnesota SPS-5 Projects 10-Year Ranking of Treatments (1989-1999)	Worel, Benjamin; Gilbertson, C; Watson, D; Skok, G; Wilson, T.
2000	Early Evaluation of LTPP Specific Pavement Studies - 2 in Colorado	Suthahar, N; Ardani, A; Morain, D.
2000	Early Evaluation of Long-Term Pavement Performance Specific Pavement Studies-2, Colorado (TRB)	Suthahar, N; Ardani, A; Morian, D. A.
2000	Evaluation of Concrete Pavement Conditions	Jiang, Y. J; Tayabji, S. D.

	and Design Features Using LTPP FWD Deflection Data	
2000	It's 10 O'Clock: Do You Know Where Your Sensors Are?	Stubstad, R. N., et al
2000	LTPP Data Analysis: Relative Performance of Jointed Plain Concrete Pavement with Sealed and Unsealed Joints	Hall, K. T; Crovetti, J. A.
2000	LTPP Findings Pay Off for Pennsylvania	
2000	Preliminary Evaluation and Analysis of LTPP Faulting Data - Final Report	Selezneva, O; Jiang, J; Tayabji, S. D.
1999	Common Characteristics of Good and Poorly Performing AC Pavements	Rauhut, J. B; Eltahan, A; Simpson, A. L.
1999	International Roughness Index of Asphalt Concrete Overlays: Analysis of Data from Long-Term Pavement Performance Program SPS-5 Projects	Perera, R. W; Kohn, S. D.
1999	Preliminary Evaluation of LTPP Continuously Reinforced Concrete (CRC) Pavement Test Sections	Tayabji, S. D; Selezneva, O; Jiang, Y. J.
1998	Common Characteristics of Good and Poorly Performing PCC Pavements	Khazanovich, L; Darter, M; Bartlett, R; McPeak, T.
1998	Design and Construction of PCC Pavements, Volume I: Summary of Design Features and Construction Practices that Influence Performance of Pavements	Owusu-Antwi, E. B; Titus-Glover, L; Darter, M. I.
1998	Design and Construction of PCC Pavements, Volume II: Design Features and Practices that Influence Performance of Pavements	Titus-Glover, L; Owusu-Antwi, E. B; Hoener, T; Darter, M. I.
1998	Reducing Roughness in Rehabilitated Asphalt Concrete (AC) Pavements	
1998	What Makes Portland Cement Concrete (PCC) Pavements Rough?	
1997	Demonstration and Evaluation of Superpave Technologies. Construction Report for Route 2	Rodrigues, N; Larsen, D. A.
1997	Roughness Characteristics of GPS Flexible Pavements in the LTPP Program	Perera, R. W; Byrum, C; Kohn, S. D; Richter, C. A.
1995	Experience with Superpave Mixtures - Update on Constructed FHWA/LTPP SPS-9 Project (with Discussion)	Johnson, A. M; Skok, E. L.
1994	Early Analyses of LTPP General Pavement Studies Data. Executive Summary	Rauhut, J. B; Darter, M. I.
1994	Early Analyses of Long-Term Pavement Performance General Pavement Studies Data: Lessons Learned and Recommendations for Future Analyses	Rauhut, J. B; Simpson, A. L; Daleiden, J F; Darter, M. I; Owusu-Antwi, E; Pendleton, O. J.
1994	Early Field Experience with SuperPave	Cominsky, R. J; Harrigan,

		E. T.
1994	Ground Penetrating Radar Surveys to Characterize Pavement Layer Thickness Variations at GPS Sites	Maser, K.
1993	Construction of LTPP SPS-1 Test Sections	
1993	Construction of LTPP SPS-2 Test Sections	
1990	Factors for Flexible Pavement	
1990	Specific Pavement Studies: Experimental Design and Participation Requirements	
1990	Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-1: Strategic Study of Structural Factors for Flexible Pavements	
1990	Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-2: Strategic Study of Structural Factors for Rigid Pavements	
1990	Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-7: Bonded Portland Cement Concrete Overlays	
1990	Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-2: Strategic Study of Structural Factors for Rigid Pavements	
1990	Specific Pavement Studies Construction Guidelines for Experiment SPS-5: Rehabilitation of Asphalt Concrete Pavements	
1990	Specific Pavement Studies Construction Guidelines for Experiment SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements	
1990	Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-7: Bonded Portland Cement Concrete Overlays	
1990	Validation in the SHRP Asphalt Research Program (October, 1991)	
1989	Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements	
1989	Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-5: Rehabilitation of Asphalt Concrete Pavements	

1989	Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements	

Title: Effects of Subsurface Drainage on Pavement Performance: Analysis of the SPS-1 and SPS-2 Field Sections

Author(s): Hall, Kathleen Theresa; Crovetti, James A.

Date: 2007

Publisher: Transportation Research Board

Abstract/Synopsis:
This report evaluates the effects of subsurface drainage features on pavement performance through a program of inspection and testing of the subsurface drainage features present in the Long-Term Pavement Performance (LTPP) SPS-1 and SPS-2 field sections. The report will be of particular interest to engineers in the public and private sectors with responsibility for the design, construction, and rehabilitation of highway pavements.

Application/Use: The results from this project are applicable to engineers responsible for pavement design, construction, and rehabilitation.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: A better understanding of the effects of subsurface drainage on pavement performance is significant in pavement engineering. This study is a useful tool for designers and construction quality control engineers considering preserving pavement life by providing drainage accommodations in their pavement designs. Furthermore, this knowledge is beneficial to pavement designers as they incorporate adequate drainage in their rehabilitation projects to better protect their roads. The LTPP database was utilized to better understand the relationship between subsurface drainage and pavement performance.

Future Benefit: As pavement design continues to move toward a mechanistic-empirical design method, the LTPP database will help lead to a better understanding of the dominant factors affecting pavement performance. As these factors are considered, pavement engineers will be better equipped to be more effective in their use of limited funds to maintain and improve their pavement network. Thus, with this knowledge, a significant cost savings can be achieved, allowing agencies to better allocate their funds over their pavement network.

Title: Evaluation of Pavement Performance on DEL 23

Author(s): Sargand, Shad M.

Date: March 2007

Publisher: Ohio University, Athens; Ohio Department of Transportation; Federal Highway Administration

Abstract/Synopsis:
In 1994, a ramp containing two Asphalt Concrete (AC) and two portland cement concrete (PCC) sections in the SPS-8 experiment was constructed on the Ohio Strategic Highway Research Program (SHRP) Test Road. In 1996, 36 more sections in the SPS-1, SPS-2 and SPS-9 experiments were opened to traffic on the mainline pavement. The response and performance of these sections, climatic information from an on-site weather station, subsurface environmental conditions from sensors installed in several test sections, and traffic loading from an on-site weigh-in-motion (WIM) system have been monitored and incorporated into the national LTPP database. Analyses of these data have been published in a number of reports, technical papers and bulletins. The research project documented in this report was the latest effort by Ohio Department of Transportation (ODOT) to continue monitoring the response and performance of many of the original 40 test sections and several sections constructed later to replace the lighter designs which, as anticipated, showed early distress. Data in this report cover the years 2000-2005. In addition to the new response and performance data obtained on the test road, this report includes: an analysis of current methodologies to mathematically model AC and PCC pavement structures, a petrographic analysis of concrete from three different PCC pavement mixes and a lean concrete base, and an in-depth analysis of WIM data. Three other experimental pavements have been constructed on ATH 50, LOG 33 and ERI/LOR 2 to evaluate the response and performance of specific parameters of interest to ODOT. These parameters included: high performance concrete containing ground granulated blast furnace slag and different types of dowel bars on ATH 50, different types of base material under flexible pavement on LOG 33, and different types of base material under rigid pavement on ERI/LOR 2. This report also contains data collected on these three pavements during 2000-2005.

Application/Use: The results from this report are applicable to pavement research engineers in obtaining a better understanding of pavement performance.

Contribution: Improvement in Knowledge; Lessons Learned

Present Benefit: The LTPP program was developed to better understand pavement behavior and performance so that cost-effective solutions could be developed for maintaining and building highways. The results from this research are beneficial to obtaining a better understanding of pavement behavior. This project utilized the pavement test sections from the LTPP program and provides collected data for 5 years from these test-sections.

Future Benefit: The results from this type of study, and from the LTPP program as a whole, will be the foundation for further advancements in the pavement industry. The data collected through the LTPP program is an invaluable resource for pavement engineers and is essential to cost-effectively design, construct, and maintain pavement systems.

Title: Effect of Design and Site Factors on the Long-Term Performance of Flexible Pavements

Author(s): Haider, Syed Waqar; Chatti, Karim; Buch, Neeraj; Lyles, Richard W; Pulipaka, Aswani S; Gilliland, Dennis

Date: 2007

Publisher: American Society of Civil Engineers

Abstract/Synopsis:
Results are presented from a study to evaluate the relative influence of design and site factors on the performance of in-service flexible pavements. The data are from the SPS-1 experiment of the Long-Term Pavement Performance program. This experiment was designed to investigate the effects of HMA surface layer thickness, base type, base thickness, and drainage on the performance of new flexible pavements constructed in different site conditions (subgrade type and climate). Base type was found to be the most critical design factor affecting fatigue cracking, roughness (IRI), and longitudinal cracking (wheel path). The best performance was shown by pavement sections with asphalt treated bases (ATB). This effect should be interpreted in light of the fact that an ATB effectively means a thicker HMA layer. Drainage and base type, when combined, also play an important role in improving performance, especially in terms of fatigue and longitudinal cracking. Base thickness has only secondary effects on performance, mainly in the case of roughness and rutting. In addition, climatic conditions were found to have a significant effect on flexible pavement performance. Wheel path longitudinal cracking and transverse cracking seem to be associated with a wet-freeze environment, while nonwheel path longitudinal cracking seems to be dominant in a freeze climate. In general, pavements built on fine-grained soils have shown the worst performance, especially in terms of roughness. Although most of the findings from this study support the existing understanding of pavement performance, they also provide an overview of the interactions between design and site factors and new insights for achieving better long-term pavement performance.

Application/Use: This study is used by those interested in the contribution of design factors on flexible pavement performance.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: The present benefit for this study is an understanding in the interaction between design parameters and climate and the resultant changes in pavement performance. The LTPP database provides a means of conducting this type of study on a national scale.

Future Benefit: The findings from this study will be useful in transferring mechanistic evaluations to field performance for various design parameters. The LTPP database will continue to be an essential resource to better understand pavement behavior under various

site conditions, and will continue to lead to further advancements in the pavement industry.

Title: Statistical Analysis of In-Service Pavement Performance Data for LTPP SPS-1 and SPS-2 Experiments

Author(s): Haider, Syed Waqar; Chatti, Karim; Buch, Neeraj; Lyles, Richard W; Pulipaka, Aswani S; Gilliland, Dennis

Date: June 2007

Publisher: American Society of Civil Engineers

Abstract/Synopsis:
Observational or experimental studies are designed to investigate the effects of various factors on a response variable. This distinction is important because the latter studies are assumed to provide a firmer basis for establishing cause-and-effect relationships. However, experimental studies involving in-service pavement sections present certain concerns in statistical analyses, which are addressed in this paper. The challenges presented by the in-service pavements data included: (1) outlier issues; (2) quantification of performance; and (3) the lack of measurable distresses due to the "young" age of test sections. Experiment-related issues included: (1) wide variation in traffic levels and ages among the test sites and (2) an unbalanced distribution of test sites among climatic zones and subgrade types. The importance of selecting appropriate analytical methods for obtaining reliable results is discussed in this paper. Though most of the methods that were applied for the analyses are well established, the choice of magnitude—versus frequency-based methods was driven by the extent and occurrence of distresses. Based on the data, frequency-based methods such as linear discriminate analysis and binary logistic regression lend themselves well to explaining trends associated with distresses with reasonable occurrence but lower magnitude while a magnitude-based method like analysis of variance is more appropriate for evaluating distresses with high numbers of occurrence and magnitude.

Application/Use: The results from this paper are applicable to pavement research engineers.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: This paper is beneficial to pavement research engineers by explaining the use of statistical models and their effectiveness in these LTPP sections. The LTPP database has contributed to many advancements in the pavement industry, therefore evaluating and identifying potential challenges within the experiment sections is greatly beneficial.

Future Benefit: The LTPP program will continue to be a foundational tool for evaluating pavement performance and improving existing methods in designing, constructing, and analyzing pavements. As challenges are identified in the LTPP program, opportunities to improve data analysis methods can be investigated and lead to better understanding of cost-effective solutions to develop higher performing pavements.

Title: Performance of Drained and Undrained Flexible Pavements in Long-Term Pavement Performance SPS-1 Experiment

Author(s): Hall, Kathleen Theresa; Crovetti, James A.

Date: 2007

Publisher: Transportation Research Board 86th Annual Meeting

Abstract/Synopsis:
Drainage is the experimental factor about which conclusions from the SPS-1 experiments are most difficult to draw. This is because two experimental factors, base type and subdrainage, are confounded in the experiment. This paper describes the findings from NCHRP Project 1-34D, in which data from the LTPP SPS-1 (flexible) pavement design experiment were used to assess whether pavements with subsurface drainage systems (permeable base, collectors, and outlets) performed differently from pavements without subsurface drainage systems. The data analyzed included IRI, rutting, cracking, and deflection data from the LTPP database, as well as drainage system flow time measurements obtained from field testing. Long-term IRI values for the SPS-1 flexible pavements were found to be more strongly correlated to initial IRI values than to all of the SPS-1 experimental factors combined. The next most influential factors were found to be age, backcalculated equivalent thickness of the pavement structure, Thornthwaite moisture index, and average annual precipitation. The base type/drainage factors showed very little correlation to long-term IRI values. Rutting levels were similar for all of the base type/drainage combinations, except that the undrained aggregate base group had a higher percentage of sections with unusually high rutting at an early age. Base stiffness, rather than drainage, is concluded to be the aspect of the base type/drainage experimental factor that is responsible for whatever role this factor has played in the development of rutting in the SPS-1 test sections. About half of the SPS-1 test sections in each base type/drainage group have not yet developed any cracking. Among those that have, the weaker pavement sections (undrained AGG base and drained PATB) have more cracking than the stronger pavement sections (undrained ATB, undrained ATB over aggregate, and drained ATB over PATB). Whatever minor effect the base type/drainage factor has had on cracking in the SPS-1 pavement sections to date is concluded to be due to differences in base stiffness rather than differences in drainage.

Application/Use: The results from this paper are applicable to pavement engineers considering the effects of drainage on pavement performance.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: A better understanding of the effects of drainage on pavement performance is beneficial to pavement managers. The results from this paper can assist pavement engineers in determining if providing adequate drainage will improve the overall pavement performance. The LTPP database, and specifically the SPS-1

experiment, was used in this paper to determine the impact of drainage on pavement performance.

Future Benefit: As pavement design moves toward a mechanistic-empirical design method, the LTPP database will lead to a better understanding of the dominant factors affecting pavement performance. As these factors are considered, pavement engineers will be better equipped to be more effective in their use of limited funds to maintain and improve their pavement network. Thus, with this knowledge, a significant cost savings can be achieved, allowing state agencies to better allocate their funds over their pavement network.

Title: Performance of Drained and Undrained Rigid Pavements in Long-Term Pavement Performance SPS-2 Experiment

Author(s): Hall, Kathleen Theresa; Crovetti, James A.

Date: 2007

Publisher: Transportation Research Board 86th Annual Meeting

Abstract/Synopsis:
Drainage is the experimental factor about which conclusions from the SPS-2 experiments are most difficult to draw. This is because two experimental factors, base type and subdrainage, are confounded in the experiment. This paper describes the findings from NCHRP Project 1-34D, in which data from the LTPP SPS-2 (rigid) pavement design experiment were used to assess whether pavements with subsurface drainage systems (permeable base, collectors, and outlets) performed differently from pavements without subsurface drainage systems. The data analyzed included IRI, faulting, cracking, and deflection data from the LTPP database, as well as drainage system flow time measurements obtained from field testing. Whatever effect the base type/drainage factor has had on the SPS-2 pavement sections' latest observed IRI values and rates of change in IRI over time is concluded to be due predominantly to differences in base stiffness. The potential effect of drainage is not necessarily ruled out, but no particular evidence was detected for the role of drainage, independent of the role of base stiffness, in the development of roughness in the SPS-2 pavements. Whatever effect the base type/drainage factor has had on the development of faulting in pavements in the SPS-2 experiment has been due to the stiffness of these bases compared to the lesser stiffness of the undrained dense-graded aggregate base. This conclusion is reinforced by the observation that the undowelled pavements with aggregate base developed more than twice as much faulting as undowelled pavements with drained or undrained stabilized bases, even those at the same sites. The stiffest base type in the SPS-2 experiment, lean concrete base, may have been good for performance in terms of roughness and faulting, but it had a pronounced detrimental effect on cracking performance, particularly in the thinner concrete slabs in the experiment. Sections with the weakest base type, undrained aggregate base, also had more cracking than sections with drained permeable asphalt-treated base. On the other hand, sections with undrained HMAC and CAM bases had even less cracking than sections with drained PATB. The above findings suggest that the differences in cracking observed to date are due not to drainage differences but differences in base stiffness.

Application/Use: The results from this paper are applicable to pavement engineers considering the effects of drainage on pavement performance.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: A better understanding of the effects of drainage on pavement performance is beneficial to pavement managers. The results from this paper can assist

pavement engineers in determining if providing adequate drainage will improve the overall pavement performance. The LTPP database, and specifically the SPS-2 experiment, was used in this paper to determine the impact of drainage on pavement performance.

Future Benefit: As pavement design continues to move toward a mechanistic-empirical design method, the LTPP database will continue to lead to a better understanding of the dominant factors affecting pavement performance. As these factors are considered, pavement engineers will be better equipped to be more effective in their use of limited funds to maintain and improve their pavement network. Thus, with this knowledge, a significant cost savings can be achieved, allowing agencies to better allocate their funds over their pavement network.

Title: Effect of Design and Site Factors on Fatigue Cracking of New Flexible Pavements in the LTPP SPS-1 Experiment

Author(s): Haider, Syed Waqar; Chatti, Karim

Date: 2009

Publisher: International Journal of Pavement Engineering Vol. 10 No. 2, Taylor & Francis Limited

Abstract/Synopsis:
This paper presents the results of a study on the relative influence of design features and site factors on the fatigue performance of in-service flexible pavements. The data used in this study were from the SPS-1 experiment of the long-term performance pavement (LTPP) program. This experiment was designed to investigate the effects of hot mix asphalt (HMA) surface layer thickness, base type, base thickness and drainage on the performance of new flexible pavements constructed in different site conditions (subgrade type and climate). Various statistical analyses (ANOVA, logistic regression, discriminant analysis) were adopted for data analyses. Among the design factors, base type was found to be the most critical factor affecting fatigue cracking. The best performance was shown by pavement sections with asphalt treated base (ATB). This effect should be interpreted in light of the fact that an ATB effectively means a thicker HMA layer. The combination of drainage and base type also played an important role in improving fatigue performance. Base thickness had a negligible effect while climatic conditions were found to have a significant effect with more fatigue-cracking occurrence in wet-freeze environment. Also, in general, pavements built on fine-grained soils showed the worst performance. Most of the findings from this study support the existing understanding of pavement fatigue performance. Yet, the analyses of data from in-service pavements in this study provide an overview of the interactions between design and site factors and provide new insights on various design options to achieve better long-term pavement performance.

Application/Use: This report can be used by pavement managers and pavement designers as they consider the site condition effects on pavement.

Contribution: Improvement in Knowledge

Present Benefit: The LTPP data was used as the basis of this study, which can assist pavement designers in determining the controlling design factors for new asphalt pavements and to accommodate for them in their design.

Future Benefit: This project will provide future benefit as it relates to new asphalt pavement construction by showing the controlling factors for pavement design, as it relates to structural thicknesses and site conditions. The SPS-1 experiment is still active and additional performance measurements over time will provide even better insights in the years to come.

Title: Effect of Design and Site Factors on Long-Term Performance of Flexible Pavements in SPS-1 Experiment

Author(s): Chatti, Karim

Date: 2006

Publisher: Transportation Research Board

Conference Title: Transportation Research Board 85th Annual Meeting

Abstract/Synopsis: Results are presented from a study to evaluate the relative influence of design and site factors on the performance of in-service flexible pavements. The data are from the SPS-1 experiment of the Long-Term Performance Pavement (LTPP) program. This experiment was designed to investigate the effects of HMA surface layer thickness, base type, base thickness, and drainage on the performance of new flexible pavements constructed in different site conditions (subgrade type and climate). Base type was found to be the most critical design factor affecting fatigue cracking, roughness (IRI), and longitudinal cracking (wheel path). The best performance was shown by pavement sections with asphalt treated bases (ATB). This effect should be interpreted in light of the fact that an ATB effectively means a thicker HMA layer. Drainage and base type, when combined, also play an important role in improving performance, especially in terms of fatigue and longitudinal cracking. Base thickness has only secondary effects on performance, mainly in the case of roughness and rutting. In addition, climatic conditions were found to have a significant effect on flexible pavement performance. Longitudinal cracking (wheel path) and transverse cracking seem to be associated with a wet-freeze environment, while longitudinal cracking (non-wheel path) seems to be dominant in a freeze climate. In general, pavements built on fine-grained soils have shown the worst performance, especially in terms of roughness. Although most of the findings from this study support the existing understanding of pavement performance, they also provide an overview of the interactions between design and site factors and new insights for achieving better long-term pavement performance.

Application/Use: This study is used by those interested in the contribution of design factors on flexible pavement performance.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The present benefit for this study is an understanding in the interaction between design parameters and climate and the resultant changes in pavement performance. The LTPP database provides a means of conducting this type of study on a national scale.

Future Benefit: The findings from this study will be useful in transferring mechanistic evaluations to field performance for various design parameters.

Title: Effects of Base Type on Modeling of Long-Term Pavement Performance Continuously Reinforced Concrete Sections

Author(s): Johnston, Daniel P; Surdahl, Roger W.

Date: 2006

Publisher: Transportation Research Board

Conference Title: Transportation Research Board 85th Annual Meeting

Abstract/Synopsis: Newer continuously reinforced concrete (CRC) pavements in South Dakota have exhibited undesirable levels of transverse cracking. This poor performance was not expected under the current recommended design practices. Long Term Pavement Performance (LTPP) CRC pavement data, previously analyzed by others, also could not account for the cracking. To seek an explanation the original LTPP CRC data was reanalyzed using a more thorough approach. Using multiple regression techniques on selected LTPP CRC data sets of comparable accuracy, consequential conclusions can be drawn once the base types are separated into subsets in the database. A similar model was developed for newer CRC pavements in South Dakota and showed the same response variables as the LTPP subset for granular bases. Significant correlation was found between cracks and steel depth, cracks and steel size, and cracks and pavement thickness, such that recommendations are made for South Dakota to decrease the steel depth and decrease the steel size and percentage. The nominal top size of the coarse aggregate was also found to be a significant contributor to crack width with a shift from ¾ inch to 1-1/2 inches resulting in a reduction in crack width and a much slower development of cracking over time.

Application/Use: The study has been used by South Dakota Department of Transportation to evaluate current and future CRCP specifications.

Contribution: Cost savings; Improvement in Knowledge.

Present Benefit: The materials and inventory data in the LTPP database along with performance monitoring provided the information required to evaluate CRCP in South Dakota. Determining factors that can improve performance is beneficial to the state highway agency as well as the traveling public.

Future Benefit: The findings from this study will be used to guide future work and specification changes in South Dakota. The LTPP database will continue to afford studies such as this to be conducted as long as the data remains accessible.

Title: Effects of Design and Site Factors on Roughness of Flexible Pavements in the LTPP SPS-1 Experiment

Author(s): Haider, Syed Waqar; Chatti, Karim

Date: 2006

Publisher: American Society of Civil Engineers

Conference Title: Airfield and Highway Pavements. Proceedings of the 2006 Airfield and Highway Pavement Specialty Conference

Abstract/Synopsis: Although considerable mechanic-empirical research exists on the factors affecting flexible pavement roughness, it is limited in scope because of inadequate field validation and the complex interactions of structural and site factors. This paper presents the results of a study on the relative influence of design and site factors on roughness of in-service flexible pavements. The data from the SPS-1 experiment of the LTPP program were used in this study to investigate the effects of hot mix asphalt (HMA) surface layer thickness, base type, base thickness, and drainage on roughness of flexible pavements constructed in different site conditions (subgrade type and climate). Since this is the first comprehensive study of SPS-1 experimental data, a thorough methodology involving mean comparisons and multivariate ANOVA was adopted for data analyses. Among the design factors, base type was found to have the most significant effect on roughness. The best performance was shown by pavement sections with asphalt-treated bases. Drainage, when combined with base type, also plays an important role in inhibiting roughness, while base thickness has only secondary effects. In addition, climatic conditions were found to have considerable influence. Pavement sections in the wet-freeze zone exhibited levels of roughness. Also, in general, pavements built on fine grained soils have shown the worst roughness levels. While most of the findings from this study support the existing understanding of factors affecting roughness, important interactions between design and site factors were identified and provide new insights for achieving better long-term pavement performance.

Application/Use: This study is used by those interested in the contribution of design factors on flexible pavement performance.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The present benefit for this study is an understanding in the interaction between design parameters and climate and the resultant changes in pavement performance. The LTPP database provides a means of conducting this type of study on a national scale.

Future Benefit: The findings from this study will be useful in comparing mechanistic evaluations to field performance for various design parameters.

Title: Evaluation of Pavement Slab Rocking and Pumping with Elevation Profile Data

Author(s): Byrum, Christopher Ronald

Date: 2006

Publisher: Transportation Research Board

Journal Title: Transportation Research Record: Journal of the Transportation Research Board No. 1947

Abstract/Synopsis: A method is presented for estimating the amount of slab rocking and the amount of earth moved beneath a jointed concrete pavement as a result of slab rocking. The estimates are obtained with data from non-contact rapidly traveling profilers that collect surface elevation profiles along roadways at normal driving speeds without lane closure or traffic control costs. With profile data from FHWA Long-Term Pavement Performance (LTPP) General Pavement Study 3 (GPS-3) test sites, examples are provided to show how the apparent slab rocking and pumping volumes develop over time for most GPS-3 test sections that have shown significant faulting. The calculated pumping volume rate per equivalent single-axle load (ESAL) is shown to be relatively constant over time at these LTPP test sites. A preliminary linear regression predictive model for pumping rate per ESAL as a function of pavement design parameters is provided based on the test group of faulting GPS-3 pavements. This study indicates that pumping rate can be reduced with thicker and longer slabs and thicker layers of erosion-resistant base and subbase overlying erosion-susceptible subgrades. Slab lengths less than 15 ft (4.57 m) long appear noticeably more susceptible to rocking and pumping. Sites with high pumping rates typically have a combination of unusually large slabs locked in upward curvature and erosion-susceptible cross-section designs.

Application/Use: This paper can be used by pavement engineers interested in mitigating pumping and faulting in JPCC pavements.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Understanding the effect of joint spacing and slab thickness on pumping and faulting can be extremely beneficial. Pumping and subsequent faulting can increase the roughness of the road significantly and will trigger maintenance activities. Mitigating or slowing this process can lead to significant cost savings. One of the largest contributions the LTPP program has made to the pavement community is a national database which supports countless research projects similar to this study that would not have been possible without LTPP.

Future Benefit: The LTPP database will continue to support studies similar to this as long as the database remains accessible.

Title: Implementation of Proven PCCP Practices in Colorado

Author(s): Ardani, Ahmad

Date: April 2006

Publisher: Colorado Department of Transportation

Abstract/Synopsis: This paper is an overview of the proven concrete pavement practices that the Colorado Department of Transportation (CDOT) has implemented over the last several years. These include implementation of the following practices:

1- **Implementation of Longitudinal Tining**: Nine test sections were constructed on I-70 near Denver, Colorado with varying textural characteristics. Texture depth, skid numbers at different speeds, and their noise properties were measured. Based on the finding of this research study CDOT adopted the longitudinal tining (uniformly spaced ¾ inch) as a preferred method of texturing concrete pavements in 1997. Longitudinally tined PCC pavement exhibits low noise levels and provides adequate friction.

2- **Implementation of the Wider Slab, SPS-2 Experiment Spin-Off Product:** This experiment dealt with various structural factors in concrete, one of which was the wider slab (14-ft slab). The results of this study revealed that 2 feet of widening was adequate. Structurally speaking, their contributions were found to be equivalent to 1 inch of slab thickness.

3- **Implementation of Single-Cut Joints, SPS-4 Experiment Spin-Off Product:** The results of this study revealed that the single cut (1/8" joints) were as effective as CDOT's standard double cut (3/8 joints). The only difference was that the narrower joints were less labor-intensive and required much less sealant material. Based on a cost-benefit analysis, a saving of 57 cents per linear foot of joint was realized, which equates to approximately 1.7 million dollars per 100 miles of 2-lane concrete pavement.

4- **Addressing Premature PCCP Longitudinal Cracking:** This experiment presents an evaluation of several Portland cement concrete pavements with premature longitudinal cracking. All of the locations discussed are in Region 1 of the Colorado Department of Transportation (CDOT). This study resulted in 2 new specifications: 1- Requiring the engineer to measure saw-cut depth at intervals of 1 per 1/10 of a mile (528 ft.). 2- Requiring paving contractors to equip their paving machines with vibrator monitoring devices.

Application/Use: This document is directly applicable to PCC pavement design in Colorado.

Contribution: Cost Savings, Implementation/Usage, Advancement in Technology.

Present Benefit: Two of the four benefits documented in the report are a direct result of the LTPP program. The results from the joint width study (based on SPS-4 data) equate to a significant cost savings ($1.7 million dollars per 200 lane-miles). Findings on the structural benefit of widened slabs also result in considerable cost savings.

Future Benefit: These are only two of the many findings based on LTPP data that have had a significant impact on pavement design. Additional savings will be realized as more states investigate the performance of their LTPP test sections and modify design policy based on local circumstances.

Title: Long-Term Pavement Performance Maintenance and Rehabilitation Data Collection Guide

Author(s): Simpson, Amy L; Thompson, Travis

Date: 2006

Publisher: MACTEC Engineering and Consulting, Incorporated; Federal Highway Administration

Abstract/Synopsis: This document provides guidelines and forms for documenting maintenance and rehabilitation treatments on test sections in the Long-Term Pavement Performance (LTPP) program and is an update to chapters 6 and 7 of the 1993 version of the "LTPP Data Collection Guide." The terms maintenance and rehabilitation are used within the LTPP program to classify how various treatments which alter a test section's structure are documented in the database. This is an important distinction, since classification of some of these treatments may differ from highway agency terminology. For example, thin overlays that some agencies may classify as maintenance are classified within the LTPP program as rehabilitation, since the data forms for overlays of any thickness are the same.

Application/Use: This is an excellent resource for those interested in the methodologies used in collecting LTPP maintenance and rehabilitation data.

Contribution: Improvement in Knowledge

Present Benefit: This document is beneficial as a reference providing information on the elements of LTPP maintenance and rehabilitation data. Understanding these elements is critical to properly analyze and evaluate the data. This will also provide insight on anomalous or potential outlier data points.

Future Benefit: Not only will this document assist LTPP data users in the future, it can also be used in laying the framework for data collection activities conducted at a state highway agency or local agency level.

Title: Network-Level Evaluation of Specific Pavement Study-2 Experiment: Using a Long-Term Pavement Performance Database

Author(s): Buch, Neeraj; Chatti, Karim; Haider, Syed Waqar; Pulipaka, Aswani S; Lyles, Richard W; Gilliland, Dennis

Date: 2006

Publisher: Transportation Research Board

Journal Title: Transportation Research Record: Journal of the Transportation Research Board No. 1947

Abstract/Synopsis: The research described here was conducted as a part of NCHRP Project 20-50 (10&16), LTPP (Long-Term Pavement Performance) Data Analysis: Influence of Design and Construction Features on the Response and Performance of New Flexible and Rigid Pavements. The relative effects of various design and site factors on the performance of jointed plain concrete (JPC) pavements are presented. The data used in this study were primarily drawn from Release 17 of DataPave. The Specific Pavement Study (SPS) 2 experiment was designed to investigate the effects of portland cement concrete (PCC) slab thickness, base type, drainage, PCC flexural strength, and slab width on the performance of JPC pavements. On the basis of the statistical analysis of 167 test sections, ranging in age from 5 to 12 years, it was concluded that base type was the most critical design factor affecting performance in terms of cracking and roughness as measured by the international roughness index. Pavement sections with a permeable asphalt-treated base and in-pavement drainage performed better than those with a dense-graded aggregate base or a lean concrete base.

Application/Use: The results from this study can be used by pavement engineers in evaluating the contribution of design features on pavement performance.

Contribution: Cost Savings, Improvement in Knowledge.

Present Benefit: The SPS-2 projects constructed and monitored as part of the LTPP program are extremely beneficial. At each site, at least 12 test sections, consisting of various base types, drainage, slab thicknesses, flexural strengths, and slab widths are located consecutively. This provides an opportunity to make direct comparisons between design features because other factors such as traffic, subgrade conditions, and climate are constant. These in-service pavements offer a wealth of knowledge that is not readily available elsewhere. Findings from this evaluation can be used to determine the cost-effectiveness of design features for specific applications. Efficient and proper pavement design can lead to significant cost savings.

Future Benefit: As the pavement community moves towards M-E PDG, the SPS-2 projects will play a vital role in the local calibration of the guide.

Title: Truck/Pavement/Economic Modeling and In-Situ Field Test Data Analysis Applications - Volume 1: Influence of Drainage on Selection of Base

Author(s): Sargand, Shad M; Wu, Shin; Figueroa, J. Ludwig

Date: 2006

Publisher: Ohio University, Athens; Ohio Department of Transportation; Federal Highway Administration

Abstract/Synopsis: The primary objective of this study was to investigate how base materials should be properly selected for specific types of pavement, not only considering the performance of individual layers but also how they interact in the total pavement structure. Base types considered in this study included granular (GB), lean concrete (LCB), asphalt treated (ATB), cement treated (CTB), and permeable asphalt treated (PATB) bases as constructed under both asphalt concrete (AC) and Portland cement concrete (PCC) pavements. The Long Term Pavement Performance (LTPP) Seasonal Monitor Program (SMP) sites investigated for this report included four SMP sections in the North Carolina SPS-2 experiment on US52 and thirteen SMP sections in the SPS-1 and SPS-2 experiments on the Ohio SHRP Test Road on US23. The NC site contained two GB and two LCB sections, and the OH site contained eight GB, one ATB, two PATB, and two LCB sections. The NC sites are located in a wet-no-freeze zone and OH sites are located in a wet-freeze zone. Environmental data were collected via seasonal monitors and time domain reflectometry. The effects of service were measured by conducting surface profiles and falling weight deflectometer (FWD) measurements. It was found that the type of base had little impact on subgrade moisture. The choice of base depends chiefly on three requirements: appropriate stiffness, sufficient permeability, and good constructability. Guidelines for the selection of base under flexible and rigid pavements are given.

Application/Use: This study will be used by those interested in the effect of base type on subgrade moisture and pavement performance.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The proper material selection and pavement design are critical to a well performing and efficient pavement section. This study provides information that is beneficial to designers.

Future Benefit: As pavement design moves towards the M-E PDG, understanding the effect of base type on moisture content will be necessary to estimate the strength of subgrade materials.

Title: LTPP Data Analysis: Influence of Design and Construction Features on the Response and Performance of New Flexible and Rigid Pavements

Author(s): Chatti, K; Buch, N; Haider, S. W; Pulipaka, A. S; Lyles, R. W; Gilliland, D; Desaraju, P.

Date: 2005

Publisher: National Cooperative Highway Research Program

Journal Title NCHRP Web Document No. 74

Abstract/Synopsis: This report documents and presents the results of a study on the relative influence of design and construction features on the response and performance of new flexible and rigid pavements, included in SPS-1 and SPS-2 experiments. The SPS-1 experiment is designed to investigate the effects of hot mix asphalt (HMA) layer thickness, base type, base thickness, and drainage on flexible pavement performance, while the SPS-2 experiment is aimed at studying the effect of portland cement concrete (PCC) slab thickness, base type, PCC flexural strength, drainage, and lane width on rigid pavement performance. The effects of environmental factors, in absence of heavy traffic, were also studied based on data from the SPS-8 experiment. Various statistical methods were employed for analyses of the LTPP NIMS data (Release 17 of DataPave) for the experiments. In summary, base type seems to be the most critical design factor in achieving various levels of pavement performance for both flexible and rigid pavements, especially when provided with in-pavement drainage. The other design factors are also important, though not at the same level as base type. Subgrade soil type and climate also have considerable effects on the influence of the design factors. Although most of the findings from this study support the existing understanding of pavement performance, the methodology in this study provides a systematic outline of the interactions between design and site factors as well as new insights on various design options.

Application/Use: This study can be used by those interested in the contribution of design factors on flexible and rigid pavement performance.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The present benefit for this study is an understanding in the interaction between design parameters and climate and the resultant changes in pavement performance. The LTPP database provides a means of conducting this type of study on a national scale. Findings can be used to optimize cost-effective design alternatives.

Future Benefit: The findings from this study will be useful in transferring mechanistic evaluations to field performance for various design parameters.

Title: Performance of SPS-1 Project in Kansas

Author(s): Onyango, Mbaki; Hossain, Mustaque; Bethu, Sagar; Gisi, Andrew J.; Romanoschi, Stefan A.

Date: 2005

Publisher: Iowa State University, Ames

Conference Title: Proceedings of the 2005 Mid-Continent Transportation Research Symposium

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) SPS-1 experiment entitled “Strategic Study of Structural Factors for Flexible Pavements” was developed to determine and evaluate the factors affecting the performance of flexible pavements. The experimental design was aimed at determining

Title: Performance of SPS-2 Project in Kansas

Author(s): Khanum, Taslima; Hossain, Mustaque; Gisi, Andrew J.

Date: 2005

Publisher: Iowa State University, Ames

Conference Title: Proceedings of the 2005 Mid-Continent Transportation Research Symposium

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) SPS-2 experiment was designed to study structural factors, such as drainage, base type, concrete strength and thickness, and lane width, of rigid pavements. The SPS-2 experiment section in Kansas, constructed in 1992, is a jointed doweled plain concrete pavement. The experiment consisted of twelve standard SPS-2 sections and one Kansas DOT control section. These sections have been monitored by the LTPP program since construction. Performance monitoring included measurements for ride quality (International Roughness Index [IRI]), faulting, cracking, and surface deflections. Performance parameters analyzed in this study included IRI, faulting, cracking (combined longitudinal and transverse crack lengths), and joint load transfer efficiency. The results show that the project has performed very well to date. Most sections are smooth and crack-free, with negligible faulting. The load transfer efficiency of the sections has been good too. The drainable sections with a permeable asphalt-treated base have performed the best. These sections were built smoother and remained so after 12 years of service. The section with low PCC slab thickness (8 inches) and low concrete design strength (550 psi) on a dense graded aggregate base has performed the worst. The combination of high slab thickness and high concrete strength tends to mask the effect of the base on pavement performance. The Kansas DOT control section with a thick slab (12 inches) over a dense graded portland cement treated base has also performed very well.

Application/Use: The findings are directly applicable to pavement engineers in Kansas designing rigid pavements.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Understanding the contribution of design features on rigid pavement performance can lead to cost savings and improved performance through optimized design.

Future Benefit: The performance of SPS-2 projects will be particularly useful in validating and calibrating the M-E PDG.

Title: Structural Factors of Jointed Plain Concrete Pavements: SPS-2--Initial Evaluation and Analysis

Author(s): Jiang, Y. Jane; Darter, Michael I.

Date: 2005

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Abstract/Synopsis: The SPS-2 experiment, "Strategic Study of Structural Factors for Jointed Plain Concrete Pavements (JPCP)," is one of the key components of the Long Term Pavement Performance (LTPP) program. The main objective of this experiment is to determine the relative influence and long-term effectiveness of JPCP design features (including slab thickness, portland cement concrete flexural strength, base type and drainage, and slab width) and site conditions (traffic, subgrade type, climate) on performance. This report documents the first comprehensive review and evaluation of the SPS-2 experiment. Thirteen SPS-2 projects have been constructed with one additional site under construction. At each site, there are 12 core sections plus various numbers of supplemental sections. The data availability and completeness for the SPS-2 experiment are good overall. A high percentage of the SPS-2 data are at level E--greater than 82 percent for all data types, and greater than 99 percent for many. However, a significant amount of data are still missing, especially traffic, distress and faulting surveys, and key materials testing data. These deficiencies need to be addressed before a comprehensive analysis of the SPS-2 experiment is conducted. Required experimental pavement design factors and site conditions were compared with the actual constructed values. Most SPS-2 sections follow the experiment design for the large majority of the design factors. When comparing designed versus constructed, eight SPS-2 projects can be characterized as good to excellent, four projects are considered poor to fair, and one new SPS-2 project does not yet have enough data in the IMS database to be evaluated. The evaluation has shown that several problems may limit the results that can be obtained from the SPS-2 experiments if not rectified. Specifically, no SPS-2 projects were built on certain subgrade types and in some climates. Some SPS-2 sites had construction deviations, and significant materials data and traffic data are missing from other sites or sections. One site has excessive early cracking that will limit its usefulness. However, even though the SPS-2 sections are relatively young (oldest project is 7.5 years) and a large majority show no or little distress, some interesting and important early trends have already been identified that will be very useful to the design and construction of JPCP. As time and traffic loadings accumulate, much more valuable performance data will be obtained. The Federal Highway Administration is conducting a concerted effort to obtain missing data. Recommendations for future analyses are provided in the last chapter of this report. Valuable information will be obtained from this experiment if these studies are carried out.

Application/Use: This report can be used by those interested in the LTPP SPS-2 experiment. Additionally, the report was intended as a tool for planning data collection at SPS-2 experiments.

Contribution: Improvement in Knowledge

Present Benefit: This evaluation has been used to prioritize data collection on SPS-2 projects within LTPP. Additional materials sampling has been initiated for these projects along with traffic monitoring through a pooled fund study. These data will provide a more complete matrix for the SPS-2 experiment, making it more valuable to researchers.

Future Benefit: It is important to understand the effectiveness of various JPCP design features and the factors contributing to performance so that the optimal design features can be selected and utilized reliably.

Title: Accelerated Testing of Ohio SHRP Sections 390101, 390102, 390105, and 390107

Author(s): Sargand, S.M; Edwards, W.

Date: 2004

Publisher: Ohio University, Athens; Ohio Department of Transportation; Federal Highway Administration

Abstract/Synopsis: The Ohio Strategic Highway Research Program (SHRP) Test Road was constructed to provide data for 40 sections in the Long Term Pavement Performance (LTPP) SPS-1, 2, 8 and 9 experiments under specific traffic, environmental and soil conditions existing at one site in Ohio. Sensors were installed at the time of construction to continuously monitor subsurface temperature, moisture and frost in 18 sections, and to measure dynamic strain, deflection and pressure response in 33 sections during controlled vehicle testing. Falling Weight Deflectometer (FWD) measurements provided additional dynamic deflection data. Four asphalt concrete SPS-1 sections which showed early distress on the test road were reconstructed at the Accelerated Pavement Loading Facility (APLF) in Lancaster, Ohio. Response measurements in the APLF included FWD and strain and deflection readings from sensors mounted similarly to those installed on the test road. Performance was gauged by surface rutting which was monitored periodically in the APLF as rolling wheel loads were applied at various combinations of temperature and load. This project compared response and performance on these four SPS-1 sections at the two facilities.

Application/Use: This study can be used by pavement designers in Ohio.

Contribution: Improvement in Knowledge

Present Benefit: A comparison of in-service and accelerated pavement loading performance is extremely beneficial in developing transfer functions. This allows results obtained by accelerated loading to be applied to in-service pavements. Pavement engineers can use information from the accelerated loading response to predict actual field performance.

Future Benefit: The LTPP database provides in-service data that can be used to develop functions for transferring lab-derived response to field performance. The results from the finding will be beneficial in future pavement design and materials selection in Ohio.

Title: Defining the Attributes of Good In-Service Portland Cement Concrete Pavements

Date: 2004

Publisher: Center for Portland Cement Concrete Paving Technology; Federal Highway Administration

Abstract/Synopsis: Much of the current research in Portland cement concrete (PCC) pavements deals with the analysis of early pavement life failures and seeks to find ways to prevent those from reoccurring. The Long Term Pavement Performance (LTPP) portion of the Strategic Highway Research Program (SHRP) has identified some of the key factors in designing and building new PCC pavements. This statement will build on the Iowa Highway Research Board (IHRB) project TR-463, Field Performance Study of Past Iowa Pavement Research: A Look Back. In Iowa and across the nation, there are multiple pavements that were built more than 20 years ago that have been and are continuing to provide very good service to the public. They are found on both state and local routes and in both low and high traffic volume areas. There is a need to learn what went into those pavements, from the subgrade to the surface, that has made them perform so well. The purpose of this research project was to conduct a scoping study that could be used to evaluate the need for additional research to study the attributes of well-performing concrete pavements. The concept of "zero-maintenance jointed plain concrete pavements" was iterated in this study for long-lasting, well-performing Portland cement concrete pavement sections. The scope of the study was limited to a brief literature survey, pavement performance data collection from many counties, cities, and primary and interstate roads in Iowa, field visits to many selected pavement sites, and analysis of the collected data. No laboratory or field testing was conducted for this phase of the project. A problem statement with a research plan was created that could be used to guide the second phase of the project.

Application/Use: This study will be used to understand PCC pavement performance and will serve as a tool in planning future work.

Contribution: Cost savings; Improvement in Knowledge.

Present Benefit: The SPS-2 experiment of the LTPP program, entitled "Strategic Study of Structural Factors for Rigid Pavements" focuses on design features of PCC pavements. The data collected at these SPS-2 sites will be extremely valuable in identifying attributes that lead to good performance life.

Future Benefit: Quantifying the contribution of design features on improved performance will allow designers to make cost-effective decisions on PCC design. Additionally, the use of proven attributes will optimize performance and overall condition of PCC pavements in the future.

Title: Effects of Base Type on the Performance of Jointed Plain Concrete Pavements

Author(s): ERES Consultants

Date: 2004

Publisher: Caltrans

Abstract/Synopsis: The base course layer directly beneath a jointed plain concrete pavement (JPCP) is known to have a big impact on the overall performance of the pavement. The purpose of this report is to document the effect of the base course on performance of JPCP through results from extensive field tests conducted throughout the US and from results of mechanistic based performance prediction models. Although current empirical design procedures such as AASHTO's indicate that the base layer provides only minimal structural capacity to the pavement, this may be misleading. Experience has shown that a base course can provide several advantages, including:

- A construction platform, thereby increasing initial smoothness of the JPCP;
- Increase the strength and uniformity of foundation support, especially over the long term, by limiting erosion and loss of support along with helping to bridge soft or weak areas of subgrade that may result in settlement and slab cracking;
- Provide good subdrainage to the pavement to minimize erosion of underlying layers.

The overall performance of JPCP depends on how well distresses in the pavement are controlled. In comparing the performance of JPCP sections with different base types, it is to be recognized that the effects of other design features and site conditions (such as joint spacing, slab thickness, subgrade support, presence of load transfer devices, climatic conditions, and magnitude of traffic loads) cannot be ignored. All these factors are integrated into the overall performance of JPCP sections, and it is usually difficult to isolate the effect of only the base type unless all other factors are common to pavements with different base types. For example, a given base may perform well with one level of traffic, but if the traffic load increases significantly, the same base may not perform well due to higher erosion.

In addition, for any given base type there is a wide range of quality that has and can be achieved. For CTB, the amount of cement and compaction are critical to its strength and erosion resistance. For ATB and PATB, their ability to resist stripping (dependent on several factors) is critical to their erosion resistance. For an unbound aggregate base, the gradation is critical to its ability to resist erosion.

Application/Use: The results from this study are directly applicable to JPCP design (new construction as well as rehabilitation).

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: This study demonstrates the benefit of the LTPP program to individual State Highway Agencies. LTPP data was utilized to study performance factors of JPCP for

use by CALTRANS. The experimental design of the SPS-2 project (supplemented by GPS-3 test sections) allows for the evaluation of various design features and pavement configurations with respect to long term field performance. The information can be used to develop policies on design procedures specific to the local conditions and constraints.

Future Benefit: The LTPP project will continue to provide insight into the extent of contribution various factors have on the performance of in-service pavements. The data available in the LTPP database will be critical in evaluating new design methodologies and performance prediction models, including the M-E PDG.

Title: Factors Affecting Rigid Pavement Performance: Evaluation of the LTPP SPS-2 Experiment

Author(s): Jiang, Y; Darter, M. I.

Date: 2004

Publisher: Center for Portland Cement Concrete Paving Technology; Federal Highway Administration

Abstract/Synopsis: The Long Term Pavement Performance (LTPP) Specific Pavement Study Experiment 2 (SPS-2), Strategic Study of Structural Factors for Jointed Plain Concrete Pavements (JPCP), is one of the key experiments of the LTPP program. The main objective of this experiment is to determine the relative influence and long-term effectiveness of JPCP design features (including slab thickness, PCC flexural strength, base type and drainage, and slab width) and site conditions on performance. It is expected that the successful completion of the SPS-2 experiment will lead to improvements in design procedures and standards for construction of jointed plain concrete pavements. These improvements will contribute to achieving the overall goal of the LTPP program-increased pavement life and better utilization of resources. This paper presents the key findings from a recently completed FHWA study that was the first-time comprehensive review and evaluation of the SPS-2 experiment. The results presented herein will be useful to both pavement researchers and practitioners for improving pavement design and management decisions, and for calibration and validation of mechanistic-empirical design models including the 2002 Design Guide models.

Application/Use: This paper will be used by those interested in PCC pavement design.

Contribution: Improvement in Knowledge

Present Benefit: The SPS-2 experiment provides side-by-side comparisons of various PCC design features. The performance data collected at these sites will provide the information needed to make sound engineering decisions in pavement design.

Future Benefit: It is important to understand the effectiveness of various JPCP design features and the factors contributing to performance so that the proper techniques can be selected and designed reliably.

Title: Evaluation of Joint and Crack Load Transfer Final Report

Author(s): Khazanovich, L; Gotlif, A.

Date: 2003

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Journal Title: Publication of: ARRB Transport Research, Limited

Conference Title: Proceedings of the 21st ARRB and 11th REAAA Conference. Transportation: Our Highway to a Sustainable Future

Abstract/Synopsis: This report documents an evaluation of load transfer efficiency (LTE) of cracks and joints for rigid pavements included in the Long-Term Pavement Performance (LTPP) program. LTE is an important parameter affecting pavement performance. This study presents the first systematic analysis of the deflection data collected under the LTPP program related to LTE. Representative LTE indexes and joint stiffnesses were calculated for all General Pavement Studies (GPS), Special Pavement Studies (SPS), and Seasonal Monitoring Program (SMP) rigid test sections. Data tables that include computed parameters were developed for inclusion in the LTPP Information Management System (IMS). Trend analysis was performed to evaluate the effect of design features and site conditions on LTE. Key findings from this study: 1. Large amounts of high quality LTE data have been collected under the LTPP program. This data will be a valuable resource in improving understanding of load transfer effect and improving pavement design and rehabilitation procedures. 2. LTE is a complex parameter, which depends on many factors, including falling weight deflectometer (FWD) load plate position, testing time (FWD LTE testing must be conducted in the early morning in cool weather to provide realistic estimation of LTE), season. 3. LTE of continuously reinforced concrete pavements (CRCP) cracks was found to be higher than LTE of joint in jointed concrete pavements (JCP). 4. LTE of doweled joints was found to be higher than LTE of nondoweled joints. 5. Nondoweled sections with a high level of LTE are less likely to develop significant faulting than sections with low LTE. 6. LTE from leave and approach side deflection testing data was found to be statistically different for a large number of JCP sections.

Application/Use: Findings from this paper can be used by those interested in load transfer efficiency.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: Understanding variations and sensitivity of computed joint stiffness indices is critical to pavement evaluations. This type of information can aid pavement engineers in determining when improvements are needed as well as in selecting the most appropriate treatment type.

Future Benefit: Pavement engineers can use findings from this study to make informed decisions on joint stiffness estimations and improvement strategies. This will lead to proper and effective treatment selection, resulting in lower life cycle costs. One of the key findings was that significant amounts of LTE data have been collected as part of LTPP.

Title: An Evaluation of LTPP SPS-2 Sections in Michigan

Author(s): Vongchusiri, K; Buch, N; Desaraju, P; Salama, H.

Date: 2003

Publisher: Universidade do Minho, Portugal

Conference Title: Maintenance and Rehabilitation of Pavements and Technological Control

Abstract/Synopsis: Twelve Long-Term Pavement Performance (LTPP) Specific Pavement Study-2 (SPS-2) sections in Michigan were constructed in 1993 along US-23 (N) near the Ohio- Michigan border. The purpose of the SPS-2 experiment is to study the interaction between design, construction, and performance of rigid pavements. Based on data collected over the nine-year period, these sections were evaluated focusing on the interaction between design and construction factors on pavement performance and pavement response. Six of eight sections without a drainage system exhibited pumping, while three of these sections with thinner slab (8-in. thick) exhibited cracks in the PCC slabs. Two of the undrained sections had low ride quality (International Roughness Index (IRI) more than 200 in./mi.). Variation in faulting between the sections was observed but the magnitude was not severe (less than 0.1 in.).

Application/Use: This study applies directly to rigid pavement design and performance in Michigan.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: This study has quantified the relative benefit of design features in terms of performance differences. This can be used to make cost-effective decisions on design features to be utilized in Michigan pavement design.

Future Benefit: The future benefit of the study will be realized as engineers incorporate the findings into design applications. The LTPP database will provide future benefit in calibration and validating the M-E PDG to Michigan conditions.

Title: Structural Factors for Flexible Pavements--Initial Evaluation of the SPS-1 Experiment

Author(s): Von Quintus, H. L; Simpson, A. L.

Date: 2003

Publisher: Fugro-BRE, Incorporated; Federal Highway Administration

Abstract/Synopsis: The SPS-1 experiment entitled "Strategic Study of Structural Factors for Flexible Pavements" is one of the key experiments of the Long-Term Pavement Performance (LTPP) program. The objective of this experiment is to determine the relative influence and long-term effectiveness of hot mix asphalt (HMA) design features (including the surface and base thickness, base type, and drainage condition) and site conditions (traffic, subgrade type, and climatic factors) on performance. This report documents the first comprehensive review and evaluation of the SPS-1 experiment. Eighteen SPS-1 projects have been constructed and each site includes 12 core test sections and some sites also include supplemental sections. A total of 248 test sections are included in the SPS-1 experiment. The data for the SPS-1 experiment are fairly complete with two exceptions: the traffic and materials test data. However, a significant amount of some types of data is still missing, especially the distress data. These data deficiencies need to be addressed before a comprehensive analysis of the SPS-1 experiment is conducted. The majority of the SPS-1 data that has been collected is at level E. Required experimental design factors were compared with the actual constructed values. A large majority of SPS-1 sections follow the experimental design and can be characterized as good to excellent. Two projects are relatively new, and the data processing and materials testing are currently underway. The evaluation and detailed review have highlighted several significant problems that will clearly limit the results that can be obtained from the SPS-1 experiment. Specifically, these include the missing traffic and materials test data. These data must be collected in order for the SPS-1 experiment to meet the expectations for calibrating and validating mechanistic models. The performance trends and effects of several design features and site conditions were noted and documented.

Application/Use: This report can be used by those interested in the LTPP SPS-1 experiment. Additionally, the report was intended as a tool for prioritizing data collection at SPS-1 experiments.

Contribution: Improvement in Knowledge

Present Benefit: This evaluation has been used to prioritize data collection on SPS-1 projects within LTPP. Additional materials sampling has been initiated for SPS-1 projects along with traffic monitoring through a pooled fund study. These data will provide a more complete data set for the SPS-1 experiment, making it more valuable to researchers.

Future Benefit: This study is beneficial in understanding the interaction between design parameters and climate and the resultant changes in pavement performance. The LTPP database provides a means of conducting this type of study on a national scale. The

findings from this study will be useful in transferring mechanistic evaluations to field performance for various design parameters.

Title: Effects of Various Design Features on Rigid Airfield Pavement Design

Author(s): Lee, Y-H; Yen, S-T.

Date: 2002

Publisher: American Society of Civil Engineers

Conference Title: Designing, Constructing, Maintaining, and Financing Today's Airport Projects. Proceedings of the Twenty-Seventh International Air Transport Conference

Abstract/Synopsis: Regardless of a shorter or longer joint spacing, a better or worse load transfer mechanism, and environmental effects, the required minimum slab thickness will be the same using the current airfield pavement design procedure. Thus, the primary objective of this paper is to investigate the effects of many design features including finite slab sizes, thermal curling, moisture warping, and the presence of a second subbase layer on rigid airfield pavements in attempts to expand the applicability of the proposed thickness design procedure. The Corps of Engineers full-scale test pavement data were reanalyzed and several prediction models were utilized to estimate the critical edge stress for design. Stress adjustment factors for finite slab width and length were determined and found to be negligible for the test data. Since the concept of transformed section was frequently utilized and sometimes misused in the literature to account for the stress reduction due to a bonded or unbonded second layer, a more complete treatment of this concept was presented. Subsequently, the stress adjustment factor was estimated assuming all subbase layers were unbonded. Climatic data close to the test track locations were obtained from the Long-Term Pavement Performance (LTPP) database and the stress adjustment factor due to effective temperature differentials was estimated. As a result, an alternative structural deterioration model was proposed for future trial analysis and design. The primary benefit of this study and recommendations for future implementation and investigations are discussed.

Application/Use: This is directly applicable to airport pavement design.

Contribution: Improvement in Knowledge

Present Benefit: This paper is an example of how climatic data collected at an LTPP test section can be applied to other nearby areas and projects. The LTPP climatic database is fairly large and may be used along with the virtual weather station procedures to approximate weather conditions in areas relatively close to operating LTPP weather stations.

Future Benefit: The LTPP climatic database will continue to add benefit as researchers and designers utilize the years of data collected. This data, coupled with the virtual weather station calculation procedures, can be used to estimate climatic conditions for project locations of interest.

Title: Pavement Smoothness Specifications for LTPP WIM Locations

Author(s): Rada, G. R; Karamihas, S; Perera, R.

Date: 2002

Publisher: Iowa State University, Ames; Federal Highway Administration; Florida Department of Transportation; Center for Transportation Research and Education

Conference Title: Third International Conference on Weigh-in-Motion (ICWIM3)

Abstract/Synopsis: Accurate traffic data is of paramount importance to the Long-Term Pavement Performance (LTPP) study. To minimize dynamic motions and therefore improve data accuracy at Weigh-in-Motion (WIM) sites, LTPP has developed smoothness specifications for both short and long pavement wavelengths. They are intended to minimize axle motion effects and vehicle body bounce, respectively. The specifications, which are the subject of this paper, will be used for WIM verification and annual checks as well as acceptance of new WIM sites.

Application/Use: This paper will be used by state highway engineers interested in collecting high quality traffic data.

Contribution: Cost Savings; Improvement in Knowledge; Advancement in Technology.

Present Benefit: Traffic data is a key component in pavement design. Designs based on inaccurate traffic data can lead to overly conservative structural pavement sections or pavements with inadequate capacity. Either case leads to inefficient use of resources. Therefore, it is critical to collect high quality traffic data and the LTPP program has been a tremendous force in improving the practice. This document is just one testament to the contribution of the LTPP program to improved traffic data.

Future Benefit: The work done as part of the LTPP program in the traffic data collection arena will add tremendous value to the highway community. The protocol developed will continue to be used as agencies install new equipment, calibrate existing equipment, and review collected data. The end result will be cost-effective pavement designs with better overall pavement performance.

Title: Site Characterization of LTPP SPS WIM Sites

Author(s): Ostrom, B. K.

Date: 2002

Publisher: Iowa State University, Ames; Federal Highway Administration; Florida Department of Transportation; Center for Transportation Research and Education

Conference Title: Third International Conference on Weigh-in-Motion (ICWIM3)

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) program is starting to intensively evaluate weigh-in-motion equipment at selected Specific Pavement Studies (SPS) sites in order to estimate the precision of loading data, particularly for the most common U.S. freight vehicle. During site evaluations weights are recorded for at least two test trucks in three speed and three pavement temperature regimes. In addition, pavement profile information is collected to evaluate causes of variability. Sites can be characterized as meeting research data quality requirements or the general cause of the failure to do so can be identified.

Application/Use: This paper will be used by state highway engineers interested in collecting high quality traffic data.

Contribution: Cost Savings; Improvement in Knowledge; Advancement in Technology.

Present Benefit: Traffic data is a key component in pavement design. Designs based on inaccurate traffic data can lead to overly conservative structural pavement sections or pavements with inadequate capacity. Either case leads to inefficient use of resources. Therefore, it is critical to collect high quality traffic data and the LTPP program has been a tremendous force in improving the practice. This document is just one testament to the contribution of the LTPP program to improved traffic data.

Future Benefit: The work done as part of the LTPP program in the traffic data collection arena will add tremendous value to the highway community. The protocol developed will continue to be used as agencies install new equipment, calibrate existing equipment, and review collected data. The end result will be cost-effective pavement designs with better overall pavement performance.

Title: Summary of CRCP Long-Term Performance

Author(s): Tawfiq, K.

Date: 2002

Publisher: Construction Technology Laboratories, Incorporated; Concrete Reinforcing Steel Institute

Abstract/Synopsis: This paper reports on a Long Term Pavement Performance (LTPP) General Pavement Section-5 (GPS-5) study on continuously reinforced concrete pavement (CRCP) performance. CRCP is a portland cement concrete pavement with continuous steel longitudinal reinforcement and no intermediate contraction or expansion joints. The GPS-5 contains 85 CRCP test sections located in four climatic regions across 29 states. The paper reports on inventory data (age, slab design, base and subgrade materials, and shoulder type), climate data, traffic data, monitoring data, profile (smoothness) data, and pavement deflection data. It also discusses the characteristics of an exceptionally well performing CRCP.

Application/Use: The results from this study can be used by those interested in the performance of CRCP.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The LTPP database provides inventory and performance data for CRCP test sections located across the United States. The information can be used to understand general performance trends of CRCP as well as the contribution of specific features to performance.

Future Benefit: Performance comparisons and evaluations can be used to determine the cost-effectiveness of CRCP design features. Life cycle cost analysis between CRCP and other pavement types can also be compared and used in the selection process.

Title: Characterization of Mechanical Properties and Variability of PCC Materials for Rigid Pavement Design

Author(s): Mallela, J; Titus-Glover, L; Ayers, M E; Wilson, T. P.

Date: 2001

Publisher: International Society for Concrete Pavements

Conference Title: Seventh International Conference on Concrete Pavements. The Use of Concrete in Developing Long-Lasting Pavement Solutions for the 21st Century

Abstract/Synopsis: The objective of this paper is to describe an analysis of strength data from the LTPP SPS-2 experiment. The paper studies the rate of strength gain under the varied influences of climate/curing conditions, specimen type, and cement type. The variability of strength data obtained from a given project and the differences between "as specified" and "as-built" strengths were also investigated. Both strength development and variability are important input parameters for pavement design and reliability analysis. Finally, commonly cited relationships between the various strength parameters were analyzed. The paper provides typical concrete material inputs to the rigid pavement mechanistic-empirical design process.

Application/Use: This paper is directly applicable to materials engineers and pavement designers involved with concrete pavement.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Evaluations of concrete pavement material properties provides knowledge needed to properly design and select materials for a project. This study provides insight into concrete strength and the effect of other factors on strength gain. This is of particular interest to materials engineers as related to construction specifications and inspection. Designers are benefited by understanding differences between design properties and actual as-built parameters. This not only aides in designing pavements but should also be useful to materials engineers in refining specifications to reduce variability.

Future Benefit: Proper design and quality construction are of utmost importance to long-term pavement performance. This paper provides information that will be useful in future rigid pavement projects and will also addresses components of the M-E PDG.

Title: Asphalt Overlay Cost-Effectiveness: Manitoba TBS and Minnesota SPS-5 Projects 10-Year Ranking of Treatments (1989-1999)

Authors: Worel, Benjamin; Gilbertson, C; Watson, D; Skok, G; Wilson, T.

Date: 2000

Publisher: Minnesota Department of Transportation

Abstract/Synopsis: This report reviews Manitoba's and Minnesota's Specific Pavement Studies (SPS-5) projects. The studies focus on investigating the performance of hot mix asphalt (HMA) overlays on HMA pavements and involve nine core test sections. The SPS-5 design variables in test sections include a control section (do nothing), amount of preparation of the existing surface (mill, no-mill), overlay thickness (50-mm, 125-mm), and the type of overlay material (virgin, recycle). Researchers plan to study the Manitoba and Minnesota SPS-5 projects, part of the Long-Term Pavement Performance (LTPP) Project, until 2010, when each project reaches the approximate age of 20 years. This project update includes a field review by the authors, a review of the existing monitoring data, and an estimate of the expected performance and cost expectations for upcoming years until 2010. Currently after 10 years all sections, excluding the control section, still are performing well. As a result at this point, researchers recommended the least costly treatment, 50-mm recycled asphalt overlay with no surface preparation, for pavement rehabilitation.

Application/Use: This study is extremely beneficial to those interested in rehabilitation pavement design and life cycle costs.

Contribution: Cost Savings; Improvement in Knowledge; Lessons Learned.

Present Benefit: The SPS-5 experiments provide side-by-side comparisons of various rehabilitation alternatives for flexible pavements. With this design, direct comparisons can be made without confounding effects of traffic, soil properties, and climate variation between alternatives. This allows performance differences to be evaluated in determining the most cost-effective treatments given in situ conditions.

Future Benefit: This study will continue to provide benefit as additional monitoring occurs and performance differences become more evident with time. The SPS-5 data can also be used in the calibration of the M-E PDG.

Title: Early Evaluation of LTPP Specific Pavement Studies - 2 in Colorado

Author(s): Suthahar, N; Ardani, A; Morain, D.

Date: 2000

Publisher: Colorado Department of Transportation; Federal Highway Administration

Abstract/Synopsis: This report presents the early results of the Specific Pavement Studies-2 (SPS-2) experiment, "Strategic Study of Structural Factors for Rigid Pavements" documenting construction details of 13 different test sections with varying structural characteristics. The SPS-2 experiment was developed as a coordinated national experiment to address the effects of various strategic environmental and structural factors on the performance of rigid pavements. The factors studied under this experiment included concrete thickness, concrete strength, base type, lane width, drainage and environmental factors such as temperature, moisture and soil type. Pavement thicknesses were constructed at 8 and 11 in. (20 and 28 cm). Alternate base types included permeable asphalt-treated base (PATB), lean concrete base (LCB), and dense-graded aggregate base (DGAB). Certain sections included a widened 14-ft (4.3-m) slab in addition to the standard 12-ft (3.7-m) width. Specific sections included the construction of pavement edge drains, while the remainder did not. Specific sections were constructed using high- and low-strength concrete mixes to provide a difference in performance as a paving material. This paper discusses the performance of these test sections after being in service for four years. The results are based on monitoring data collected by the Long Term Pavement Performance (LTPP) Program. The monitoring data includes deflection data collected by a falling weight deflectometer, profile data collected by a profilometer, friction data using the ASTM E 274 procedure and manually collected distress data. Based on the early results of the SPS-2 experiment and a supplemental study conducted by the Colorado Department of Transportation (CDOT), the use of 14-ft (4.3-m) slabs is highly recommended. The results of this study revealed that wider slabs improved the load-carrying capacity of the outside lane by keeping the trucks away from the longitudinal joint at the shoulder. Structurally speaking, their contributions were found to be equivalent to 1 in. (2.54 cm) of slab thickness. The 14-ft (4.3-m) slab is now an option for CDOT designers, primarily in a rural setting.

Application/Use: This study is directly applicable to rigid pavement design in Colorado but can be used by other agencies as well.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The SPS-2 project provides side-by-side performance comparisons for various rigid pavement design features. In this way, differential performance can be evaluated while keeping all other factors constant (i.e., subgrade, climate, and traffic). Pavement design practices can be optimized based on this information.

Future Benefit: Revising design policies to reflect the structural benefit of increased slab width and allowing a reduction in pavement thickness will result in a significant reduction in construction costs for CDOT. Investigation into other design features may also reduce costs while improving performance.

Title: Early Evaluation of Long-Term Pavement Performance Specific Pavement Studies-2, Colorado

Author(s): Suthahar, N; Ardani, A; Morian, D. A.

Date: 2000

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1699

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) Program included the construction of rigid pavement sections for evaluation. These test sections, designated Specific Pavement Studies (SPS)-2, were constructed on the basis of an experiment matrix that includes pavement slab thickness [202 mm (8 in.) and 280 mm (11 in.)], base type (permeable asphalt-treated base, lean concrete base, and dense-graded aggregate base), widened lane of 4.27 m (14 ft) and state standard lane of 3.66 m (12 ft), and drainage (with and without pavement edge drains). In addition, a standard Colorado Department of Transportation design section was constructed to provide a performance comparison. The performance of these test sections after 4 years of service is discussed. The results are based on deflection, profile, and distress data collected by the LTPP Program. Virtually no distress and no change in ride quality are evident in these pavement test sections at this time. However, the evaluation of deflection data provides an early indication of anticipated variation in test section performance. Currently, no difference can be identified between the deflection magnitude of the widened-lane section and the state standard section with tied concrete shoulders. However, both these sections exhibit lower deflections at this time than those sections with untied shoulders. High deflections of 202-mm sections indicate that perhaps these sections do not provide adequate structural strength for this roadway.

Application/Use: This study is directly applicable to rigid pavement design in Colorado but can be used by other agencies as well.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The SPS-2 project provides side-by-side performance comparisons for various rigid pavement design features. In this way, differential performance can be evaluated while keeping all other factors constant (i.e., subgrade, climate, and traffic). Pavement design practices can be optimized based on this information.

Future Benefit: Revising design policies to reflect the structural benefit of increased slab width and allowing a reduction in pavement thickness will result in a significant reduction in construction costs for CDOT. Investigation into other design features may also reduce costs while improving performance.

Title: Evaluation of Concrete Pavement Conditions and Design Features Using LTPP FWD Deflection Data

Author(s): Jiang, Y. J; Tayabji, S. D.

Date: 2000

Publisher: American Society for Testing and Materials

Conference Title: Symposium on Nondestructive Testing of Pavements and Backcalculation of Moduli: Third Volume

Abstract/Synopsis: The Long Term Pavement Performance (LTPP) study uses falling weight deflectometers (FWDs) to collect data. As part of a study sponsored by the Federal Highway Administration, load transfer efficiencies (LTEs) were calculated for all the test points of each section of the LTTP GPS 3, 4, and 5 experiments. From statistical analysis, it was found that the doweled joints have significantly higher LTEs that the non-doweled joints. Voids at the slab joints and corners were computed by examining the deflection data of the joint and corner tests at different load levels. The loss of support was then expressed as the percentage of joints or slab corners with voids for each LTPP concrete pavement test section. By examining the ratio of the maximum deflection at the mid slab test location versus the edge locations, the concrete shoulders were found to provide significantly greater edge support than asphalt shoulders based on a one tailed student t-test.

Application/Use: This study is directly applicable to pavement engineers involved with Jointed Concrete Pavement (JCP).

Contribution: Improvement in Knowledge

Present Benefit: The study provides insight in to void development and analysis methods to identify these areas using FWD data. This information can be beneficial to pavement engineers evaluating maintenance and rehabilitation alternatives for JCP.

Future Benefit: LTPP will continue to provide value as a resource for evaluating various design features. The implementation of the M-E PDG will be largely dependent of the use of LTPP data.

Title: It's 10 O'Clock: Do You Know Where Your Sensors Are?

Author(s): Stubstad, R. N; Irwin, L. H; Lukanen, E. O; Clevenson, M. L.

Date: 2000

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1716

Abstract/Synopsis: More than 400 falling weight deflectometer (FWD) devices are presently in use throughout the world, and deflection reading accuracy is very important. Deflections are measured in microns, or hundredths of a mil, and even very small errors in the deflection readings can have a profound effect on the results of backcalculation. One question that has somehow escaped scrutiny is the one alluded to in the title to this paper--exactly where along the deflection basin are the FWD deflection sensors positioned? This is an extremely important issue for proper definition of the deflection basin as a function of distance from the center of the loading plate. A review of the FWD load-deflection data in the Long Term Pavement Performance (LTPP) study found that in at least 7 percent of some 4 million lines of FWD deflection data in the National Information Management System (NIMS) database, the sensors were not positioned as reported. This problem is not limited to LTPP and NIMS, and it occurs all too frequently on FWDs everywhere. How sensor positioning errors influence backcalculated moduli, even if all other facets of the FWD data are 100 percent correct, is described. Examples of the errors found in NIMS are also presented--real-life illustrations of what can go wrong and how much influence these errors can have on pavement analysis. A method of scanning for sensor positioning errors without carrying out backcalculation is presented. By use of the suggested transform, sensor positioning errors are clearly evident when suspect data are compared with correct data along the same, or other, pavement sections.

Application/Use: This study was used to improve the quality of FWD data in the LTPP database. Findings were also useful to LTPP FWD data collection practices.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: The LTPP database provides sufficient data to allow the development of new quality control and review procedures. This paper is an example of one such suggested approach. High quality FWD data is necessary for cost effective pavement designs and efficient pavement management systems.

Future Benefit: The LTPP database will continue supporting the development of new FWD analysis techniques and quality control tools. These procedures will provide benefit to agencies using FWD data in pavement design and management.

Title: LTPP Data Analysis: Relative Performance of Jointed Plain Concrete Pavement with Sealed and Unsealed Joints

Authors: Hall, K. T; Crovetti, J. A.

Date: 2000

Publisher: National Cooperative Highway Research Program

Journal Title: NCHRP Web Document 32

Abstract/Synopsis: This project compared, based on the data available from the Long Term Pavement Performance (LTPP) studies, the performance of Jointed Plain Concrete Pavement (JPCP) designed and constructed with unsealed joints to that of JPCP with sealed joints. The five LTPP sites suitable for this analysis are all located in the dry western region of the United States, for which reason it would be unwise to extrapolate the results of this analysis to other regions of the country that receive more precipitation. The report is organized in five chapters. Chapter 1 provides an introduction and discusses the research approach. Chapter 2 contains the results of a literature review. Chapter 3 describes the analysis methods. Chapter 4 presents a project-level evaluation of the relative performance of JPCP with unsealed and sealed joints at each one of the five selected sites. Chapter 5 presents conclusions on the relative performance of JPCP with unsealed and sealed joints, drawn from the project-level evaluations, and recommendations for further research.

Application/Use: The report can be used by agencies in the dry regions of the United States in determining the cost-effectiveness of jointed concrete pavement maintenance alternatives.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: This study provides information on differential performance between various maintenance alternatives in dry climates. This is beneficial to pavement management in setting policy for the application of jointed concrete pavement maintenance. Life-cycle cost analysis provides useful information on cost-effective solutions.

Future Benefit: The results can be used to implement maintenance strategies. This will result in better overall condition of jointed concrete pavement. Additional benefit will be realized in cost savings through proper treatment selection.

Title: LTPP Findings Pay Off for Pennsylvania

Date: 2000

Publisher: Federal Highway Administration

Journal Title: Application Notes

Abstract/Synopsis: The Pennsylvania Department of Transportation (PennDOT) decided to change its practice of using skewed joints after reviewing the results of a Long Term Pavement Performance (LTPP) program analysis project. The project analyzed LTPP pavement performance data to identify what worked and what didn't work to control the development of joint faulting. As of calendar year 1999, Pennsylvania policy specified perpendicular joints for any limited-access, four-lane concrete pavement highway projects. By changing its pavement joint design standard, PennDOT can reduce the occurrence of joint faulting and realize the following benefits: a smoother ride for motorists; reduced construction problems and related costs; reduced maintenance requirements; and fewer maintenance-related disruptions to traffic.

Application/Use: Results from LTPP research were implemented in Pennsylvania to improve performance and reduce costs.

Contribution: Cost Savings; Improvement in Knowledge; Implementation/Usage.

Present Benefit: LTPP data collection and analysis resulted in significant benefits for Pennsylvania. Improvements include reduced costs, reduced maintenance needs, and better user perception of the pavement.

Future Benefit: Implementation of these finding in Pennsylvania will continue to benefit the highway agency and highway users. Additional benefits will be realized as other agencies adopt findings and recommendations from LTPP-related research.

Title: Preliminary Evaluation and Analysis of LTPP Faulting Data - Final Report

Author(s): Selezneva, O; Jiang, J; Tayabji, S. D.

Date: 2000

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Abstract/Synopsis: A major goal of the Long-Term Pavement Performance (LTPP) study is the development of recommendations for improving the design and construction of new and rehabilitated pavements to provide longer lasting pavements. As part of the condition monitoring of the LTPP test sections, joint and crack faulting data are being collected on a regular basis at each jointed concrete pavement test site. The LTPP faulting data are collected using the Georgia Faultmeter. Data are collected at joints and cracks along the wheelpath and along the outside pavement edge. As part of the study reported here, the quality of the faulting data was evaluated and missing and questionable data were identified. The data were then used to develop faulting data indices (average joint faulting for each visit) and related statistical parameters. Also, data analysis was carried out to determine the usefulness of joint faulting and related data in identifying factors that affect joint faulting. The analysis indicated that doweled joints exhibit very little faulting even after many years of service and that the effect of design features such as drainage, tied-concrete shoulder use, and joint spacing is not as significant when doweled joints are used. For non-doweled jointed plain concrete (JPC) pavements, the following design features were found to significantly reduce faulting: use of widened lanes, effective drainage system, stabilized base/subbase, and shorter joint spacing. Effect of faulting on ride quality was also investigated using JPC pavement sections with three or more faulting and International Roughness Index (IRI) surveys. A strong correlation was found between the rates of change in faulting values versus rate of change in IRI values for JPC pavement sections. The results indicate that faulting is a major component of increased roughness of JPC pavements.

Application/Use: Findings from the study will also be used as internal planning tool for the LTPP program. Additionally, the study is applicable to pavement engineers and pavement managers involved with JPC.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The study improved data quality in the LTPP database. Additionally, the faulting indices are beneficial to performance evaluations. The correlations provide pavement engineers with information on the contribution of design features to faulting and roughness accumulation. This is beneficial in selecting cost-effective design features.

Future Benefit: Improved faulting performance will result in smoother pavements and slower deterioration. Faulting data in the LTPP database will be used in further research endeavors, thereby providing additional benefit.

Title: Common Characteristics of Good and Poorly Performing AC Pavements

Authors: Rauhut, J. B; Eltahan, A; Simpson, A. L.

Date: 1999

Publisher: Brent Rauhut Engineering, Incorporated; Federal Highway Administration

Abstract/Synopsis: This report documents the analysis and findings of a study to identify the site conditions and design/construction features of flexible pavements that lead to good performance and those that lead to poor performance. Data from the Long Term Pavement Performance (LTPP) test sections were used along with findings from previous and ongoing analyses of LTPP data. As there were no known criteria for identifying performance expectations over time as good, normal, or poor, a group of experts was convened to establish criteria. Separate criteria were developed for performance in roughness (International Roughness Index, IRI), rutting, transverse cracking, and fatigue cracking. This work attempted to identify the pavement characteristics that have a significant impact on the occurrence of these four distress types. In many cases, definitive conclusions could not be drawn, because the effects of the different characteristics are interactive. More in-depth analysis is needed to sort out these interactive effects.

Application/Use: The evaluation can be used by State Highway Agencies in understanding how to improve performance of flexible pavements.

Contribution: Cost Savings; Lessons Learned.

Present Benefit: There are many factors that contribute to pavement performance. This study attempts to sort out attributes that have the largest impact on performance. The LTPP database provides an excellent source of data for this type of evaluation because pavement inventory data and in situ conditions are stored with condition data.

The relative contribution of various pavement components can be used to make policy decisions regarding design features, materials selection, construction techniques and specifications.

Future Benefit: Additional data has been collected since the completion of this study. With more complete deterioration trends now available, the LTPP database will provide greater insights for developing additional conclusions and findings.

Title: International Roughness Index of Asphalt Concrete Overlays: Analysis of Data from Long-Term Pavement Performance Program SPS-5 Projects

Authors: Perera, R. W; Kohn, S. D.

Date: 1999

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1655

Abstract/Synopsis: The Specific Pavement Studies 5 (SPS-5) experiment in the Long-Term Pavement Performance (LTPP) program was developed to investigate the performance of selected asphalt concrete rehabilitation treatment factors. Results of an analysis are presented that was conducted to compare the International Roughness Index (IRI) values of the test sections before and after overlay and to compare the IRI values that were obtained on the test sections subjected to different treatments. The data presented will be useful for highway agencies to gain an insight into the typical IRI values that can be expected when overlays are placed on asphalt concrete pavements and to obtain information on the reduction in roughness from an asphalt concrete overlay. The analysis indicated that the IRI of a pavement after overlay was not a function of the IRI before overlay. It was observed that a 50-mm-thick overlay (placed in one lift) was capable of achieving similar IRI values as a 125-mm-thick overlay (placed in two lifts). No differences in IRI values were obtained on overlays that were placed on pavement surfaces milled before the overlay when compared with surfaces not milled before the overlay. A frequency analysis of the IRI values after overlay indicated that in 85 percent of the cases, the IRI of the pavement was less than 1.2 m/km for both 50-mm- and 125-mm-thick asphalt concrete overlays.

Application/Use: This study is valuable to those involved in selecting and designing rehabilitation alternatives.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The findings from this report are beneficial because they quantify the contribution of various rehabilitation techniques to roughness accumulation. This is important to designers attempting to select the most appropriate alternative with consideration given to end user cost and perception.

Future Benefit: The evaluation conducted as part of this project will continue to be useful. Quantifying the relationship between rehabilitation strategy and roughness accumulation will be quire valuable in making design decisions.

Title: Preliminary Evaluation of LTPP Continuously Reinforced Concrete (CRC) Pavement Test Sections

Authors: Tayabji, S. D; Selezneva, O; Jiang, Y. J.

Date: 1999

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Abstract/Synopsis: As part of the study reported here, analysis of data from the Long Term Pavement Performance (LTPP) GPS-5 test sections was conducted to identify factors that influence long-term crack spacing in continuously reinforced concrete (CRC) pavements and to determine the effect of crack spacing on pavement performance. Data from the 85 test sections from the GPS-5 experiment were analyzed. Due to the limitations of the available data and the lack of certain key data, the study was not able to produce definitive findings on factors that affect long-term crack spacing and CRC pavement performance. Lack of early-age cracking due to ambient weather conditions at the time of construction will continue to limit the value of GPS-5 to produce meaningful data on factors affecting early-age cracking. Continued monitoring of GPS-5 sites and subsequent data analysis should yield information on how CRC pavement cracking and performance changes with time, loading, and other factors. It is expected that as additional data from the GPS-5 experiment become available, it will be possible to perform more in-depth analysis of the test data to derive definitive results. Results to date, as presented in this report, do indicate that CRC pavements have the potential to provide long-term, low-maintenance service life as evidenced by the many well-performing sections in the LTPP GPS-5 experiment.

Application/Use: This study is directly applicable to pavement engineers involved with design, construction, and maintenance of CRCP.

Contribution: Cost Savings, Improvement in Knowledge.

Present Benefit: The LTPP database contains inventory and performance data for CRCP test sections. This information is beneficial in evaluating current CRCP design practices as well as understanding key design factors in performance. This type of research can lead to refinements in current design practices, thereby creating more cost-effective designs.

Future Benefit: The data available through LTPP will continue to provide a means of evaluating pavement performance to enhance design, construction, and maintenance activities. This will lead to improved performance at reduced overall cost.

Title: Common Characteristics of Good and Poorly Performing PCC Pavements

Authors: Khazanovich, L; Darter, M; Bartlett, R; McPeak, T.

Date: 1998

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Abstract/Synopsis: This report documents the analysis and findings of a study to identify the site conditions and design/construction features of concrete pavements (JPCP, JRCP, CRCP) that lead to good performance and those that lead to poor performance. Data from Long-Term Pavement Performance (LTPP) test sections were used along with findings from previous and ongoing analyses of LTPP data. As there were no known criteria for identifying performance expectations over time as good, normal, or poor, a group of experts was convened to establish criteria. Separate criteria were developed for performance in roughness (IRI), joint faulting, transverse cracking, and localized failures (CRCP). Many significant site conditions and design/construction features were identified that lead to good and poor performance. The site conditions (traffic, climate, and subgrade) cannot be controlled by the designer, however, steps can be taken to mitigate their effects. Several design and construction features can be controlled or specified by the highway agency and these should be given careful consideration. Knowledge about the design features identified as being critical to concrete pavement performance will contribute to improved guidelines for the design and construction of long-lived PCC pavements.

Application/Use: The evaluation can be used by State Highway Agencies in understanding how to improve performance of rigid pavements.

Contribution: Cost Savings; Improvement in Knowledge; Lessons Learned.

Present Benefit: There are many factors that contribute to PCC pavement performance. This study attempts to sort out attributes that have the largest impact. The LTPP database provides an excellent source of data for this type of evaluation because pavement inventory data and in situ conditions are stored with condition data.

The relative contribution of various pavement components can be used to make policy decisions regarding design features, materials selection, construction techniques and specifications.

Future Benefit: Additional data has been collected since the completion of this study. With more complete deterioration trends now available, the LTPP database will provide greater insights for developing additional conclusions and findings.

Title: Design and Construction of PCC Pavements, Volume I: Summary of Design Features and Construction Practices that Influence Performance of Pavements

Authors: Owusu-Antwi, E. B; Titus-Glover, L; Darter, M. I.

Date: 1998

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Abstract/Synopsis: A study has been conducted to evaluate and analyze portland cement concrete (PCC) pavements in order to develop recommendations for the design and construction of long-lived concrete pavements. It involved a detailed evaluation and analysis of the PCC pavement data in the Long Term Pavement Performance (LTPP) database using a variety of means to determine the beneficial effects of design features and construction practices on long-term performance. Emphasis was placed on identifying those specific design features that can be included during design to improve the performance of PCC pavements under various combinations of environmental and traffic loading conditions, and for different subgrade support conditions. The study focused on the development of practical recommendations that can be easily implemented by highway agencies to increase pavement life. This volume provides a concise summary of the results that were obtained from the study. It includes an overview of the engineering and statistical analyses that were conducted and presents results that can be used by State highway agencies to obtain high-performance PCC pavements. Implementation of the recommendations will increase the reliability of PCC pavements.

Application/Use: This study has been used to modify rigid pavement design practices.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The LTPP database supported the evaluation of existing design procedures based on actual field performance. In doing this, revised procedures were developed to better reflect observed performance. With these revisions, improvements were made to rigid pavement design that led to better performance and more cost-efficient design. Additionally, agencies can use the findings from this evaluation to revise design policies.

Future Benefit: The comprehensive nature of the LTPP database is unmatched. As such, the LTPP database will continue to add benefit in validating and calibrating the M-E PDG as part of the implementation process. Calibration will provide improved prediction capabilities of the M-E PDG given local conditions and will optimize performance.

Title: Design and Construction of PCC Pavements, Volume II: Design Features and Practices that Influence Performance of Pavements

Authors: Titus-Glover, L; Owusu-Antwi, E. B; Hoener, T; Darter, M. I.

Date: 1998

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Abstract/Synopsis: A study has been conducted to evaluate and analyze portland cement concrete (PCC) pavements in order to develop recommendations for the design and construction of long-lived concrete pavements. It involved a detailed evaluation and analysis of the PCC pavement data in the Long-Term Pavement Performance (LTPP) database using statistical techniques to determine the design features and construction practices that have a beneficial effect on long-term performance. The study focused on the development of practical recommendations that can be easily implemented by highway agencies to increase pavement life. This volume describes and provides information on design features and construction practices that improve pavement performance. A key focus was to develop canonical discriminate functions that can be used to discriminate between groups of pavements in the sense of being able to tell them apart. The pavements were grouped according to their performance classification, namely, above expectation, as expected, and below expectation. The canonical functions consist of linear combinations of the variables that describe and quantify the pavement design features, site conditions, and construction practices.

Application/Use: The models developed in this study are directly applicable to rigid pavement design.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The distress and roughness prediction models are beneficial in understanding the contribution of design features to pavement performance. Additionally, the interaction between these design features and in situ conditions, such as climate, subgrade, and traffic can also be evaluated. This information can be used by pavement designers in selecting cost-effective pavement design alternatives. Additionally, design policy can be modified to accommodate useful findings from this analysis.

Future Benefit: The findings from this study can assist in the implementation of the M-E PDG. The prediction curves may be useful in the local calibration and validation process. Additionally, the results from this study can be used as part of sensitivity analysis.

Title: Reducing Roughness in Rehabilitated Asphalt Concrete (AC) Pavements

Date: 1998

Publisher: Federal Highway Administration

Journal Title: LTPP TechBrief

Abstract/Synopsis: A recently completed study entitled, "The Investigation of Development of Pavement Roughness" (FHWA-RD-97-147), initiated by the Long Term Pavement Performance (LTPP) program, provides an answer to the question of how much different rehabilitation treatments reduce roughness. A component of the study investigated selected asphalt concrete (AC) rehabilitation treatment factors in reducing roughness. Specific factors considered include: overlay mix type (recycled and virgin), overlay thickness, and surface preparation of the existing AC surface prior to overlay (minimal and intensive preparation). Key findings were as follows: regardless of the roughness before overlay, the roughness for each test section at a site after the overlay fell within a relatively narrow band, the range of which varied from project to project; even thin overlays substantially reduced the roughness of a pavement; and 85 percent of the sections that received either a 50-mm or 125-mm AC overlay had an International Roughness Index (IRI) of less than 1.2 m/km.

Application/Use: This can be used by those interested in the improvement in roughness that can be attributed to rehabilitation activities.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: This study has provided value in many forms. The prediction models developed can be used in pavement management to estimate the progression of roughness with time. Investigations of roughness on new and rehabilitated pavement can provide information to be used in selecting design alternatives. The recommendations are also useful in developing future data collection intervals and procedures.

Future Benefit: The evaluation conducted as part of this project will continue to provide value. Quality assurance recommendations will improve the quality of data in the LTPP database. Roughness trends can be used in future analysis.

Title: Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-5: Rehabilitation of Asphalt Concrete Pavements

Date: 1989

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The objective of this study is to develop improved performance prediction models to be used for determining the additional pavement life that can be expected from application of a variety of asphalt concrete (AC) rehabilitation methods and strategies ranging from minimal to maximal investment in the rehabilitation treatment. The treatments being studied include combinations of surface preparations, overlay thicknesses, and AC overlay type. The study objective includes a determination of the influence of environmental region and soil type on these factors. The experimental designs and research plans presented here for Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-5, were adapted from the Specific Pavement Studies on hot recycling of asphalt concrete pavements originally described in the May 1986, "Strategic Highway Research Program Research Plans," issued by the Transportation Research Board.

Application/Use: This report can be used by those interested in the SPS-5 experiment.

Contribution: Cost Savings, Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-5 experiment and provides background on the objectives of the project. Each SPS-5 project provides a direct side-by-side performance comparison of various flexible rehabilitation alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of rehabilitation features on performance. Policy decisions can then be made on design practices.

The SPS-5 experiment as a whole can be used to predict performance, estimate service life extension due to overlays, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of flexible rehabilitation treatments.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-5 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-5 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous rehabilitation strategies on flexible pavement performance.

Title: What Makes Portland Cement Concrete (PCC) Pavements Rough?

Date: 1998

Publisher: Federal Highway Administration

Journal Title: TechBrief

Abstract/Synopsis: Roughness is widely regarded as the most important measure of pavement performance. To better understand how and why roughness occurs in pavements, Long Term Pavement Performance (LTPP) program recently completed a study entitled, "Investigation of Development of Pavement Roughness." A component of the study investigated the changes in three types -- Jointed Plain Concrete Pavement, Jointed Reinforced Concrete Pavement, and Continuously Reinforced Concrete Pavement -- of Portland Cement Concrete (PCC) pavement roughness over time and its relationship to design factors, subgrade conditions, and climatic conditions.

Application/Use: The results from this paper can be used to understand roughness accumulation and the effects of in situ conditions on this accumulation.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: Roughness significantly affects the end user's perception on pavement quality. The ability to predict roughness accumulation, as well as the factors that contribute to improved ride quality, are extremely beneficial to the transportation industry. Roughness predictions can be used as a tool in programming funds for future rehabilitation.

Future Benefit: The LTPP offers approximately 20 years of performance data for in-service pavements. The data can be used to predict performance in areas with limited monitored data. Understanding the contribution of in situ factors on roughness will also be helpful to agencies as they investigate rehabilitation alternatives.

Title: Demonstration and Evaluation of Superpave Technologies. Construction Report for Route 2

Authors: Rodrigues, N; Larsen, D. A.

Date: 1997

Publisher: Federal Highway Administration; Connecticut Department of Transportation

Abstract/Synopsis: A federal aid resurfacing project on Connecticut State Route 2 in Colchester, Lebanon and Bozrah was modified to include Superpave mix designs. Six 3.3-km sections, four Superpave, and two Connecticut Department of Transportation (ConnDOT) Class 1 62.5-mm overlays, were placed between May and September 1997. Two of the Superpave mixes and one Class 1 mix utilized 20 percent Recycled Asphalt Pavement (RAP) obtained by milling the existing surface layer from Route 2. This is Connecticut's first large-scale Superpave project, as well as the first Hot Mix Asphalt (HMA) project in the state where quality control was the contractor's responsibility. This document reports on the construction phase of ConnDOT's research study. The Federal Highway Administration's (FHWA's) Mobile Asphalt Laboratory was on-site to perform mix design verification and simulated quality assurance as part of FHWA Demonstration #90. This project is also part of FHWA's Long Term Pavement Performance (LTPP) Special Pavement Study (SPS) 9A, Verification of SHRP Asphalt Specification and Mix Design. The selected 305-m segments within each of the six 3.3-km pavement sections will continue to be monitored, sampled and tested for at least the next four years.

Application/Use: This report is useful to pavement and materials engineers who are interested in Superpave mixtures.

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: The long term monitoring of various Superpave mixtures provides excellent information currently unavailable outside of LTPP. The SPS-9 experiment provides side-by-side comparisons of Superpave and conventional mixtures. This provides materials engineers with the information needed to adjust mixtures to improve performance.

Future Benefit: The data collected at SPS-9 projects will continue to add value to the pavement community. This project will be useful in the calibration and validation of the M-E PDG for Superpave mixtures.

Title: Roughness Characteristics of GPS Flexible Pavements in the LTPP Program

Authors: Perera, R. W; Byrum, C; Kohn, S. D; Richter, C. A.

Date: 1997

Publisher: University of Washington, Seattle

Conference Title: Eighth International Conference on Asphalt Pavements

Abstract/Synopsis: The Long Term Pavement Performance (LTPP) program in the United States was designed as a 20 year study of pavement performance. One aspect of the LTPP program is the monitoring of over 800 General Pavement Study (GPS) test sections that were established on in-service pavements in all fifty states of the United States and in Canada. A major data collection effort at the GPS sections is the collection of profile data that is performed annually. This paper presents the results of a study conducted to investigate the changes in roughness on: (i) GPS-1 experiment sections, which studies asphalt concrete pavements on granular base, and (ii) GPS-6B experiment sections, which studies asphalt concrete overlays of flexible pavements. The changes in roughness at test sections were investigated by using the International Roughness Index (IRI) as the roughness parameter. The test sections were classified according to environmental zones and the IRI trends for the group of test sections included in each zone were studied. Correlation analysis was conducted for GPS-1 sections in the dry freeze and the wet freeze zone between IRI and the factors that have an influence on roughness development. This paper presents a model that was developed to predict IRI for GPS-1 sections in the dry freeze zone. For the GPS-6B sections, the reduction in IRI due to the overlay was examined.

Application/Use: This paper is directly applicable to performance modeling of pavement roughness.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: Pavement roughness directly affects the service life of a pavement in terms of user perception and cost. The roughness data collected as part of the LTPP program provides an excellent source to develop roughness prediction models as well as to evaluate the factors influencing roughness. The results from this study can be used in pavement management for proper treatment selection/timing, pavement design, and budgeting purposes.

Future Benefit: The LTPP database offers insight into the progression of roughness over time for a large variety of test sections. The comprehensive nature of the database allows a range of traffic, subgrade, and climatic conditions to be investigated. This will provide continued value for years to come.

Title: Experience with Superpave Mixtures - Update on Constructed FHWA/LTPP SPS-9 Project (with Discussion)

Authors: Johnson, A. M; Skok, E. L.

Date: 1995

Publisher: Association of Asphalt Paving Technologists

Journal Title: Journal of the Association of Asphalt Paving Technologists Vol. 64

Conference Title: Asphalt Paving Technology 1995

Abstract/Synopsis: This paper is a review of the design, construction, and preliminary evaluation of the performance of seven SPS-9 pilot projects. These projects provide a direct comparison between agency standard mixes and Superpave mixes. Performance is evaluated using standard LTPP (Long Term Pavement Performance) procedures to measure rut depth, profile, and cracking. Each agency has received a summary of the condition of their sections, traffic and FWD, and profilometer data.

Application/Use: The SPS-9 projects are directly applicable to materials engineers involved with Superpave mixtures.

Contribution: Cost Savings; Improvement in Knowledge; Advancement in Technology.

Present Benefit: Data collected from the SPS-9 projects provides a side-by-side comparison of Superpave and agency standard mixes. This information will be extremely valuable to SHAs in understanding performance differences between mixes and will provide insight into mitigating problems in the design and construction of Superpave mixtures.

Future Benefit: The SPS-9 data will continue to add value to the pavement community in linking material properties to in-service performance. This link may be useful in calibrating Superpave mixes in the M-E PDG.

Title: Early Analyses of LTPP General Pavement Studies Data. Executive Summary

Authors: Rauhut, J. B; Darter, M. I.

Date: 1994

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This summary presents the results of the first data analyses of the Strategic Highway Research Program Long-Term Pavement Performance (LTPP) project. Data analyzed included information collected up to 1992. These analyses included: 1) developing a data analysis plan, 2) receipt and processing of data into suitable data bases for analysis and conducting statistical evaluations of the data bases, 3) using the LTPP data to evaluate the American Association of State Highway and Transportation Officials (AASHTO) design equations, 4) conducting sensitivity analyses to identify the independent variables that have significant impacts on pavement performance and to quantify the relative impact of each, and 5) using the experience gained from these early data analyses to recommend concepts for future data analyses.

Application/Use: Early analysis reports can be used by those interested in early program activities. These reports were also used as internal planning tools.

Contribution: Cost Savings; Lessons Learned; Advancement in Technology.

Present Benefit: Findings from status or summary reports can provide significant insight into the early activities of the program. This information can be used to understand how the program evolved and provides background on the decision process.

Future Benefit: Establishing a national, long-term research program requires significant planning and coordination. Program documentation since the inception of the LTPP program will be extremely beneficial to future endeavors of data users.

Title: Early Analyses of Long-Term Pavement Performance General Pavement Studies Data: Lessons Learned and Recommendations for Future Analyses

Authors: Rauhut, J. B; Simpson, A. L; Daleiden, J F; Darter, M. I; Owusu-Antwi, E; Pendleton, O. J.

Date: 1994

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The purpose of this report is to share the experience gained and lessons learned by research staff during early data analyses of the General Pavement Studies (GPS) and to recommend procedures for future analysts. A review of the techniques used is provided. Shortcomings of the Long-Term Pavement Performance (LTPP) database, known at the time of early analyses, are discussed and data base expectations for future analyses were identified. Some interesting and useful distress and roughness prediction models were developed that illustrate the effects of several design variables. Other analytical procedures for developing predictive equations were identified and described, which may be of use in future analyses. Ten techniques used by the research staff for evaluating the American Association of Highway and Transportation Officials (AASHTO) design equations are identified and recommendations for future evaluations provided.

Application/Use: Early analysis reports can be used by those interested in early program activities. These reports were also used as internal planning tools.

Contribution: Cost Savings; Lessons Learned; Advancement in Technology.

Present Benefit: Findings from status or summary reports can provide significant insight into the early activities of the program. This information can be used to understand how the program evolved and provides background on the decision process.

Future Benefit: Establishing a national, long-term research program requires significant planning and coordination. Program documentation since the inception of the LTPP program will be extremely beneficial to future data users.

Title: Early Field Experience with SuperPave

Authors: Cominsky, R. J; Harrigan, E. T.

Date: 1994

Publisher: Swedish Road and Transport Research Institute

Conference Title: Strategic Highway Research Program (SHRP) and Traffic Safety on Two Continents, Proceedings of the Conference

Abstract/Synopsis: The ninth Specific Pavement Study (SPS-9) in the Strategic Highway Research Program's Long Term Pavement Performance (LTPP) project will validate the SUPERPAVE specifications and mix design method in the context of a controlled field performance experiment. The main SPS-9 pavement construction activity will take place in 1994, 1995 and 1996. However, four pilot projects (SPS-9P) were built in 1992 to gain the benefit of early field experience with the tentative Superpave specifications, test methods and mix design method before the SHRP research program ended in March 1993. Several additional SPS-9P projects are planned for 1993. The design and construction of four SPS-9P pavements are briefly described. Initial observations of field performance and preliminary estimates of long-term performance obtained with the performance prediction models in the Superpave software are presented.

Application/Use: The SPS-9 projects are directly applicable to materials engineers involved with Superpave mixtures.

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: Data collected from the SPS-9 projects provides a side-by-side comparison of Superpave and agency standard mixes. This information will be extremely valuable to SHAs in understanding performance differences between mixes and will provide insight into mitigating problems in the design and construction of Superpave mixtures.

Future Benefit: The SPS-9 data will continue to add value to the pavement community in linking material properties to in-service performance. This link may be useful in calibrating Superpave mixes in the M-E PDG.

Title: Ground Penetrating Radar Surveys to Characterize Pavement Layer Thickness Variations at GPS Sites

Authors: Maser, K.

Date: 1994

Publisher: Strategic Highway Research Program

Abstract/Synopsis: Pavement layer thickness data are required for network- and project-level pavement management. Until now, adequate amounts of these data were difficult to obtain because of the cost, time, and interference involved in taking cores. A new nondestructive, noncontact method for thickness measurement is available and can be implemented from a survey vehicle moving at highway speed. The technology incorporates horn antenna radar equipment coupled with customized processing software. This report describes an accuracy evaluation of this technology in which results from 10 Strategic Highway Research Program Long Term Pavement Performance (SHRP-LTPP) asphalt pavement sections in 10 states were compared to core data. The results were evaluated and reported in two steps--blind and calibrated.

Application/Use: Ground Penetrating Radar (GPR) information is applicable to pavement management, evaluation, and design.

Contribution: Cost Savings; Advancement in Technology; Implementation/Usage.

Present Benefit: GPR data has many benefits. It allows layer thickness information to be collected quickly and efficiently by reducing or eliminating the need for destructive testing such as coring. GPR allows continuous data to be collected, which can be used to better identify changes in pavement structures. By doing this, pavement rehabilitation designs can be better optimized to existing conditions. The LTPP database provided a source for pavement sections with known structures to evaluate the capabilities of GPR devices.

Future Benefit: GPR information is promising and will continue to add benefit as the procedures are refined and further implemented. The LTPP database provides an excellent source of data that can be used to evaluate new procedures as they become available.

Title: Construction of LTPP SPS-1 Test Sections

Date: 1993

Publisher: Arizona Transportation Research Center; Arizona Department of Transportation

Journal Title

Title: Construction of LTPP SPS-2 Test Sections

Date: 1993

Publisher: Arizona Transportation Research Center; Arizona Department of Transportation

Journal Title: Research Notes

Abstract/Synopsis: The Arizona Department of Transportation is constructing the second Special Pavement Studies-2 (SPS-2) project in the United States. This SPS-2 project is part of the Federal Highway Administration's national Long Term Pavement Performance (LTPP) Program SPS-2 experiment, Strategic Study of Structural Factors for Rigid Pavements. The project consists of 21 experimental test sections scheduled to be built July-August 1993, in conjunction with a major construction project on I-10 west of Phoenix, Arizona. This Research Note provides additional information on the project background and project objective.

Application/Use: This report can be used by those interested in the Arizona SPS-1 project.

Contribution: Improvement in Knowledge

Present Benefit: A construction report was developed for every SPS project constructed as part of the LTPP program. The reports fully document construction activities and report any deviations from the experimental design. This provides valuable information for those interested in the performance of specific SPS projects.

Future Benefit: SPS projects will be a critical component for the local calibration/ validation of the M-E PDG. Construction reports provide information needed to supplement the performance observed on the sections.

Title: Factors for Flexible Pavement

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This document provides guidelines and information for nominating candidate projects for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-1, "Strategic Study of Structural Factors for Flexible Pavements," and outlines participation requirements. Detailed project nomination forms and instructions are included in this document.

Application/Use: This report can be used by those interested in the SPS-1 experiment.

Contribution: Cost Savings, Improvement in Knowledge.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-1 experiment and provides background on the objectives of the project. This document also summarizes the requirements for a project to be included in the LTPP program.

Each SPS-1 project provides a direct side-by-side performance comparison of various flexible pavement design features while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of design features on performance. Policy decisions can then be made on design practices. The SPS-1 experiment as a whole can be used to predict performance, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between design features and in situ conditions. These are all extremely beneficial to improving the performance of flexible pavements.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-1 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well.

As the SPS-1 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous structural factors on flexible pavement performance.

Title: Specific Pavement Studies: Experimental Design and Participation Requirements

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The initial Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies (SPS) program consists of eight experiments, designated SPS-1 through SPS-8, divided into four categories as follows: 1. Structural Factors (a) SPS-1: Strategic Study of Structural Factors for Flexible Pavements, (b) SPS-2: Strategic Study of Structural Factors for Rigid Pavements; 2. Preventive Maintenance (a) SPS-3: Preventive Maintenance Effectiveness of Flexible Pavements, (b) SPS-4: Preventive Maintenance Effectiveness of Rigid Pavements; 3. Pavement Rehabilitation (a) SPS-5: Rehabilitation of Asphalt Concrete Pavements, (b) SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements, (c) SPS-7: Bonded Concrete Overlays of Concrete Pavements; 4. Environmental Effects (a) SPS-8: Study of Environmental Effects in the Absence of Heavy Loads. The Preventive Maintenance Effectiveness experiments SPS-3 and SPS-4, which are part of the Highway Operations research program, are not included in this report. Each LTPP SPS experiment (SPS-1, 2, 5, 6, 7, and 8) will require a number of test sites in each of the four environmental regions (wet-freeze, dry-freeze, wet-no freeze and dry-no freeze). This report describes the experimental design for each of the six experiments and outlines state or province participation requirements. In addition, forms for nominating projects for these experiments are included.

Application/Use: This provides an overview of the SPS projects, experimental design, and the requirements used to select projects.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: The SPS projects provide tremendous value to the pavement community. They can be used to compare various pavement features, develop prediction tools, and study the effect of in situ conditions on performance. The experimental design was established to obtain a comprehensive set of test sections covering a wide array of climatic, traffic, and subgrade conditions across the United States and Canada.

Future Benefit: The wealth of data collected at the SPS projects will continue to provide value. The information will be useful in calibrating/validating the M-E PDG as well as supplementing ongoing and future research endeavors. Documentation on the structure and design of a large scale, national program can be applied to other initiatives. One such example is the Long Term Bridge Performance program.

Title: Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-1: Strategic Study of Structural Factors for Flexible Pavements

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The objective of this study is to more precisely determine the relative influence of strategic factors that influence the performance of flexible pavements. The factors addressed in this study include drainage, base type and thickness, and asphalt surface thickness. The study objective includes a determination of the influence of environmental region and soil type on these factors. This report includes a revised experimental design for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment on SPS-1, "Strategic Study of Structural Factors for Flexible Pavements" that incorporates recommended changes. Based on comments received, the experimental plan has been revised to increase the minimum asphalt surface thickness and thus extend the performance period for heavily trafficked sites, and to add test sections with different base thicknesses to enable better evaluation of the effect of base thickness and type.

Application/Use: This report can be used by those interested in the SPS-1 experiment.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-1 experiment and provides background on the objectives of the project.

Each SPS-1 project provides a direct side-by-side performance comparison of various flexible pavement design features while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of design features on performance. Policy decisions can then be made on design practices. The SPS-1 experiment as a whole can be used to predict performance, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between design features and in situ conditions. These are all extremely beneficial to improving the performance of flexible pavements.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-1 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-1 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous structural factors on flexible pavement performance.

Title: Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-2: Strategic Study of Structural Factors for Rigid Pavements

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The objective of this study is to more precisely determine the relative influence of strategic factors that influence the performance of rigid pavements. The factors addressed in this study include drainage, base type, concrete strength and thickness, and lane width. Other factors addressed in the study include load transfer, joint orientation, and reinforcement. The study objective includes a determination of the influence of environmental region and soil type on these factors. This report describes the experimental design for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment on SPS-2, Strategic Study of Structural Factors for Rigid Pavements.

Application/Use: This report can be used by those interested in the SPS-2 experiment.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-2 experiment and provides background on the objectives of the project.

Each SPS-2 project provides a direct side-by-side performance comparison of various rigid pavement design features while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of design features on performance. Policy decisions can then be made on design practices. The SPS-2 experiment as a whole can be used to predict performance, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between design features and in situ conditions. These are all extremely beneficial to improving the performance of rigid pavements.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-2 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-2 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous structural factors on rigid pavement performance.

Title: Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-7: Bonded Portland Cement Concrete Overlays

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The objective of this study is measure the additional pavement life that results from the use of bonded concrete overlays, evaluate the effectiveness of surface preparation techniques, and investigate the influence of climate on the performance of bonded concrete overlays. The proposed experiment encompasses overlays on jointed plain, jointed reinforced and continuously reinforced concrete pavements. The factors to be addressed in this experiment include surface preparation, use of bonding grout, and overlay thickness. The experimental designs and research plans presented here for Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-7, were adapted from General Pavement Studies experiment on bonded concrete overlays originally described in the May 1986, "Strategic Highway Research Program Research Plans," issued by the Transportation Research Board.

Application/Use: This report can be used by those interested in the SPS-7 experiment.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-7 experiment and provides background on the objectives of the project.

Each SPS-7 project provides a direct side-by-side performance comparison of various bonded concrete overlay design alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of design features on performance. Policy decisions can then be made on design practices. The SPS-7 experiment as a whole can be used to predict performance, estimate service life extension due to overlays, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of bonded concrete overlays.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-7 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well.

Title: Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-2: Strategic Study of Structural Factors for Rigid Pavements

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This document provides guidelines and information for nominating candidate projects for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-2, "Strategic Study of Structural Factors for Rigid Pavements," and outlines participation requirements. Detailed project nomination forms and instructions are included in this document.

Application/Use: This report can be used by those interested in the SPS-2 experiment.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-2 experiment and provides background on the objectives of the project. This document also summarizes the requirements for a project to be included in the LTPP program.

Each SPS-2 project provides a direct side-by-side performance comparison of various rigid pavement design features while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of design features on performance. Policy decisions can then be made on design practices. The SPS-2 experiment as a whole can be used to predict performance, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between design features and in situ conditions. These are all extremely beneficial to improving the performance of rigid pavements.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-2 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-2 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous structural factors on rigid pavement performance.

Title: Specific Pavement Studies Construction Guidelines for Experiment SPS-5: Rehabilitation of Asphalt Concrete Pavements

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This document describes the guidelines for the construction of test sections for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-5, Rehabilitation of Asphalt Concrete Pavements. This experiment requires the construction of multiple test sections with similar details and materials at each of sixteen sites equally distributed in the four climatic regions. The experiment has been developed as a coordinated national experiment to address the needs of the highway community at large, and not only the participating highway agencies. Therefore, it is important to control construction uniformity at all test sites to reduce the influence of construction variability on test results.

Application/Use: This report can be used by those interested in the SPS-5 experiment.

Contribution: Improvement in Knowledge

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-5 experiment and provides background on the objectives of the project.

Each SPS-5 project provides a direct side-by-side performance comparison of various flexible rehabilitation alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of rehabilitation features on performance. Policy decisions can then be made on design practices. The SPS-5 experiment as a whole can be used to predict performance, estimate service life extension due to overlays, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of flexible rehabilitation treatments.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-5 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-5 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous rehabilitation strategies on flexible pavement performance.

Title: Specific Pavement Studies Construction Guidelines for Experiment SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This document describes the guidelines for the construction of test sections for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-6, Rehabilitation of Jointed Portland Cement Concrete Pavements. This experiment requires the construction of multiple test sections with similar details and materials at each of twenty-four sites distributed in the four climatic regions. The experiment has been developed as a coordinated national experiment to address the needs of the highway community at large, and not only the participating highway agencies. Therefore, it is important to control construction uniformity at all test sites to reduce the influence of construction variability on test results.

Application/Use: This report can be used by those interested in the SPS-6 experiment.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-6 experiment and provides background on the objectives of the project.

Each SPS-6 project provides a direct side-by-side performance comparison of various rigid rehabilitation alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of rehabilitation features on performance. Policy decisions can then be made on design practices. The SPS-6 experiment as a whole can be used to predict performance, estimate service life extension due to rehabilitation, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of rigid rehabilitation treatments.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-6 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-6 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous rehabilitation strategies on rigid pavements.

Title: Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-7: Bonded Portland Cement Concrete Overlays

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This document provides guidelines and information for nominating candidate projects for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-7, Bonded Portland Cement Concrete Overlays, and outlines participation requirements. Detailed project nomination forms and instructions are included in this document.

Application/Use: This report can be used by those interested in the SPS-7 experiment.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-7 experiment and provides background on the objectives of the project. This document also summarizes the requirements for a project to be included in the LTPP program.

Each SPS-7 project provides a direct side-by-side performance comparison of various bonded concrete overlay design alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of design features on performance. Policy decisions can then be made on design practices. The SPS-7 experiment as a whole can be used to predict performance, estimate service life extension due to overlays, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of bonded concrete overlays.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-7 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well.

Title: Validation in the SHRP Asphalt Research Program (October, 1991)

Authors: Kennedy, T. W; Moulthrop, J; Cominsky, R. J; Harrigan, E. T; Leahy, R. B; Von Quintus, H.

Date: 1990

Publisher: Strategic Highway Research Program

Abstract/Synopsis: A three stage validation process is described: the first two stages to be completed during its life and the final stage subsequent to March, 1993 as part of the ongoing Long Term Pavement Performance program. The first stage confirms that variation of asphalt binder properties identified as probable, significant determinants of pavement performance, yield physically reasonable, meaningful changes in relevant performance characteristics of asphalt-aggregate mixes. Details of the second stage validation are described including the direct correlation method and the indirect/mechanistic method. Post SHRP (Strategic Highway Research Program) third stage validation will offer the opportunity for refinement of those specifications through the LTPP Specification Pavement Study 9, Validation of Performance-Based Specifications and Mix Design and Analysis System.

Application/Use: This paper can be used by those interested in Superpave mixtures.

Contribution: Improvement in Knowledge

Present Benefit: The SPS-9 project provides an excellent source for direct comparisons between Superpave and agency standard mixtures. The performance data available at these sites can be used to understand differences in service life between the various mixtures and will help agencies modify Superpave mixtures for local conditions.

Future Benefit: The SPS-9 projects will continue to provide value and may be used to calibrate the M-E PDG to local conditions.

Title: Specific Pavement Studies Experimental Design and Research Plan for Experiment SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements

Date: 1989

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The objective of this study is to develop improved performance prediction models to be used for determining the additional pavement life that can be expected from application of a variety of jointed plain concrete (JPC) and jointed reinforced concrete (JRC) pavement rehabilitation methods and strategies ranging from minimal to maximal investment in the rehabilitation treatment. The treatments being studied include combinations of surface preparations, with and without asphalt concrete (AC) overlay, as well as crack and seat preparation with AC overlay. The study objective includes a determination of the influence of environmental region and initial pavement condition on the effectiveness of rehabilitation methods. The experimental designs and research plans presented here for Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-6, were adapted from the Specific Pavement Studies on restoration of jointed concrete pavements (JCP) and pretreated JCP with AC overlay originally described in the May 1986, "Strategic Highway Research Program Research Plans," issued by the Transportation Research Board.

Application/Use: This report can be used by those interested in the SPS-6 experiment.

Contribution: Cost Savings, Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-6 experiment and provides background on the objectives of the project.

Each SPS-6 project provides a direct side-by-side performance comparison of various rigid rehabilitation alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of rehabilitation features on performance. Policy decisions can then be made on design practices. The SPS-6 experiment as a whole can be used to predict performance, estimate service life extension due to rehabilitation, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of rigid rehabilitation treatments.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-6 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-6 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous rehabilitation strategies on rigid pavements.

Title: Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-5: Rehabilitation of Asphalt Concrete Pavements

Date: 1989

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This document provides guidelines and information for nominating candidate projects for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-5, "Rehabilitation of Asphalt Concrete Pavements," and outlines participation requirements. Detailed project nomination forms and instructions are included in this document.

Application/Use: This report can be used by those interested in the SPS-5 experiment.

Contribution: Cost Savings, Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-5 experiment and provides background on the objectives of the project. This document also summarizes the requirements for a project to be included in the LTPP program.

Each SPS-5 project provides a direct side-by-side performance comparison of various flexible rehabilitation alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of rehabilitation features on performance. Policy decisions can then be made on design practices. The SPS-5 experiment as a whole can be used to predict performance, estimate service life extension due to overlays, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of flexible rehabilitation treatments.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-5 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-5 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous rehabilitation strategies on flexible pavement performance.

Title: Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements

Date: 1989

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This document provides guidelines and information for nominating candidate projects for the Strategic Highway Research Program (SHRP) Long Term Pavement Performance (LTPP) Specific Pavement Studies experiment SPS-6, "Rehabilitation of Jointed Portland Cement Concrete Pavements," and outlines participation requirements. Detailed project nomination forms and instructions are included in this document.

Application/Use: This report can be used by those interested in the SPS-6 experiment.

Contribution: Cost Savings, Improvement in Knowledge; Implementation/Usage.

Present Benefit: Significant effort was devoted to the experimental design, structure, data requirements, and performance monitoring of LTPP test sites. Documentation of these efforts is available to those who are interested in the SPS-6 experiment and provides background on the objectives of the project. This document also summarizes the requirements for a project to be included in the LTPP program.

Each SPS-6 project provides a direct side-by-side performance comparison of various rigid rehabilitation alternatives while keeping other confounding features (i.e., subgrade, traffic, and climate) constant. This allows researchers to evaluate the effectiveness of rehabilitation features on performance. Policy decisions can then be made on design practices. The SPS-6 experiment as a whole can be used to predict performance, estimate service life extension due to rehabilitation, evaluate the effects of traffic, climate, and subgrade on performance, and investigate the interaction between overlay alternatives and in situ conditions. These are all extremely beneficial to improving the performance of rigid rehabilitation treatments.

Future Benefit: The LTPP project was instrumental in the development of the M-E PDG. The SPS-6 project will provide future benefit in the local calibration/validation of the guide during the implementation phase. Documentation on the design of the LTPP experiments can be applied to the implementation of future research endeavors as well. As the SPS-6 sections reach the end of their service lives, sufficient data will be available to allow researchers to evaluate the impacts of numerous rehabilitation strategies on rigid pavements.