Year	Title	Author(s)
2009	Artificial Neural Networks and Regression Analysis for Predicting Faulting in Jointed Concrete Pavements Considering Base Condition	Saghafi, Behrooz; Hassani, Abolfazl; Noori, Roohollah; Bustos, Marcelo Gaston
2009	Development of Critical Tensile Strain Criterion to Evaluate Fatigue Cracking using Field Performance Data of Existing Pavement Sections of the States of Rhode Island and New Jersey	Jha, V; Saridaki, E; Metha, Y A; Manning, F J; Byrne, M.P.
2009	A Systematic Approach of Field Calibration of Fatigue Equation for Asphalt Pavements	Rajbongshi, Pabitra; Das, Animesh
2009	Evaluating the Utility of Existing Pavement Management System State Deflection Data for Use in the Implementation of the ME-PDG for Arizona	Cary, Carlos; Zapata, Claudia E.
2009	Detailed Profile Analysis on the Arizona SPS-5 Project	Karamihas, Steve M; Senn, Kevin Andrew
2009	Evaluation of LTPP Profile Data for Flexible Pavements	Corley-Lay, Judith B; Mastin, Jeffery
2009	Quality Management of Network-Level Pavement Condition Data Collection: Current Methods and Practices	Hudak, Jordan; Flintsch, Gerardo W; McGhee, Kevin Kenneth
2008	Enhancing Pavement Management System Analyses Through Consideration of Construction Quality	Zaghloul, Sameh; Chowdhury, Tanveer Holland, T Joseph
2008	Development of Asphalt Pavement Transverse Crack Initiation Models Based on LTPP Dat	Hong, Feng; Rosales-Herrera, Vanessa Ivette; Prozzi, Jorge A.
2008	Trends in Deflection with Application of Repeated Loads: Impact on Deflection Data Averaging	Schmalzer, Peter Nils; Thompson, Travis R; Simpson, Amy
2008	Pavement Performance Evaluation and Prediction Based on Extension Theory	Li, Qiang; Wang, Kelvin C.P.
2008	Robust Optimization for Managing Pavement Maintenance and Rehabilitation	Gao, Lu; Zhang, Zhanmin
2008	Profile Analysis of the LTPP SPS-5 Site in Arizona	Karamihas, Steven M.
2008	Regression Models for Permanent Deformation Parameters using In-Service Pavement Data from the SPS-1 Experiment	Salama, Hassan Kamal; Chatti, Karim; Haider, Syed Waqar
2008	Long Term and Seasonal Variations of Pavement Surface Friction	Ahammed, M.A; Tighe, S.L.
2008	LTPP Manual for Profile Measurements and Processing	Perera, R W; Kohn, S D; Rada, G.R.
2008	Calibration of HDM-4 road deterioration models and development of works effects models for	Martin, T; Choummanivong, L.

	Australian conditions	
2008	Effectiveness of Asphaltic Concrete Overlays of Rigid Highway Pavements Using LTPP SPS-6 Data	Khurshid, Muhammad Bilal; Irfan, Muhammad; Labi, Samuel A; Sinha, Kumares C.
2007	Dynamic Time Domain Backcalculation of FWD Data	Liu, Ming-Lou; Chuang, Yi-Fang; Chuang, Jui-Chang
2007	Nondestructive Evaluation of Iowa Pavements: Phase I	

2006	Assessment of Overlay Roughness in the LTPP--A Canadian Case Study	Smith, James Trevor; Tighe, Susan L.
2006	Development of Roughness Deterioration Models for National Park Service Network	Helali, Khaled, et al
2006	Effects of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost	Jackson, N; Puccinelli, J.
2006	LTPP Falling Weight Deflectometer Maintenance Manual	Belt, Robin; Morrison, Tyler; Weaver Eric
2006	Guidelines for the Collection of Long-Term Pavement Performance Data	Simpson, A. L; Ostrom, B K; Schmalzer, P. N
2006	LTPP Manual for Falling Weight Deflectometer Measurements, Version 4.1	Schmalzer, Peter
2006	Profile Data Variability in Pavement Management: Findings and Tools from LTPP	Yin, Hao; Stoffels, Shelley M; Antle, Charles A.
2006	Quantification of Smoothness Index Differences Related to LTPP Equipment Type	
2006	Simple Model for Structural Evaluation of Asphalt Concrete Pavements at the Network Level	Agarwal, Pradeep Kumar; Das, Animesh; Chakroborty, Partha
2006	Statistical Analysis Between Roughness Indices and Roughness Prediction Model Using Neural Networks	Oliveira de Souza, Ricardo, et al
2006	Use of LTPP Data to Verify the Acceptance Limits Developed for PennDOT Pavement Distress Data	Ganesan, Venkatesa Prasanna Kumar, et al
2005	Digital Image Processing for Pavement Distress Analyses	Teomete, Egemen, et al
2005	The Effect of Faulting on IRI Values for Jointed Concrete Pavements	Byrum, Christopher R; Perera, Rohan W
2005	Evaluation of the Cost Benefits of Continuous Pavement Preservation Design Strategies versus Reconstruction	Smith, K.L, et al
2005	LTPP ProQual 2005 User Guide Documentation	Macpherson, Donald; Olmedo, Chris; Merrill, Cory
2005	Quantification of Smoothness Index Differences Related to Long-Term Pavement Performance Equipment Type	Perera, R. W; Kohn, S. D.
2005	Transforming LTPP Distress Information for Use in MTC-PMS	Dewan, Shameem A.
2005	Wavelet Analysis and Interpretation of Road Roughness	Wei, Liu; Fwa, T. F; Zhe, Zhao

Year	Title	Author(s)
2004	Collection and Interpreting Long-Term Pavement Performance Photographic Distress Data: Quality Control - Quality Assurance Processes	Rada, G R; Simpson, A. L; Hunt, J. E.
2004	LTPP Manual for Profile Measurements and Processing, Version 4.1	Perera, R.W., Kohn, S.D., and Rada, G.R.
2004	ProVAL	
2004	Slurry Seal / Micro-Surface Mix Design Procedure	
2004	Use of Artificial Neural Networks for Predicting Rigid Pavement Roughness	Teomete, Egemen, et al
2003	Automated Pavement Analysis in Missouri Using Ground Penetrating Radar	Cardimona, S., et al
2003	Distress Identification Manual for the Long-Term Pavement Performance Program (Fourth Revised Edition)	Miller, John S; Bellinger, William Y.
2003	Distress Data Consolidation Final Report	Simpson, A. L; Daleiden, J. F.
2003	Flexible Pavements - Results of Vicroads Pavement Performance Monitoring Program	Papacostas, A; Bowman, A.
2003	PCC Joint Faulting Measurements at the Mn/ROAD Project	Burnham, Tom
2003	Prediction of Longitudinal Roughness Using Neural Network	Farias, M. M; Neto, SAD; Souza, R. O.
2002	Application Notes: FWD Calibration Centers Ensure States Get Quality Data	Richter, Cheryl
2002	Benefiting from LTPP - A State's Perspective	Hoffman, G.
2002	Issues in Pavement Smoothness: A Summary Report	Perera, R. W; Kohn, S. D.
2002	LTPP Data Analysis: Factors Affecting Pavement Smoothness	Perera, R. W; Kohn, S. D.
2002	LTPP Distress Identification Manual Sets a Standard for States: Illinois, Michigan, Mississippi, Missouri, Nevada, and Oklahoma Use Manual as a Baseline for Identifying and Quantifying Distresses	
2002	Utilizing the Long-Term Pavement Performance Database in Evaluating the Effectiveness of Pavement Smoothness	Ksaibati, K; Mahmood, S. A.
2001	Adequacy of Rut Bar Data Collection	
2001	Assessing Variability of Surface Distress Surveys in Canadian Long-Term Pavement Performance Program	Goodman, S. N.
2001	Characterization of Transverse Profiles	Simpson, A. L.
2001	Key Findings from LTPP Distress Data	
2001	Survey of Current Practices of Using Falling	Nazef, Abdenour;

	Weight Deflectometers (FWD)	Choubane, Bouzid
Year	Title	Author(s)
2000	Analysis by High-Speed Profile of Jointed Concrete Pavement Slab Curvatures	Byrum, C. R.
2000	LTPP Data Analysis: Relative Performance of Jointed Plain Concrete Pavement with Sealed and Unsealed Joints	Hall, K. T; Crovetti, J. A.
2000	LTPP Profile Variability	Evans, L. D; Eltahan, A.
2000	NDT Approach to Monitoring PCC Deterioration Due to D-Cracking in Highway Pavements	Kumapley, R. K; Kumapley, N. K.
2000	Variability of Pavement Distress Data from Manual Surveys	
1999	Assessment of LTPP Friction Data	Titus-Glover, L; Tayabji, S. D.
1999	Characterization of Transverse Profile	Simpson, A. L.
1999	Study of LTPP Distress Data Variability, Volume I	Rada, G. R., et al
1999	Study of LTPP Distress Data Variability, Volume II: Appendix A, Appendix B, and Appendix C	Rada, G. R., et al
1999	Working with Your FWD Calibration Center Videotape	
1998	Assessment of Long-Term Pavement Performance Plan Wall Projection-Based Distress Data Variability	Shekharan, A. R; Rada, G. R; Elkins, G. E; Bellinger, W. Y
1998	Establishment of a Falling Weight Deflectometer Calibration Facility	Hossain, M.
1998	Investigation of Development of Pavement Roughness	Perera, R. W; Byrum, C; Kohn, S. D.
1998	“Off-The-Wall” Pavement Distress Variability Study	Daleiden, J. F; Simpson, A. L.
1998	Update of Long-Term Pavement Performance Manual Distress Data Variability: Bias and Precision	Rada, G. R., et al
1997	Analysis of LTPP Profile Data for Jointed Concrete Pavement Sections	Moody, E. D.
1997	Assessment of Long-Term Pavement Performance Program Manual Distress Data Variability: Bias and Precision	Rada, G. R; Bhandari, R K; Elkins, G. E; Bellinger, W. Y.
1997	Capabilities of Multimedia Pavement Distress Identification Training	Lake, A. I; Van Dam, T. J; Zimmerman, K. A.
1997	LTPP Data Analysis: Frequently Asked Questions About Joint Faulting with Answers from LTPP	
1996	Prediction of Pavement Remaining Life	Vepa, T. S; George, K. P; Shekharan, A. R.
1995	Pavement Management System - Phase II. Final	George, K. P.

	Report	
Year	Title	Author(s)
1995	Quality Standards for Reliable Pavement Roughness Evaluation	Henderson, B; Phang, W. A; Richter, C.
1994	Evaluation of Strategic Highway Research Program—Long-Term Pavement Performance Surface Distress Data Collection Procedures	Daleiden, J. F; Simpson, A. L.
1994	Ground Penetrating Radar Surveys to Characterize Pavement Layer Thickness Variations at GPS Sites	Maser, K.
1994	SHRP-LTPP Monitoring Data: Five-Year Report	Rada, G. R.
1993	Accreditation for the Long-Term Pavement Performance Studies Pavement Distress Raters	
1993	Accreditation of Strategic Highway Research Program Long-Term Pavement Performance Pavement Distress Raters	Rada, G. R; Miller, J. S; Bellinger, W. Y; Rogers, R. B.
1993	Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity. FWDCheck Version 2.00. Volume III - Program Listing	
1993	Design Specifications and Implementation Requirements for a Texas Long-Term Pavement Performance Program. Interim Report	Saeed, A; Hudson, W. R; Dossey, T; Weissmann, J.
1993	Distress Interpretation from 35mm Film for the LTPP Experiments	
1993	Falling Weight Deflectometer Relative Calibration Analysis	
1993	High-Tech Deflectometers Aid PMS	Harrington-Hughes, K.
1993	Pacific Rim Trans Tech Conference Proceedings. Volume II. Design Implications for Concrete Pavement from LTPP Analyses	Owusu-Antwi, E; Darter, M. I; Ahmad, R.
1993	Photographic Pavement Distress Record Collection and Transverse Profile Analysis	Gramling, W. L; Hunt, J. E.
1992	Data Readability and Completeness FWDScan Version 1.30 Program Background and User's Guide	
1992	Effects of Buffers on Falling Weight Deflectometer Loadings and Deflections (with Discussion)	Lukanen, E. O.
1992	Strategic Highway Research Program Falling Weight Deflectometer Quality Assurance Software	Rada, G. R; Rabinow, S. D; Witczak, M. W; Richter, C. A.
1991	Non-Destructive Testing in SHRP's Long-Term	Richter, C. A; Witczak,

	Pavement Performance Studies	M. W.
Year	Title	Author(s)
1991	Using Strip Films to Record Pavement Distress in the Strategic Highway Research Program: Long-Term Pavement Performance Study	de Solminihac, H; Roper, H.
1990	Condition Surveys in the Strategic Highway Research Program Long-Term Pavement Performance Study and Pavement Condition Rating for Pre-Overlay Conditions (Abridgment)	Goulias, D. G; Castedo, H; Hudson, W. R.
1990	Performance Monitoring and Data Acquisition for Pavement Performance Evaluation. Proceedings of Strategic Highway Research Program and Traffic Safety on Two Continents, Gothenburg, Sweden, 27-29 September 1989	Richter, C. A.

Title: Applicability of the International Roughness Index as a Predictor of Asphalt Pavement Condition

Author(s): Park, Kyungwon; Thomas, Natacha E; Lee, K Wayne

Date: December 2007

Publisher: Journal of Transportation Engineering Vol. 133 No. 12; American Society of Civil Engineers

Abstract/Synopsis:
This note establishes the relationship between the surface distress of an asphalt pavement and its roughness, as conveyed respectively by the pavement condition index (PCI) and the international roughness index (IRI). The DataPave software provides the roughness of varied roadway pavement sections from the North Atlantic region that were investigated under the long term pavement performance (LTPP) study. The MicroPAVER1 software system computes the condition of the same sections using cross-referenced distress data from DataPave. A transformed linear regression model predicts pavement condition given roughness. It confirms the acceptability of the IRI as a, albeit not the sole, predictor variable of the PCI whereby the former accounts for the majority, close to 59%, of the variations in the latter. Further, an analysis of variance confirms the existence of a strong relationship between both variables.

Application/Use: The results from this project are directly applicable to pavement managers.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: Pavement roughness plays a large role in overall pavement performance. Therefore the ability to predict the pavement condition based on the IRI, is a useful tool for pavement managers and can assist them in effectively prioritizing their maintenance backlog. The LTPP program provided the IRI data needed to generate this regression model, relating IRI to pavement condition.

Future Benefit: Since pavement performance can be significantly dependent upon the pavement IRI, it is important to gain a better understanding of this relationship. The LTPP database has a vast amount of data that will continue to aid pavement researchers and engineers better understand the dominant factors affecting pavement performance and will assist in developing ways to quantify these effects so that resources can be strategically focused to address those needs.

Title: Pavement Management; Monitoring, Evaluation, and Data Storage; and Accelerated Testing 2007

Author(s): Transportation Research Board

Date: 2007

Publisher: Transportation Research Record: Journal of the Transportation Research Board No. 1990, Transportation Research Board

Abstract/Synopsis:
This collection of 17 papers is concerned with the management and monitoring of pavements, as well as their evaluation, data storage and accelerated testing. Among the topics discussed are gray theory-based prediction of pavement smoothness, condition measurement, a damage model to analyze stabilized soil layers, the length of the resurfacing cycle, video logging, long-term pavement restoration, calculating the runway pavement classification number, quality assurance/quality control, maintenance contracts, life-cycle cost analysis, frost effects, service life of Long-Term Pavement Performance Program pavements, network-level falling weight deflectometer testing, automated pavement distress data collection, transient dynamic loading, nonlinear elastic models for unbound granular materials, and mechanistic analyses of pavements.

Application/Use: The results from this study are applicable to pavement management, monitoring, and accelerated testing as well as holding applications for data storage and evaluation.

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

Present Benefit: The ability to monitor and manage pavements effectively is an ongoing challenge for pavement engineers. Furthermore, this data collection process can be costly, so it is also imperative to effectively evaluate and store the data once it has been collected so that pavement managers can fully capitalize on effectively improving their pavement network. The LTPP program has developed various protocols for monitoring and managing pavements as wells as effective methods for evaluating and storing monitored data.

Future Benefit: Agencies can obtain a significant cost savings as they utilize the methods from this research compilation to more effectively manage their pavement network. The LTPP program has made significant advancements in properly monitoring and managing pavements, and in handling and evaluating that collected data.

Title: Profile Analysis of the LTPP SPS-1 Site in Arizona

Author(s): Karamihas, Steven M.

Date: May, 2007

Publisher: University of Michigan Transportation Research Institute

Abstract/Synopsis:
This report characterizes the longitudinal profiles of sixteen pavement sections within the Arizona Specific Pavement Studies 1 project throughout their service life. This project was built and monitored as part of the Long-Term Pavement Performance Study. Road profile measurements were collected on this site about once per year since the winter after it was opened to traffic. This study analyzed the profiles in detail by calculating their roughness values, examining the spatial distribution of roughness within them, viewing them with post-processing filters, and examining their spectral properties. These analyses provided details about the roughness characteristics of the road and provided a basis for quantifying and explaining the changes in roughness with time, as well as linking profile properties to each section's maintenance history and observations of surface distress.

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 benefits for this study are a better understanding in the interaction between pavement roughness and surface distress, as well as understanding the change in pavement roughness over time. The LTPP database provides a means of conducting this type of study on a national scale.

Future Benefit: As pavement design continues to move toward mechanistic-empirical design methods, this study and the LTPP program will continue to be an invaluable asset for pavement engineers to more accurately quantify the effect of pavement roughness on pavement performance and accurately relating pavement roughness to surface distress. The future benefit of this study is a significant cost savings as pavement engineers can be more strategic in maintaining and rehabilitating their pavement network by considering the effects of pavement roughness.

Title: Profile Analysis of the LTPP SPS-9A Site in Arizona

Author(s): Karamihas, Steven M.

Date: May 2007

Publisher: University of Michigan Transportation Research Institute

Abstract/Synopsis:
This report characterizes the longitudinal profiles of eight pavement sections within the Arizona Specific Pavement Studies 9A project throughout their service life. This project was built and monitored as part of the Long-Term Pavement Performance Study. SPS-9A sites were designed to compare Superpave mix performance with that of standard mix designs. This report covers site 04B900. Road profile measurements were collected on this site about once per year since the winter after it was opened to traffic. This study analyzed the profiles in detail by calculating their roughness values, examining the spatial distribution of roughness within them, viewing them with post-processing filters, and examining their spectral properties. These analyses provided details about the roughness characteristics of the road and provided a basis for quantifying and explaining the changes in roughness with time, as well as linking profile properties to each section's maintenance history and observations of surface distress.

Application/Use: The result of this paper is applicable to pavement designers and rehabilitation engineers dealing with pavement roughness and its effect on pavement performance.

Contribution: Improvement in Knowledge

Present Benefit: Pavement roughness plays a large role in overall pavement performance. This ability to quantify the change in pavement roughness over time is a valuable tool for pavement managers as it will enable them to be more strategic in planning maintenance and rehabilitation methods in their pavement networks. The LTPP program offered the foundational data for this research project.

Future Benefit: Because pavement roughness can be a large factor on the pavement condition, IRI data from the LTPP program will continue to provide a better understanding regarding how pavement roughness affects overall pavement performance.

Title: Effectiveness of Asphaltic Concrete Overlays of Rigid Highway Pavements Using LTPP SPS-6 Data

Author(s): Khurshid, Muhammad Bilal; Irfan, Muhammad; Labi, Samuel A; Sinha, Kumares C.

Date: 2008

Publisher: Transportation Research Board 87th Annual Meeting

Abstract/Synopsis:
Pavement rehabilitation, a key aspect of pavement management, aims at improving pavement condition and extending pavement life. As such highway agencies strive to identify and implement effective rehabilitation practices to preserve the large investments made in the highway pavement infrastructure and increasingly do so using observational and experimental studies. LTPP's SPS-6 experiment was set up to assist highway agencies identify effective and efficient treatments for rigid pavement rehabilitation. Using data from LTPP database and other sources, the present paper evaluated the effectiveness of five rehabilitation treatments under this experiment. The performance measures used are the increase in pavement condition and the treatment service life. For each rehabilitation treatment, the evaluation involved the construction of post-treatment performance curves. The study determined that the pre-treatment condition is a significant predictor of the post-treatment performance. The paper also suggests that for a given traffic load, increasing climate severity translates into lower treatment effectiveness. Also, for a given climate severity, increasing traffic load translates into lower treatment effectiveness. At high traffic loads, there seem to be little difference in treatment effectiveness across various climate severities. The "crack-and-seat existing pavement and 8-inch AC overlay" was adjudged the most effective in terms of both service life and increase in average pavement condition, irrespective of SHRP regional group. The methodology and findings of this paper can be useful to highway managers who seek to assess or compare the effectiveness of their treatments and to carry out the pavement management functions of life-cycle analysis and work planning.

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 performance of asphalt overlays over rigid pavements, addressing their effectiveness in high traffic conditions and severe climates. This is important to designers attempting to select the most appropriate overlay design with consideration given to end user cost and perception. The LTPP database was a significant resource for this project.

Future Benefit: The evaluation conducted as part of this project will continue to be useful. Currently, rehabilitation is the most common type of major asphalt concrete

pavement improvement. Quantifying the impact of asphalt overlay thicknesses in various climate and traffic conditions is of great benefit. The LTPP database significantly contributed to this project and will continue to be a valuable resource in further advancements in the pavement industry.

Title: Experimentation with Gray Theory for Pavement Smoothness Prediction

Author(s): Wang, Kelvin C P; Li, Qiang; Hall, Kevin D; Elliott, Robert P.

Date: 2007

Publisher: Transportation Research Record: Journal of the Transportation Research Board No. 1990, Transportation Research Board

Abstract/Synopsis:
Riding quality is a dominant characteristic of pavement performance. In the proposed mechanistic–empirical pavement design guide (MEPDG), the functional performance indicator is pavement smoothness as indicated by the international roughness index (IRI). The MEPDG IRI prediction models were developed on the basis of a general hypothesis in which changes in smoothness are caused in part by various distresses, which can be predicted. With pavement distress data from the Long-Term Pavement Performance (LTPP) database, traditional regression analysis was used statistically to establish the MEPDG prediction equations. The gray system theory was devised in the 1980s for modeling uncertain systems with the characteristics of partially known information. A pavement performance prediction system can fit the domain of the gray system. The gray theory–based prediction method was used to develop IRI prediction equations. With the data exported from the LTPP database, it was found that certain specific distresses significantly affect the accuracy of the predictions. Combined with the results of gray relational analysis and the gray prediction methodology, gray model–based smoothness predictions are established by using influencing factors similar to those used in MEPDG. From comparisons of results from the two prediction methodologies with actual LTPP data, it is shown that the gray model–based method provides promising results and is useful for modeling pavement performance.

Application/Use: The paper can be used by those interested in pavement roughness predictions.

Contribution: Improvement in Knowledge

Present Benefit: The study provides comparisons between two roughness prediction models: the MEPDG, and the gray model. This comparison is beneficial because it introduces an additional prediction tool (the gray model) and studies the output of this model relative to the MEPDG model.

Future Benefit: The LTPP database will continue providing data that will allow evaluations of new and existing prediction models. The study at hand may be used further in new modeling techniques.

Title: Changes in Key Flexible Pavement Condition Measurements for Typical Warranty Periods

Author(s): Stroup-Gardiner, Mary; Zech, Wesley Charles; Rathod, Jignesh

Date: 2007

Publisher: Transportation Research Record: Journal of the Transportation Research Board No. 1990, Transportation Research Board

Abstract/Synopsis:

The Long-Term Pavement Performance (LTPP) DataPave database was used to extract pavement condition and limited structural information along with traffic data for 191 randomly selected new asphalt pavement sections from across the country. Pavement performance data were limited to the collection of longitudinal cracking in the wheelpaths, fatigue cracking, and transverse cracking. Rather than models for the type and extent of pavement distresses with age, a simplified process that coded the database for the first occurrence of a given distress in each of the 191 new test sections was developed. This approach was used to determine the percentage of pavements exhibiting a given type of distress at 3, 5, 7, 10, 15, and 20 years. The results indicate the following: at 3 years, no longitudinal, fatigue, or transverse cracking is present; at 5 years, less than 2% of the sections experienced longitudinal (wheelpath), fatigue, or transverse cracking; at 7 years, between 3% and 6% of the sections exhibited longitudinal, fatigue, or thermal cracking; at 15 years, approximately 50% of sections showed signs of cracking distresses; at 20 years, between 60% and 70% of the sections contained excessive cracking.

Contribution: The results from this paper are applicable to pavement managers and maintenance engineers interested in changes in pavement condition for typical warranty periods.

Contribution: Cost Savings, Improvement in Knowledge; Lessons Learned

Present Benefit: A better understanding of pavement deterioration over time is a powerful tool for pavement engineers. This project was able to simply depict the deterioration of pavement conditions over typical warranty periods so that pavement engineers can better plan for implementing warranty programs and allocate funds strategically to meet those needs. The observations made from this project were heavily dependent upon the LTPP database.

Future Benefit: One of the challenges pavement engineers face is being able to accurately predict the future conditions of the pavements in their network and strategically plan to meet those needs. Pavement warranties are another tool to assist in optimizing available resources. The LTPP database will continue to be an invaluable resource for better understanding changes in pavement condition over time and will assist pavement engineers plan and strategically allocate funds to meet those needs.

Title: Updated LTPP Manual Distress Data Bias and Precision Estimates

Author(s): Rada, Gonzalo R; Simpson, Amy L; Elkins, Gary E.

Date: 2007

Publisher: Transportation Research Board 86th Annual Meeting, Transportation Research Board

Abstract/Synopsis:
Distress data are an important element of the Long-Term Pavement Performance (LTPP) program since distresses are a primary performance measure. To promote distress data uniformity and consistency, standard definitions, measurement procedures, equipment, data collection forms and distress rater accreditation workshops were implemented. Since distress identification and quantification requires subjective interpretation by a rater, rater variability is a primary concern. The level of variability in the LTPP manually collected distress data was first quantified in 1997 based on the data from nine rater accreditation workshops. An additional 13 distress rater accreditation workshops have been conducted since, more than doubling the amount of data previously available. This follow-up study was undertaken to examine possible changes to the original bias, precision and variability of the data. The results of this update show that little change has occurred since 1997 and provide confirmation of the results of the previous study.

Application/Use: The results from this paper are applicable to pavement engineers and those interested in the distress data precision, particularly as related to the variability of the distress raters.

Contribution: Improvement in Knowledge; Advancement in Technology

Present Benefit: The LTPP database is a valuable tool for pavement researchers and engineers. Therefore, it is important that the data is examined to ensure that it is consistent and reliable. The results from this program verified data consistency and showed the reliability of the distress data in the LTPP database.

Future Benefit: The LTPP database will continue to be an invaluable resource for pavement researchers and engineers. Much advancement in the pavement industry will heavily depend upon the reliability and the accuracy of the LTPP data, and in understanding the variability of pavement-related date.

Title: Forwardcalculation of Pavement Moduli with Load-Deflection Data

Author(s): Stubstad, Richard N; Jiang, Y Jane; Lukanen, Erland O.

Date: 2007

Publisher: Transportation Research Record: Journal of the Transportation Research Board No. 2005, Transportation Research Board

Abstract/Synopsis:
A new approach has been developed for determining layered elastic moduli from in situ load-deflection data. This approach is called forwardcalculation, and it differs from backcalculation in that modulus values are calculated directly from the load-deflection data by using closed-form formulas rather than through iteration. The closed-form equations are used for the subgrade and the bound surface course for both flexible and rigid pavement systems. Intermediate-layer moduli are estimated through commonly used modular ratios between adjacent layers. The entire pre-1998 Long-Term Pavement Performance (LTPP) set of backcalculated results was screened with forwardcalculated moduli. Because both back- and forwardcalculation techniques use identical falling weight deflectometer load-deflection data as input, it was expected that the moduli derived from each approach should be reasonably close to each other. This result was not always the case, however. Forwardcalculated values were, in most cases, more stable on a section-by-section basis than the backcalculated values in the LTPP database. Similarly, the forwardcalculated values usually appeared more reasonable. The exception to this finding was the portion of the database based on slab-on-dense-liquid or slab-on-elastic-solid theory, in which the correspondence between the two approaches was excellent, and both approaches were stable.

Application/Use: This study can be used for pavement investigations and by those interested in evaluating pavement sublayer properties.

Contribution: Improvement in Knowledge

Present Benefit: This report investigates existing backcalculation results for LTPP test sections as well as provides an alternative method for forwardcalculating the sublayer structural parameters. This information could be beneficial in identifying the conditions of the pavement structural layers, yielding more stable results of the calculated layer moduli. The LTPP database was used to compare the backcalculation methods with the developed forwardcalculation method, and for validating this alternative forwardcalculation method.

Future Benefit: The results from this study may provide future use in the areas of pavement evaluation, in situ material properties, and pavement design. The LTPP database is a very useful tool for pavement researchers and engineers and will continue to assist them in obtaining a better understanding of identifying more effective pavement evaluation methods of analysis.

Title: Condition Assessment of Composite Pavement Systems Using Neural-Network-Based Rapid Backcalculation Algorithms

Author(s): Guclu, Alper; Ceylan, Halil

Date: 2007

Publisher: Transportation Research Board 86th Annual Meeting

Abstract/Synopsis:
The objective of this study was to develop artificial neural network (ANN)-based advanced backcalculation models as pavement structural analysis tools for the rapid and accurate prediction of asphalt concrete (AC) overlaid Portland cement concrete (PCC) composite pavement layer moduli under typical highway loadings. The DIPLOMAT program was used for solving deflection profiles of composite pavement systems. The DIPLOMAT solutions were compared with the solutions of ISLAB2000 and ILLI-PAVE pavement analysis programs. ANN-based backcalculation models trained with the results from the DIPLOMAT solutions have been found to be practical alternatives for routine pavement evaluation using the falling weight deflectometer (FWD) deflection data. The trained ANN models in this study were capable of predicting AC and PCC layer moduli, and the coefficient of subgrade reaction value with low average absolute errors. A dimensional analysis approach was also adopted by introducing the dimensional terms of AC modulus over PCC modulus ratio and PCC modulus over coefficient of subgrade reaction ratio value. Both methods were verified by synthetically generated DIPLOMAT deflection profiles. ANN-based backcalculation models developed in this study were also capable of successfully and rapidly (capable of analyzing 100,000 FWD deflection profiles in one second) predicting the pavement layer moduli from the FWD deflection basins in real time during field testing. The developed models were successfully validated by results from the Long-Term Pavement Performance (LTPP) FWD tests conducted on US29, Spartanburg County, South Carolina.

Application/Use: The results from this paper are applicable to pavement managers and maintenance/rehabilitation engineers.

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

Present Benefit: Composite pavements comprise a signification portion of many pavement networks. The ability to accurately and rapidly predict pavement layer modulli from FWD data is extremely useful to pavement managers and forensic engineers. With this information, pavement engineers can quickly and accurately assess pavement properties and use them to evaluate the pavement condition and determine the most effective rehabilitation methods. The LTPP program was a valuable tool in this project to verify the accuracy of this method, based on collected field data.

Future Benefit: As engineers are able to utilize these analysis methods on composite pavement sections, a significant cost savings can be achieved due to the non-destructive

nature of these methods and the quick data collection. The LTPP database will continue to be an invaluable resource to verify new pavement analysis methods based on field results.

Title: Long-Term Performance of Superpave in Specific Pavement Study 9A

Author(s): Middleton, Brent; Falls, Lynne Cowe

Date: 2007

Publisher: Transportation Research Record: Journal of the Transportation Research Board No. 2001; Transportation Research Board

Abstract/Synopsis:
As part of the Long-Term Pavement Performance Program, an experiment identified as Specific Pavement Study 9A (SPS-9A) was established to evaluate the long-term performance of the Superpave® mix design methodology. At each project location, three main test sections were constructed, incorporating the conventional agency mix design, the Superpave Level I mix design with a 98% reliability performance-grade (PG) asphalt binder, and Superpave with an alternative PG binder to evaluate rutting or thermal cracking performance. Further supplementary test sections were constructed at most projects to evaluate the use of other PG asphalt binders with the Superpave mix design. This paper provides a performance comparison and paired T-test analysis of the Superpave Level I mix methodology with conventional agency mix methodology based on the SPS-9A experiment test sections. In addition, the performance impact of PG asphalt binder grades and the use of reclaimed asphalt pavement in Superpave was assessed by statistical analysis of field distresses. Field distresses evaluated in the study include fatigue cracking, thermal cracking, and rutting. Although some trends were identified, overall there was no statistically significant difference in performance between the considered PG asphalt binder grades and mix design types. These results would indicate that asphalt binder and mixture properties probably play a larger role in performance than binder and mix design classification. However, because of the level of asphalt binder and mixture property data in DataPave Release 20.0, a more detailed evaluation of binder and mixture properties on performance was not possible.

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 is an excellent source of information currently unavailable outside of the LTPP program. The SPS-9 experiment gives researchers 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 MEPDG for Superpave mixtures.

Title: Development of Transfer Functions for Spectral Compatibility of Inertial Profilers Used in Long-Term Pavement Performance Program

Author(s): Kutay, Muhammed Emin; Weaver, Eric; Wiser, Larry J.

Date: 2007

Publisher: Transportation Research Record: Journal of the Transportation Research Board No. 2005 Transportation Research Board

Abstract/Synopsis:
A quantification of the difference in the wavelength content produced by K. J. Law Engineers and International Cybernetics Corporation (ICC) profilers is presented. Transfer functions were developed to modify the power spectral density (PSD) of profiles recorded by the ICC profilers to produce a pseudo–K. J. Law PSD so that it is compatible with the spectral content of the profiles recorded by the K. J. Law profiler. Comparison of PSDs of the original K. J. Law and pseudo–K. J. Law profilers exhibited an excellent match in most pavements. Furthermore, a transfer function was developed and used to reconstruct a pseudo–K. J. Law pavement profile from the ICC profile, whose spectral content is similar to that of the K. J. Law profile, by using the inverse fast Fourier transform technique. The international roughness indexes (IRIs) of pseudo–K. J. Law profiles were in general closer to the IRIs of K. J. profiles than those of the ICC profiles. The technique presented here has the potential to be applied to inertial profile equipment types other than those considered in this study, therefore allowing comparisons of data sets.

Application/Use: The results from this project are applicable to pavement managers and pavement engineers.

Contribution: Improvement in Knowledge; Advancement in Technology

Present Benefit: The ability to quantify the difference between the IRI readings of different manufacturer profilers is a significant tool for pavement managers, allowing them to better interpret the IRI values on their pavements when various profilers were used for data acquisition. The LTPP database provided the necessary information for pavement researchers to relate the two profile outputs and develop transfer functions to convert the data.

Future Benefit: The results from this study could have potential applications for assisting pavement engineers and researchers interpret profile data from multiple agencies where different profile equipment was used for data collection. The LTPP database will continue to be an essential tool for pavement researchers and engineers to develop and validate new mathematical models and transfer functions in pavement design.

Title: Evaluation of Concrete Pavements Surface Friction Using LTPP Data: Preliminary Analysis and Texture Performance Models

Author(s): Ahammed, Alauddin M; Tighe, Susan L.

Date: 2007

Publisher: Transportation Research Board 86th Annual Meeting

Abstract/Synopsis:
Providing cost-effective, safe and smooth pavement surface is a priority for transportation agencies. The major challenge, however, is to provide a sustainable surface skid resistance for economy and preservation of superior safety, yet smooth enough for quiet and comfortable ride. Some advancement in smoothness indices and texturing methods has occurred as part of this balancing act between the pavement smoothness and surface friction. However, the sustainability issue of different surface textures has not yet fully addressed. There is also a need to develop comprehensive models that predict the short- and long-term performances of different surface textures. This paper addresses the performance of concrete pavement surface textures using the Federal Highway Administration (FHWA) Long Term Pavement Performance Program (LTPP) data in GPS 3, 4 and 5. The analysis shows that tined/grooved textures maintain consistently higher skid resistance over time and concrete pavements surface friction is insensitive to ambient condition. Cumulative traffic passes was more sensitive to frictional performance than the cumulative axle loads. Two alternative models have also been successfully developed for prediction of concrete pavements long-term skid resistance as a function of texture type, cumulative traffic passes, speed, and concrete compressive strength. These models were shown to be statistically significant at 95% confidence levels with reasonable prediction accuracy.

Application/Use: The results from this study are applicable to pavement designers considering pavement surface friction on concrete pavements.

Contribution: Improvement in Knowledge

Present Benefit: Pavement surface friction is a considerable factor affecting safety and pavement noise. The benefit of this study is the ability to accurately predict long-term skid resistance of pavements, which is a valuable tool for pavement managers and designers in improving the safety of the roads in their pavement network. Data collected from the LTPP program was used to generate these prediction models.

Future Benefit: As traffic volumes increase on the nation's pavement networks, pavement designers will need to discover the dominant factors affecting pavements, as they relate to safety, and many other issues. The LTPP database will continue to provide researchers with the information needed to pursue these issues further and discover ways to address and maintain pavements in a manner that considers the safety of those using the roads.

Title: Simple Model to Predict Structural Condition of Asphalt Concrete Pavements at the Network Level

Author(s): Chakroborty, Partha; Agarwal, Pradeep Kumar; Das, Animesh

Date: 2007

Publisher: Transportation Research Board 86th Annual Meeting

Abstract/Synopsis:
With an ever increasing road infrastructure it is becoming essential that the maintenance budget is judiciously allocated. This is especially true for countries where the maintenance budget invariably falls short of the total requirement. In order for such allocations to be possible it is important that decision makers are aware of (i) what the pavement conditions for different sections are at present and (ii) what they are expected to be if no actions are taken now. One requires models which will perform these tasks using information which can be readily and easily obtained. This paper concentrates on asphalt concrete pavements and presents two models which utilize surface distress conditions like fatigue cracking and rutting to (i) evaluate the present structural health and (ii) predict the future structural health (assuming nothing is done now) of pavement sections. The prediction model is the main contribution of this paper and is based on the evaluation model developed earlier by the same authors. The prediction model is calibrated using the Long Term Pavement Performance (LTPP) database developed and maintained by the U.S. Department of Transportation. The results highlight the effectiveness of the proposed model.

Application/Use: The results of this project are directly applicable to pavement managers and maintenance engineers on a network level.

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

Present Benefit: The ability to accurately evaluate a pavement network, asses the needs, and properly allocate the funds necessary to meet those needs in a cost-effective and strategic way is the challenge for pavement engineers. This research project developed a simple model to assist pavement engineers in their network-level evaluation process, allowing pavement managers to be more effective in identifying the greatest needs, strategically allocating funds for maintenance projects, and optimizing the use of their resources by having the maximum impact with the available funds. The LTPP program was calibrated using the LTPP database.

Future Benefit: A significant cost savings can be obtained by agencies who implement this prediction model in their network-level evaluation process. The LTPP database will continue to be a valuable tool for pavement researchers and engineers to refine existing prediction methods and calibrate and verify new methods for evaluating pavements on a network level.

Title: Artificial Neural Networks and Regression Analysis for Predicting Faulting in Jointed Concrete Pavements Considering Base Condition

Author(s): Saghafi, Behrooz; Hassani, Abolfazl; Noori, Roohollah; Bustos, Marcelo Gaston

Date: January 2009

Publisher International Journal of Pavement Research and Technology Vol. 2 No. 1, Chinese Society of Pavement Engineering

Abstract/Synopsis:
Important aspects of pavement engineering are pavement management and maintenance. Financial resources and existing distress types should be considered when carefully choosing maintenance and rehabilitation. A key distress in jointed concrete pavements is transverse joint faulting, considerably influencing ride quality and road smoothness. Heavy traffic, pavement structure, climatic conditions, and pavement age are among many factors affecting joint faulting. One of those important factors is base layer condition, having a big effect on jointed concrete pavement performance. Both jointed concrete pavement early age behavior and long term performance are affected by base layer. Multivariate Linear Regression and Artificial Neural Networks (ANNs) have been applied in this research to predict joint faulting. In the analysis, which used the Long Term Pavement Performance project database, there was consideration of pavement age and different base layer parameters. The ANNs approach has been shown, in research results, to be able to successfully and more accurately predict joint faulting in jointed concrete pavement, showing a very low amount of error and a high coefficient of multiple determination values.

Application/Use: This study is directly applicable to pavement management and pavement maintenance/rehabilitation.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: This paper is an example of how LTPP data can be used to better model and predict future distress of pavements in Jointed Concrete Pavements (JCP), which has applications in improving pavement maintenance/rehabilitation programs.

Future Benefit: The LTPP database will continue to add benefit as researchers and designers utilize the years of data collected. This data, when integrated with mathematical modeling programs, can be used to estimate future distress conditions for various pavement networks and allow pavement managers to plan accordingly.

Title: Development of Critical Tensile Strain Criterion to Evaluate Fatigue Cracking using Field Performance Data of Existing Pavement Sections of the States of Rhode Island and New Jersey

Author(s): Jha, V; Saridaki, E; Metha, Y A; Manning, F J; Byrne, M.P.

Date: June 2009

Publisher: Sixth International Conference on Maintenance and Rehabilitation of Pavements and Technological Control (MAIREPAV6), Politecnico di Torino

Abstract/Synopsis:
The purpose of this study was to present an alternate process to the Mechanistic Empirical Pavement Design Guide (M-EPDG) for the analysis of fatigue cracking. For the model used in M-EPDG for predicting bottom up fatigue cracking, the standard error was found to be 6.2%. Level 3 analyses in M-EPDG requires fewer user defined inputs and more default data as compared to level 1 and thus leads to higher error. In four out of the nine long-term pavement performance (LTPP) sections, the average error was approximately 30% when level 3 results were compared to measured data. In this study a process was developed to provide accurate results in respect to fatigue cracking using regularly collected data by the pavement management system, which can be used until the state agency prepares itself for level 1 analysis with M-EPDG. The process outlined in this study uses elastic analysis and is independent of traffic and site location which was verified in two states, New Jersey and Rhode Island, and hence can be used by researchers and other state agencies.

Application/Use: The prediction and analysis of bottom-up fatigue cracking is applicable to pavement management, evaluation, and design.

Contribution: Improvement in Knowledge; Implementation/Usage

Present Benefit: An accurate prediction/analysis of bottom-up fatigue cracking is beneficial to pavement management programs in enabling them to better maintain their pavements and rehabilitate them at a more manageable stage of fatigue, before more costly rehabilitation methods are needed. The LTPP pavement sections were a source for developing the M-EPDG methods of fatigue cracking analysis and revealed their accuracy and limitations, exposing the need for a more accurate analysis for state agencies in the intermediate stage between applying level 1 and level 3 analysis methods.

Future Benefit: Refining pavement analysis methods will continue to be an integral part of advancing the effectiveness of pavement management programs. The LTPP database has been the foundation for further studies to benefit the application and use of pavements.

Title: A Systematic Approach of Field Calibration of Fatigue Equation for Asphalt Pavements

Author(s): Rajbongshi, Pabitra; Das, Animesh

Date: January, 2009

Publisher: Road Materials and Pavement Design Vol. 10 No. 1, Hermes Science Publications

Abstract/Synopsis:
In this paper, the authors present a systematic approach for calibrating fatigue equations for asphalt pavements. Using a variable shift factor in the approach, a more accurate prediction for pavement life is achieved in comparison to predictions achieved from existing approaches. Data from the Long Term Pavement Performance (LTPP) Database is used in the study.

Application/Use: A systematic approach calibrating the fatigue equation for asphalt pavements is directly applicable to pavement managers and pavement maintenance/rehabilitation specialists.

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

Present Benefit: The ability to more accurately predict the life-cycle for pavements is an invaluable asset for pavement mangers, as they will be able to be more cost-effective in planning the necessary pavement maintenance and rehabilitation. The data from the LTPP project made this research possible and contributed to this advancement.

Future Benefit: There is a significant benefit for cost savings, in the future, as agencies adopt and implement this approach in their pavement management groups. This cost savings and better understanding of the life-cycle of asphalt pavements was heavily dependent on the data from the LTPP program.

Title: Evaluating the Utility of Existing Pavement Management System State Deflection Data for Use in the Implementation of the ME-PDG for Arizona

Author(s): Cary, Carlos; Zapata, Claudia E.

Date: 2009

Publisher: Transportation Research Board 88th Annual Meeting

Abstract/Synopsis:
The modulus backcalculation from Falling Weight Deflectometers is one of the primary means for evaluating in-situ resilient properties of pavement materials. When evaluating material moduli from the same location by using deflection data from different sources, it is highly probable that different methodologies will lead to differing results. This study presents a comparative analysis of backcalculated moduli results performed to quantify the differences between the historic Arizona Department of Transportation - Pavement Management System (ADOT-PMS) and the Strategic Highway Research Program – Long Term Pavement Performance (SHRP-LTPP) databases. Pavement sections were selected from numerous SHRP sites in Arizona, having both forms of deflection data available at the same location and in the same general time frame. The results of this study indicated that there was a poor correspondence between backcalculated layer moduli from both databases. As a general rule, the degree of layer correspondence improved as layer depths gradually increased (subgrade was the most accurate comparison). On the other hand, fairly good correspondence was obtained for all moduli between two differing backcalculation schemes (MODCOMP v4.2 and MODULUS v6.0). Finally, it was found that the use of the simple, closed form solution to estimate subgrade moduli from the outer geophones, gave comparable answers to the more complex backcalculated solutions based upon total deflection basin results. This gives rise to the possibility that significant reductions in cost and labor can be achieved in maintaining PMS systems and by utilizing the outer geophone equation as an implementation approach for the Mechanistic-Empirical Pavement Design Guide (ME-PDG).

Application/Ue: The ability to accurately determine the resilient properties of pavements is directly applicable to pavement designers and maintenance/rehabilitation specialists.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: Improvements in the accuracy and consistency of FWD data collection result in cost savings through proper selection of rehabilitation strategies and pavement designs. This research could not have been performed and these discoveries would not have been made without the LTPP database. In addition, the difference between agency-collected information and LTPP data likely alerted ADOT regarding a potential equipment calibration issue.

Future Benefit: The FWD data collection by LTPP will continue to benefit pavement management and design practices, particularly as pavement design continues to move toward a mechanistic-empirical approach. As the quantity of FWD data increases, so will the demand on the accuracy of that data to be used in pavement design.

Title: Detailed Profile Analysis on the Arizona SPS-5 Project

Author(s): Karamihas, Steve M; Senn, Kevin Andrew

Date: 2009

Publisher: Transportation Research Board 88th Annual Meeting

Abstract/Synopsis:
This paper characterizes the longitudinal profiles of eleven pavement sections within the Arizona Long Term Pavement Performance Study Specific Pavement Studies 5 project throughout their service life. The flexible pavements associated with this project were rehabilitated and monitored as part of the Study. Road profile measurements were collected on the in-service pavement before rehabilitation and twelve times over the sixteen years afterward. Detailed profile analyses of the sections, including calculating roughness values, examining the spatial distribution of roughness, viewing with post-processing filters, and examining spectral properties are included herein. The value of examining performance utilizing the full suite of methods is demonstrated, and these analyses provided a basis for quantifying and explaining the changes in localized roughness and overall roughness with time, as well as for linking profile properties to each section's maintenance history and observations of surface distress.

Application/Use: The result of this paper is applicable to pavement designers and rehabilitation specialists dealing with pavement roughness its effect on pavement performance.

Contribution: Improvement in Knowledge; Advancement in Technology

Present Benefit: Pavement roughness plays a large role in overall pavement performance. This ability to quantify the change in pavement roughness over time is a valuable tool for pavement managers as it will enable them to be more strategic in planning maintenance and rehabilitation methods in their pavement networks. This paper demonstrates the utility of profile characteristics beyond IRI to fully understand pavement performance. The LTPP program offered the foundational data for this research project.

Future Benefit: Because pavement roughness is a large factor on the pavement condition, the profile data from the LTPP program will continue to provide a better understanding of how pavement roughness affects overall pavement performance.

Title: Evaluation of LTPP Profile Data for Flexible Pavements

Author(s): Corley-Lay, Judith B; Mastin, Jeffery

Date: 2009

Publisher: Transportation Research Board 88th Annual Meeting

Abstract/Synopsis:
The Long Term Pavement Performance (LTPP) program has collected longitudinal profile data for a wide variety of pavements nationally for almost 20 years. The program is managed by the Federal Highway Administration, which also maintains the LTPP database. Another portion of FHWA increased the testing frequency for longitudinal profile by state agencies for the HPMS from biannually to annually. This paper looks at the LTPP data to see if the increased frequency being required for HPMS is justified. The data sets used in the study were all General Pavement Studies (GPS) with either aggregate base or asphalt stabilized base. International Roughness Index (IRI) and the time between successful data collections were used to plot IRI versus time for each section. A polynomial of form ax2 + bx + c was fit for each site, and the polynomial was used to calculate the number of years to a 30 point change in IRI, using English units of inches per mile. Plots were also made of change in IRI versus the time between test events by climatic region. As has been reported by others, the largest contribution to future IRI is initial IRI. In all climatic zones, the time to reach a 30 point increase in IRI decreased with increasing initial roughness. Straight lines fit through the change in IRI versus time between tests have very low slopes ranging from .0052 to .0096 points per day. Even at the maximum slope, it takes 3 years to reach a ten point change in IRI using English Units. Based on the LTPP data for GPS flexible pavements nationally, annual testing is not warranted.

Application/Use: This paper examines the effectiveness of the increased frequency of IRI testing by state agencies for the Highway Performance Monitoring System (HPMS) and is applicable to the FHWA and state agencies in determining whether or not to continue testing annually.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: The present benefit of this project is cost savings. Testing the IRI of the pavement networks throughout the nation at a lesser frequency, if warranted, can result in significant cost savings on both federal and state levels. The LTPP database largely contributed to this finding.

Future Benefit: The LTPP database will continue to be an invaluable resource to analyze the way pavements are currently tested, designed, and maintained, and will serve as a foundation for further discoveries on becoming more effective with limited resources and for identifying opportunities to be more strategic in various pavement testing and maintenance procedures.

Title: Quality Management of Network-Level Pavement Condition Data Collection: Current Methods and Practices

Author(s): Hudak, Jordan; Flintsch, Gerardo W; McGhee, Kevin Kenneth

Date: 2009

Publisher: Title Transportation Research Board 88th Annual Meeting

Abstract/Synopsis:
Over the past three decades, most highway agencies have adopted Pavement Management Systems (PMS) to help manage their pavement networks more cost-effectively. One of the most costly parts of operating a PMS relates to collecting network-level pavement condition information and, as a result, agencies are faced with developing procedures and guidelines for quality management of these activities. The quality of collected data has a direct impact on the utility of, and confidence in the PMS, which in turn has an effect on the use of scarce resources for preserving highway networks. However, until recently there was little attention given to the quality and consistency of collected data. The Long Term Pavement Performance (LTPP) program, in conjunction with advances in automated methods of collecting many types of pavement condition data, focused new attention on the topic of pavement condition data quality management. This attention on quality management has led some agencies to develop methods and practices to ensure the appropriateness of the collected data for use in their respective PMS, but these practices are far from universal and many agencies lack a formalized data collection quality management plan. The objective of this paper is to summarize current quality management practices being employed by public road and highway agencies for both automated and manual pavement condition data collection using information collected in a recent survey of 55 highway agencies throughout the United States and Canada.

Application/Use: The results from this project are directly applicable to federal and state agencies with the desire to improve the quality of their collected pavement data.

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

Present Benefit: Because it is a costly process to collect pavement condition data, it is important that the investment is protected by assuring quality data. Therefore, improving the quality control methods in pavement condition data collection is important, enabling state agencies to use more cost-effective strategies when maintaining and rehabilitating their pavement networks. The LTPP focus on data quality management had a significant impact on this study.

Future Benefit: The focus of the LTPP program on data quality management is significant in developing cost effective solutions and higher performing pavements. Evaluating the current methods of practice for data collection can lead to more cost effective practices for future pavement evaluations.

Title: Calibration of HDM-4 road deterioration models and development of works effects models for Australian conditions

Author(s): Martin, T; Choummanivong, L.

Date: July 2008

Publisher: ARRB Conference, 23rd, 2008, Adelaide, South Australia, Australia Corp., ARRB Group Limited

Abstract/Synopsis:
HDM-4 road deterioration (RD) models (roughness, rutting and cracking) were calibrated for Australian conditions based on extensive performance data derived from long term pavement performance (LTPP and LTPPM) monitoring sites, performance data supplied by state road authorities and accelerated load testing (ALF) from Austroads funded projects. Specific works effects (WE) models for a typical range of surface maintenance treatments were also developed using the above data. This paper summarizes the outcomes of this work and presents the basis for its application in practice for sealed road network asset management.

Application/Use: The results of this project are directly applicable to pavement maintenance/rehabilitation specialists in Australia. However, these results are also of use to state agencies and pavement engineers looking at the effects of road deterioration on pavement networks.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: Calibrating road deterioration models is essential in order to more accurately predict pavement deterioration. Therefore, this calibration is very significant in order to strategically maintain and rehabilitate pavement networks more cost-effectively. The LTPP database was essential for providing the means to more accurately predict road deterioration and to calibrate these prediction models for specific site conditions.

Future Benefit: The construction, maintenance, and rehabilitation of pavement networks have large financial demands on the agencies maintaining them. Therefore, the ability to more accurately predict the deterioration of these pavement networks based on the specific site conditions can lead to significant cost savings for those maintaining them. Additionally, a more accurate evaluation of the pavement deterioration in the network can enable pavement engineers to be more strategic in their rehabilitation approach. The LTPP database largely exists to improve the way pavements are designed, constructed, and maintained and will continue to be an invaluable resource for future advancements in the pavement industry.

Title: LTPP Manual for Profile Measurements and Processing

Author(s): Perera, R W; Kohn, S D; Rada, G.R.

Date: November 2008

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

Abstract/Synopsis:
This manual describes operational procedures for measuring longitudinal pavement profiles for the Long-Term Pavement Performance (LTPP) program using the International Cybernetics Corporation (ICC) road profiler, Face Company Dipstick, and the rod and level. It also contains procedures for measuring transverse profiles of the pavement using the Face Company Dipstick. Procedures for calibration of equipment, data collection, record keeping, and maintenance of equipment for each of these profiling devices are described in this manual. This manual also describes procedures to be followed in the office when processing the profile data that were collected in the field as well as guidelines for performing inter-regional comparison tests among the LTPP profilers.

Application/Use: The operational guidelines provided can be used by agencies interested in collecting network-level, project-level, or research quality longitudinal/transverse profile data

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

Present Benefit: The protocol established by LTPP has provided benefit to agencies collecting longitudinal/transverse profile data. Data obtained by these procedures can be used to determine the structural condition of pavements, which is beneficial for pavement management and design. The calibration protocol established by LTPP ensures accurate pavement profile data are obtained from the road profiler and dipstick equipment. Inaccurate data can result in improper selection of rehabilitation strategies and inadequate or overly conservative structural pavement designs. Improvements in the accuracy and consistency of longitudinal/transverse profile data collection result in cost savings through proper selection of rehabilitation strategies and pavement designs.

Additional cost savings are realized when consideration is given to the reduced start up time required by an agency implementing longitudinal/transverse profile data collection. The guidelines and protocol have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedure without expending significant effort developing a new protocol.

The software developed by LTPP to convert and review longitudinal/transverse profile data is an additional benefit to the pavement community as it allows outliers and erroneous data to be easily identified and addressed.

Future Benefit: The longitudinal/transverse profile data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design practices, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach.

Title: Long Term and Seasonal Variations of Pavement Surface Friction

Author(s): Ahammed, M.A; Tighe, S.L.

Date: 2008

Publisher: 2008 Annual Conference of the Transportation Association of Canada

Abstract/Synopsis:
Pavement surfaces should have adequate friction to minimize the skid related accidents. Pavement surfaces should also exhibit sufficient friction withstanding the seasonal and long term variation. Several past studies have addressed these aspects with no significant or useful conclusions. The seasonal variation of surface friction was measured monthly for both portland cement concrete (PCC) and asphalt concrete (AC) pavements. For long term friction performance analysis, field data of Long Term Pavement Performance (LTPP) program were obtained for both PCC and AC pavements incorporating all geographic/climatic regions of Canada and United States. Analysis has shown that seasonal variation of AC and PCC pavements wet surface friction are identical and dependent on ambient or pavement temperature during the testing (driving). AC surface friction was shown to increase for up to about eighteen months following the construction and decrease thereafter for about six years. For PCC pavements, friction increases for about 2.5 years following the construction and then decreases for about twelve years.

Application/Use: This article can be used by those responsible for pavement management and pavement design.

Contribution: Improvement in Knowledge

Present Benefit: The need to maintain an adequate level of safety throughout the nation's pavement networks is a significant issue. This study showed the effects of seasonal variations on pavement friction, which has a direct effect on the safety of the roads. The LTPP program contribution to this project was extensive by providing the surface friction information for various pavements in a variety of climatic conditions.

Future Benefit: As traffic volumes increase on the nation's pavement networks, pavement designers will need to quantify the dominant factors affecting pavements, as they relate to safety issues. The LTPP database will continue to provide researchers with the information needed to pursue these issues further and discover ways to address and maintain pavements in a manner that considers the safety of those using the roads.

Title: Regression Models for Permanent Deformation Parameters using In-Service Pavement Data from the SPS-1 Experiment

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

Date: 2008

Publisher: International Journal of Pavement Engineering Vol. 9 No. 5

Abstract/Synopsis:
This paper uses the results of multivariate regression analyses on rutting data from the SPS-1 experiment in the Long Term Pavement Performance (LTPP) program to develop models for predicting permanent deformation parameters (alpha and mu) for a three layers pavement system. All available material, structural and climatic data were extracted from the LTPP database and using simple linear regression, a and m were regressed against each data category as an independent variable. The variables that have relatively high R squared values were introduced into the multiple linear regression models. Backward regression analysis was used to develop the final models from statistically significant variables, which differed between layers. Since a- and m-values were backcalculated from time series data, a-prediction models for all layers are more accurate than m-prediction models. Also, m-values were significantly affected (positively) by their corresponding a-values, suggesting pavements with lower m-values (lower initial rutting) will show lower a-values (higher rut growth with time). The regression equations developed in this paper should be used within the range of the data presented herein to obtain reasonable predictions. Also, the parameters a and m are not material properties, but parameters to be used within the prescribed empirical procedure to predict the rut depth.

Application/Use: The results from this research project are of significant use for state agency engineers and rehabilitation specialists.

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

Present Benefit: The ability to accurately predict the permanent deformation of pavements is of great value to pavement engineers, enabling them to better strategize use of limited resources. The end result is achieving higher performing pavements in more cost-effective ways. The LTPP database was a critical instrument in the development of these linear regression models to predict permanent deformation in pavements.

Future Benefit: As these linear regression models are used more widely by state agencies, there is a significant cost savings to be gained. The LTPP program has been instrumental in bringing advancements to the pavement industry, and will continue to be an invaluable resource to gaining a better understanding of pavement behavior and for developing cost-effective strategies to improve pavement performance.

Title: Profile Analysis of the LTPP SPS-5 Site in Arizona

Author(s): Karamihas, Steven M.

Date: February 2008

Publisher: University of Michigan Transportation Research Institute

Abstract/Synopsis:
This report characterizes the longitudinal profiles of eleven pavement sections within the Arizona Specific Pavement Studies 5 (SPS-5) project throughout their service life. The pavement associated with this project was rehabilitated and monitored as part of the Long-Term Pavement Performance Study. Road profile measurements were collected on the in-service pavement before rehabilitation was performed and twelve times over the sixteen years afterward. This study analyzed the profiles in detail by calculating their roughness values, examining the spatial distribution of roughness within them, viewing them with post-processing filters, and examining their spectral properties. These analyses provided details about the roughness characteristics of the road and provided a basis for quantifying and explaining the changes in roughness with time, as well as linking profile properties to each section's maintenance history and observations of surface distress.

Application/Use: The results from this paper are applicable for state agency pavement managers and highway engineers interested in the relationship between pavement roughness and time.

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

Present Benefit: Pavement roughness plays a large role in overall pavement performance. Therefore, the ability to quantify and explain the changes of pavement roughness with time is of great benefit to pavement managers, enabling them to be more strategic in planning rehabilitation projects to address the needs of their pavement network. The LTPP program, and specifically the SPS-5 project, offered the foundational data for this research project.

Future Benefit: Because pavement roughness is a large factor on the pavement condition, data collected from Special Pavement Studies sections in the LTPP program will continue to provide a better understanding of the behavior of pavement roughness and enable researchers and engineers to address the dominant causes affecting pavement roughness to achieve better overall pavement performance.

Title: Robust Optimization for Managing Pavement Maintenance and Rehabilitation

Author(s): Gao, Lu; Zhang, Zhanmin

Date: 2008

Publisher: Transportation Research Board

Abstract/Synopsis:
A pavement management system should help a decision maker to select the best preservation program, decide which preservation treatment to use, and where and when to apply it to maximize the use of the available resources. One of the essential roles of pavement management is to provide a rational, cost-effective optimal funding planning and allocation strategy for highway agencies. Researchers have previously developed deterministic optimization methods for programming pavement maintenance and rehabilitation strategies. However, pavement infrastructure deterioration is a dynamic, complicated, and stochastic process affected by a variety of factors such as traffic loading, environmental conditions, and structural capacities, as well as certain unobserved factors. Ignoring these fundamental characteristics may limit the usefulness of an optimal solution. To take the uncertainties into consideration, some researchers have introduced stochastic programming techniques into pavement maintenance management. However, difficulties in characterizing the distribution of data and the substantial computational challenge have compromised the practical application of those techniques. A project-level robust optimization method for maintenance budget planning to overcome these difficulties is presented. The solutions from this proposed method are computationally tractable and not overly sensitive to any specific realization of the uncertainties. An application of this method is demonstrated by using long-term pavement performance data collected during the past 20 years, yielding promising preliminary results.

Application/Use: This study can be used by pavement management engineers involved with the proper selection and timing of maintenance/rehabilitation treatments.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: The LTPP database provides performance data for various maintenance and rehabilitation alternatives. Some of the LTPP experiments offer side-by-side comparisons of treatment alternatives. This allows a direct comparison while keeping other factors (such as subgrade, traffic, and climate) constant. The results can be used to determine the most cost-effective treatments based on life cycle cost analysis.

Future Benefit: These experiments can also be used to predict the expected service life of treatments based on in situ conditions. By knowing the expected life, pavement management engineers can develop proper timing intervals and determine budgetary needs.

Title: Pavement Performance Evaluation and Prediction Based on Extension Theory

Author(s): Li, Qiang; Wang, Kelvin C.P.

Date: 2008

Publisher: Transportation Research Board

Abstract/Synopsis:
Pavement performance evaluation and prediction are of great importance to facilitate pavement management system. However, due to the multi-attribute properties of a pavement, no analytical solution can be employed to elucidate these intricate relationships. In a pavement management system of a state highway agency, engineers constantly struggle in the decision process to make a comprehensive pavement performance evaluation and prediction according to one or more indicators. This paper presents a novel pavement performance evaluation methodology using Extension Theory. The Extension Theory concept was first introduced in 1980's to solve contradictions and incompatibility problems. This new methodology provides a unique approach to handling the potential interrelations among the pavement performance criteria, and at the same time, to reveal quantitative interactions among the criteria. Three pavement types, flexible pavement, Joint Plain Concrete Pavement (JPCP) and Continuous Reinforced Concrete Pavement (CRCP), are studied in this research with the Extension Theory. The performance criteria used in Mechanistic Empirical Pavement Design Guide (MEPDG) to evaluate existing pavements are partially adopted in the new method and the corresponding data are obtained from LTPP database. With the designed procedures of Extension Theory based pavement performance evaluation process, case studies are carried out and the Extension Theory based comprehensive performance indexes are generated, and Extension Theory based prediction models are developed. Rather than relying on the discretion and judgment of staff involved in traditional pavement prioritization, the Extension Theory based approach can trace the quantitative deteriorations of the overall pavement performances. Results of the studied cases show that the proposed method is suitable as a practical pavement evaluation and prediction tool.

Application/Use: The findings from this study can be used in pavement management applications.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The analysis procedure developed in this study can be extremely useful to pavement managers. Because pavement performance is based on multiple variables including climate, loading, and structural properties of pavements, it can be difficult to determine the most effective strategies for pavement management. Therefore, the Extension Theory is a valuable tool that can be used to assist pavement managers in implementing strategic solutions and optimizing the use of limited resources. The LTPP database was a valuable resource in developing this analysis method.

Future Benefit: As the pavement industry continues to move toward a mechanistic-empirical design method, the use of the LTPP database will continue to be a great resource for refining current design methods based on field data. As these methods are refined the end result will be cost-effective pavement designs with better overall pavement performance.

Title: Trends in Deflection with Application of Repeated Loads: Impact on Deflection Data Averaging

Author(s): Schmalzer, Peter Nils; Thompson, Travis R; Simpson, Amy

Date: 2008

Publisher: Transportation Research Board

Abstract/Synopsis:
Falling weight deflectometer (FWD) testing is now considered routine for the evaluation of pavement structures. Averaging of FWD load and deflection data collected at the same location and similar drop loads is common before further analysis. The stated reason for this averaging is to decrease the effect of the random error inherent in FWD deflection sensors. Implicit in this methodology is the assumption that there is no significant trend in deflection results with successive load applications. FWD data from the Long-Term Pavement Performance program were analyzed to determine whether a significant trend exists between deflection and drop number. In a majority of data sets, a statistically significant trend does exist for at least one deflection sensor. The trends are most common for the highest load level and the center deflection sensor. These trends are less often practically significant but are common enough that averaging deflection data can be expected to increase total error in a large minority of cases.

Application/Use: The results from this project are applicable for pavement managers and designers.

Contribution: Improvement in Knowledge

Present Benefit: Because data collection is a costly process for many agencies it is imperative that they capitalize on their investment through a more accurate analysis of their collected data. In this instance, FWD data were analyzed to evaluate the expected error and look for trends that may help in reducing the total error, allowing agencies to better evaluate their pavements and develop cost-effective strategies to direct their efforts to address those needs. The FWD data collected throughout the LTPP program was a significant contributor to the findings in this project.

Future Benefit: The LTPP program has been an invaluable resource to pavement research and will continue to aid in the further advancement of the pavement industry. As data analyses and their effectiveness are further investigated, the future benefit is significant in being able to more effectively utilize the data collected to lead to more strategic and cost-effective pavement designs.

Title: Development of Asphalt Pavement Transverse Crack Initiation Models Based on LTPP Data

Author(s): Hong, Feng; Rosales-Herrera, Vanessa Ivette; Prozzi, Jorge A.

Date: 2008

Publisher: Transportation Research Board

Abstract/Synopsis:
Deterioration modeling plays a key role in pavement design and management. Accurate deterioration models that predict the initiation of pavement distress can provide a crucial insight into the expected condition of pavement infrastructure along its service life, which in turn is particularly useful in planning maintenance and rehabilitation activities, budget estimation and resource allocation at both the project and network levels. This paper focuses on developing a distress initiation model for transverse cracking in flexible pavements. Data from the in-service pavements in the Long Term Pavement Performance (LTPP) program are used to develop a survival model that accounts for censoring bias due to unobserved events such as limited observation duration. The model estimation results reflect pavement transverse cracking initiation time from a probabilistic viewpoint and also are consistent with engineering judgment.

Application Use: The results from this research project are directly applicable to pavement managers and pavement engineers.

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

Present Benefit: The ability to predict the initiation of pavement distress is a valuable tool for pavement managers and pavement engineers. These prediction models can allow researchers to allocate their resources more effectively to meet the needs in their pavement network. The LTPP database was a critical resource in developing these probability models.

Future Benefit: A significant cost savings can be achieved as agencies incorporate the use of these or similar models in their assessments and designs. The LTPP database will continue to be invaluable resource for pavement researchers and engineers in advancing the understanding of pavement behavior, leading to cost-effective solutions for higher performing pavements.

Title: Enhancing Pavement Management System Analyses Through Consideration of Construction Quality

Author(s): Zaghloul, Sameh; Chowdhury, Tanveer Holland, T Joseph

Date: 2008

Publisher: Transportation Research Board

Abstract/Synopsis:
The concept of Pavement Management Systems (PMS) has gained significant momentum in the last few decades. The advances made in PMS in the last few decades have allowed highway agencies to plan their future spending and select their capital improvement programs based on the analysis performed by their PMS to set priorities for improvements. One issue that has had a negative impact on the accuracy of the capital improvement programs determined by PMS is dependence on only functional pavement performance measures, in terms of the International Roughness Index (IRI) and Surface Distress Indices (SDI). Progress has been made in this regard by many highway agencies through the consideration of a structural performance measure in their PMS, which should ultimately lead to better priority analysis results and capital investment programs. Another challenge facing PMS predictions, priority analysis, and capital programming is the gap between what was designed and what was actually constructed. Despite the fact that long-term pavement performance is highly dependent on the quality of construction, construction quality has rarely been addressed in PMS. Pavement performance prediction, and hence the accuracy of the priority analysis and capital investment programs generated from PMS, would greatly improve if construction quality were considered. This paper shows the impact that construction quality can have on pavement performance and hence the accuracy of predicted performance used in PMS analyses. It also outlines an approach that could be used to integrate a construction quality measure into PMS, including the priority analysis and capital investment programs.

Application/Use: The results from this paper are useful for agencies implementing a pavement management system for their pavement network.

Contribution: Cost Savings; Improvement in Knowledge

Present Benefit: One of the greatest challenges agencies face is how to most effectively allocate limited funds to achieve the maximum impact on improving their pavement network. This study is beneficial in helping pavement managers address this challenge by considering the effect of construction quality on pavements. By gaining this understanding, agencies can consider the effect of construction quality in order to improve the accuracy of their pavement condition predictions and develop a more accurate priority analysis. These findings compliment the LTPP program, which has largely contributed to understanding the relationship between pavement properties and their affect on overall pavement performance.

Future Benefit: As researchers continue to investigate pavement performance, a better understanding of how to develop cost-effective designs of higher performing pavements is achieved. A partnered understanding of the effects of construction quality and pavement properties on overall pavement performance will be a valuable tool for pavement engineers to capitalize on a significant cost savings in developing higher performing pavements. The LTPP database will continue to be a valuable resource in achieving this goal.

Title: Nondestructive Evaluation of Iowa Pavements: Phase I

Author(s): Ceylan, Halil; Guclu, Alper; Bayrak, Mustafa Birkan; Gopalakrishnan, Kasthurirangan

Date: December 2007

Publisher: Iowa State University, Ames Iowa Department of Transportation; National Concrete Pavement Technology Center

Abstract/Synopsis:
Evaluating structural conditions of existing, in-service pavements is a part of the routine maintenance and rehabilitation activities undertaken by the most departments of transportation (DOTs). In the field, the pavement deflection profiles (or basins) gathered from the nondestructive falling weight deflectometer (FWD) test data are typically used to evaluate pavement structural conditions. Over the past decade, interest has increased in a new class of computational intelligence system, known as artificial neural networks (ANNs), for use in geomechanical and pavement systems applications. This report describes the development and use of ANN models as pavement structural analysis tools for the rapid and accurate prediction of layer parameters of Iowa pavements subjected to typical highway loadings. ANN models trained with the results from the structural analysis program solutions have been found to be practical alternatives. The ILLI-PAVE, ISLAB2000, and DIPLOMAT programs were used as the structural response models for solving the deflection parameters of flexible, rigid, and composite pavements, respectively. The trained ANN models in this study were capable of predicting pavement layer moduli and critical pavement responses from FWD deflection basins with low errors. The developed methodology was successfully verified using results from long-term pavement performance (LTPP) FWD tests, as well as Iowa DOT FWD field data. All successfully developed ANN models were incorporated into a Microsoft Excel spreadsheet-based backcalculation software toolbox with a user-friendly interface. The final outcome of this study was a field-validated, nondestructive pavement evaluation toolbox that will be used to assess pavement condition, estimate remaining pavement life, and eventually help assess pavement rehabilitation strategies by the Iowa DOT pavement management team.

Application/Use: The results from this project are directly applicable to Iowa DOT pavement management engineers. However, these findings can also be useful to other agencies with the desire to develop/implement a similar approach in their pavement management system.

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

Present Benefit: The application of artificial neural networks in backcalculating pavement layer moduli from FWD data is a useful tool for pavement managers and rehabilitation engineers. One of the greatest benefits of the FWD test is that is nondestructive. Furthermore, the use of ANNs in conjunction with FWD has enabled

pavement managers to assess the current pavement condition and estimate the remaining pavement life. The LTPP FWD data were used to verify this approach.

Future Benefit: The use of artificial neural networks in pavement analysis and design will continue to be an effective tool for pavement managers. Furthermore, this discusses the use of ANN to assess pavement rehabilitation strategies, which will assist pavement rehabilitation engineers in making optimizing their strategies to cost-effectively meet the needs in their pavement network. The LTPP database contains a wide array of information that will continue to be used to further pavement advancements and verify pavement analytical methods.

Title: Dynamic Time Domain Backcalculation of FWD Data

Author(s): Liu, Ming-Lou; Chuang, Yi-Fang; Chuang, Jui-Chang

Date: 2007

Publisher: Fifth International Conference on Maintenance and Rehabilitation of Pavements and Technological Control (MAIREPAV5); University of Iowa, Iowa City

Abstract/Synopsis:
A dynamic finite element method is incorporated with an optimization approach to develop a time domain backcalculation program, and it is used to backcalculate and predict the dynamic response of the FWD test from LTPP test sections. The advantage of a time domain analysis is that it can use the time history data directly and is less affected by the error data and the coupling effect between the sensor and asphalt concrete. The predictor-corrector form of Newmark scheme is used for the time integration of the dynamic system, and the pattern search approach of optimization is adopted to perform the backcalculation analysis. First, the backcalculations based on the synthetic data generated by the dynamic finite element program show a good agreement between the predicted and given material properties. Then, the backcalculation is performed to analyze two sets of FWD data collected in the field from the LTPP database; the difference between the prediction and measurement is small. Finally, the backcalculation properties are used to predict the dynamic response of the FWD test in which the deflection time history is from different drop weight; the results show that the predictions and test results agree very well.

Application/Use: The results from this paper are applicable to pavement engineers interested in an alternative backcalculation analysis method for FWD data.

Contribution: Improvement in Knowledge

Present Benefit: The development of a dynamic time domain backcalculation program for FWD data is a useful tool for pavement managers and engineers. One of the greatest benefits of the FWD test is that is nondestructive. Furthermore, the advantage of a time domain analysis is that it is has a smaller margin of error, than existing methods. The LTPP FWD tests were used to verify this approach.

Future Benefit: As existing backcalculation analysis methods are evaluated and refined, pavement engineers will be better equipped in making strategic decisions to maintain and improve their pavement network. The LTPP database contains a wealthy supply of information that will continue to be used to further pavement advancements and verify pavement analytical methods.

Title: Assessment of Overlay Roughness in the LTPP--A Canadian Case Study

Author(s): Smith, James Trevor; Tighe, Susan L.

Date: 2006

Publisher: Federal Highway Administration; American Society of Civil Engineers

Abstract/Synopsis: This paper studies asphalt pavement overlay performance in the Canadian environment. It investigates the impact of asphalt overlay thickness, climatic zone, and subgrade type on the progression of roughness as described by the International Roughness Index (IRI). Data from the Canadian Long-Term Pavement Performance (LTPP) program test sites were analyzed. Through the investigation, pavement factors that significantly impact overlay performance in the Canadian environment can be identified. Data collected over the first 13 years of study were used to show national and provincial roughness trends from 53 test sites. The IRI data were statistically summarized (mean, standard deviation) for each category by the age of the overlay section. Using the summarized data, regression analysis was used to determine an equation that best describes the progression of roughness. Two-factor analysis of variance was used to determine any significant differences within specific categories. The results of the regression analysis were compared to the Canadian Strategic Highway Research Program (C-SHRP) LTPP data to confirm the validity of the roughness progression equations. Results show that overlay thickness and climatic zones significantly impact roughness, while subgrade type has little influence on the IRI values. The roughness progression equations achieved squared correlation coefficients (R^2) between 0.93 and 0.39, demonstrating the accuracy of the model equations.

Application/Use: The results from this paper can be used to understand roughness accumulation and the effects of overlay thickness and climatic zone on this accumulation.

Contribution: Improvement in Knowledge

Present Benefit: Roughness significantly affects the end user's perception of the quality of the pavement. The ability to predict the accumulation of roughness, as well as the factors that contribute to improved ride quality performance, 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 overlay thickness and other factors on roughness will also be beneficial to agencies as they investigate rehabilitation alternatives.

Title: Development of Roughness Deterioration Models for National Park Service Network

Author(s): Helali, Khaled; Voth, Michael D; Bekheet, Wael; Amenta, James A; VanDerHurst, Perry

Date: 2006

Publisher: Transportation Research Board

Conference Title: Transportation Research Board 85th Annual Meeting

Abstract/Synopsis: The National Parks Services (NPS) road system of Park Roads and Parkways (PRP) includes over 8,000 miles of paved and unpaved roads jointly administered by NPS and the Federal Highway Administration (FHWA). Recently, NPS and the Federal Lands Highway Program (FLHP) took an initiative to develop a Pavement Management System (FLH-PMS) to manage the PRP network. As part of the development of FLH-PMS, it was necessary to generate a complete set of performance prediction models for the various pavement performance indices used by NPS. Developing these models represented a unique challenge since the PRP road network primarily consists of low volume roads spread across the nation with different climatic conditions, subgrade soil conditions, and traffic levels. Also, the amount of historic performance and construction history data available was very limited. Utilizing the performance class approach, Long Term Pavement Performance (LTPP) data was used to supplement the limited amount of data available for the PRP network, by developing general performance trends or base models. These models were then adjusted using the data available for the PRP road network, as well as NPS-specific experience. In this paper the analyses performed to develop roughness deterioration models using the performance classes approach and the LTPP database is presented. The development of various environmental zone boundaries, which presented a particular challenge in project, is also detailed. The development of the models through PRP specific data and the FLHP and NPS expert opinion is then discussed, followed by the validation of the models through ground truth visits.

Application/Use: The outcome from this study is used by the National Park Services to manage the system of roads under their jurisdiction.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Developing performance curves for the National Park Services provides a means of properly and efficiently maintaining the pavement network. The curves can also be used a tool for planning future improvements and for budgeting purposes. Because of the limited amount of available data on the network, LTPP data was instrumental in the development of base curves for the project.

Future Benefit: The performance curves will be used in the future and will continue to add benefit. As additional information is collected, the curves can be fine-tuned for improved prediction.

Title: Effects of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost

Authors: Jackson, N; Puccinelli, J.

Date: November 2006

Publisher: Federal Highway Administration

Abstract/Synopsis: The objectives of this study are to: (1) quantify the effects of frost penetration on pavement performance in climates with deep sustained frost as compared to environments with multiple freeze-thaw cycles, (2) investigate the effect that local adaptations have on mitigating frost penetration damage, and (3) estimate the associated cost of constructing and maintaining pavements in freezing climates. The approach consisted of modeling various pavement performance measures using both climatic and nonclimatic input variables and performance data collected as part of the Long Term Pavement Performance program. Five climatic scenarios are defined in terms of climatic input variables for the models. Predicted performance measures are presented for each of the climatic scenarios and compared at a 95 percent confidence interval to determine statistically significant performance differences. Participating Pooled Fund States were queried as to standard specifications, standard designs, average life expectancies, and construction costs specific to each State Highway Agency (SHA). This data along with information acquired through literature review of SHA standard practices is summarized with consideration given to the mitigation of frost-related damage. Life cycle cost analysis for each climatic scenario using predicted performance to determine average life and average agency construction costs for standard pavement sections is also discussed and compared. The use of the performance models for local calibration as required in the National Cooperative Highway Research Program Mechanistic-Empirical design guide is explored along with the possible application of the performance models in pavement management systems.

Application/Use: This document can be used to make pavement design decisions to mitigate climatic effects. It is also useful in pavement management as the performance trends developed in the study can be used at a local level to predict service life and pavement condition.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: This document provides insight into the performance of pavements exposed to various climates and investigates possible mitigation techniques. The costs associated with differential performance are also discussed. The models developed were based on national data—only available from the LTPP database—and have a large inference range. The models are applicable to pavement management as well as to the implementation of the M-E PDG.

Future Benefit: The performance curves will be used in the future by agencies to supplement their pavement management data as well as to evaluate the prediction capabilities of the M-E PDG on regional basis.

Title: LTPP Falling Weight Deflectometer Maintenance Manual

Author(s): Belt, Robin; Morrison, Tyler; Weaver Eric

Date: 2006

Publisher: FHWA, Office of Infrastructure Research and Development, McLean, VA

Abstract/Synopsis: The Federal Highway Administration's (FHWA) Long-Term Pavement Performance (LTPP) program operates eight Dynatest Model 8000 FWDs. In spring 2003, the LTPP Southern Region support contractor overhauled one of the FWDs operated for the LTPP program. During the overhaul, the contractor documented the process photographically and described the process of disassembling and reassembling the FWD components and subcomponents. This document provides FWD owners, operators, and technicians supplemental information to the Dynatest 8000 owner's manual. Maintenance guidelines are based on continuous operation of FWDs.

This manual is supplemented by various other documents including:

- LTPP FWD Data Collection Software Manual
- LTPP Manual for Falling Weight Deflectometer Measurements
- SHRP-LTPP FWD Calibration Protocol
- FWDConvert Software User's Manual
- FWDScan Software User's Manual
- FWDCal Software User's Manual
- LTPP FWD Directives

Application/Use: The maintenance manual can be used by public agencies as well as private companies that own and operate FWDs.

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

Present Benefit: Proper and timely maintenance reduces overall operating costs and downtime. Maintaining FWD equipment also improves data quality. Inaccurate data can result in improper selection of rehabilitation strategies and inadequate structural pavement designs. Improvements in the accuracy and consistency of FWD data collection result in cost savings through proper selection of rehabilitation strategies and pavement designs.

The document provides the knowledge and information needed to perform many of the FWD maintenance and overhaul activities in-house, making these activities more cost effective.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design practices, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach. As the quantity of FWD data increases, so will the demand on data collection equipment and the subsequent need for robust maintenance activities.

Title: Guidelines for the Collection of Long-Term Pavement Performance Data

Author(s): Simpson, A. L; Ostrom, B K; Schmalzer, P. N.

Date: 2006

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

Abstract/Synopsis: A set of data collection guidelines has been provided for the collection of all data obtained for the Long-Term Pavement Performance (LTPP) program. These guidelines were provided to the Regional Support Contractors (RSCs) to facilitate data collection on a uniform basis. Over time, additional documents were developed providing more specific requirements for the collection of LTPP data. The primary purpose for the various data collection guides is to provide a uniform basis for data collection during long-term monitoring of the performance of pavement test sections under study by the LTPP program initiated under the Strategic Highway Research Program (SHRP) and continued under the Federal Highway Administration (FHWA). As methods for collection of the data have changed and improved over the years, the guidelines used in obtaining these data have changed. The objective of this document is not to provide the exact guidelines, but rather to provide references for the guidelines and revisions to those guidelines used in collecting each type of data for LTPP over the lifetime of the LTPP program.

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

Contribution: Improvement in Knowledge

Present Benefit: This document is beneficial as a reference providing information on the collection of LTPP data. Understanding the method of collection is critical to properly analyzing and evaluating 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: LTPP Manual for Falling Weight Deflectometer Measurements, Version 4.1

Author(s): Schmalzer, Peter

Date: 2006

Publisher: FHWA, Office of Infrastructure Research and Development, McLean, VA

Abstract/Synopsis: This document provides background information and field operations guidelines for the collection of Falling Weight Deflectometer (FWD) data on Long Term Pavement Performance (LTPP) test sections. It includes equipment setup, equipment calibration, test locations, and test procedures.

This manual is supplemented by various other documents including:

- LTPP FWD Data Collection Software Manual
- LTPP FWD Maintenance Manual
- SHRP-LTPP FWD Calibration Protocol
- FWDConvert, FWDScan, and FWDCal Software User's Manual
- LTPP FWD Directives

Application/Use: The operational guidelines provided can be used by agencies interested in collecting network-level, project-level, or research quality FWD data.

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

Present Benefit: The protocol established by LTPP has provided benefit to agencies collecting FWD data. Data obtained by these procedures can be used to determine the structural condition of pavements, which is beneficial for pavement management and design. The calibration protocol established by LTPP ensures accurate loading and deflection data are obtained from FWD equipment. Inaccurate data can result in improper selection of rehabilitation strategies and inadequate or overly conservative structural pavement designs. Improvements in the accuracy and consistency of FWD data collection result in cost savings through proper selection of rehabilitation strategies and pavement designs.

Additional cost savings are realized when consideration is given to the reduced start up time required by an agency implementing FWD data collection. The guidelines and protocol have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedure without expending significant effort developing a new protocol.

The software developed by LTPP to convert and review FWD data is an additional benefit to the pavement community as it allows outliers and erroneous data to be easily identified and addressed.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design practices, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach.

Title: Profile Data Variability in Pavement Management: Findings and Tools from LTPP

Author(s): Yin, Hao; Stoffels, Shelley M; Antle, Charles A.

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: One aspect of pavement management systems (PMS) that has begun to receive increased attention is that of data quality and variability. This paper provides recommendations for quantifying and controlling the variability of longitudinal profile data, and the resulting International Roughness Index (IRI) values. The recommendations were determined from an analysis of the profile data collected by the Long-Term Pavement Performance Program (LTPP). In particular, the effort was focused on developing quantifications of variability that could be useful and economical for network-level pavement management.

Application/Use: The findings of this study can be used by pavement management engineers interested in quantifying network level variability of roughness data.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Variability and erroneous data in pavement management systems can lead to inefficiencies in programming and scheduling improvements at a network-level. Understanding the inherent variability and its causes can be useful to pavement management engineers not only in decision making but also in adjusting data collection protocol to improve consistency and quality of roughness data. This paper is a starting point for implementing new collection techniques or quality control measures. It also quantifies variability, which impacts proper selection and timing of rehabilitation alternatives.

Future Benefit: This study will provide future benefit as pavement management engineers evaluate the sensitivity of rehabilitation decisions relative to the inherent variability in the roughness data. With this information, adjustments to the data collection techniques and/or decision trees can be made.

Title: Quantification of Smoothness Index Differences Related to LTPP Equipment Type

Date: 2006

Publisher: Federal Highway Administration

Journal Title: TechBrief No. FHWA-HRT-06-064

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) program conducted a research project recently to (1) compare International Roughness Index (IRI) values obtained by different inertial profilers, (2) investigate data collection characteristics and compare profile data collected by the different inertial profilers, and (3) investigate the factors that contribute to differences in IRI values for data obtained from the LTPP profilers and Dipstick®. That analysis indicated good agreement in the IRI values among the different inertial profilers used in the LTPP program. This indicates that the IRI values in the LTPP database can be used to analyze roughness progression at test sections without any adjustments to the IRI values obtained by the different profilers. This TechBrief provides further discussion of the project findings and recommendations.

Application/Use: This evaluation is used by those interested in understanding differences between various profile data collection techniques.

Contribution: Improvement in Knowledge

Present Benefit: This study provides insight to the potential differences in data collected between the various profile collection techniques employed by LTPP. This is beneficial in situations where techniques have changed over the monitoring period. The analysis and evaluation in these cases can account for differences in techniques based on the findings from this study.

Future Benefit: The LTPP database contains the data to make comparison studies such as this possible. Benefits will be realized as decisions are made from pavement management systems with consistent data, leading to improved prioritization and proper scheduling of improvements.

Title: Simple Model for Structural Evaluation of Asphalt Concrete Pavements at the Network Level

Author(s): Agarwal, Pradeep Kumar; Das, Animesh; Chakroborty, Partha

Date: 2006

Publisher: American Society of Civil Engineers

Abstract/Synopsis: Evaluation of the structural conditions and estimation of the remaining structural life of each pavement section are important considerations for prioritizing the maintenance needs of any highway network. Many highway agencies, where equipment for evaluation is not available and maintenance funds are limited, may not be able to carry out a detailed structural evaluation on individual pavement sections. An attempt has been made in this paper to develop a simple and cost effective model for structural evaluation of existing pavements. The important features of the model are (1) it can be executed with minimal amount of data, (2) the model is simple and does not require use of any costly equipment, and (3) the output of the model can be directly used for prioritization of maintenance needs at the network level. Two such models have been developed. The models are statistical and are derived from the long term pavement performance (LTPP) database developed by the U.S. Department of Transportation. The models have been validated and their predictions for remaining structural life (RSL) have been compared with the RSL obtained using the fatigue and rutting distress models of the Asphalt Institute. The results indicate that the proposed models are capable of predicting the RSL of existing pavements with reasonable accuracy and consistency, given that their primary use is in evaluating pavement structural conditions at the network level and for the purpose of prioritizing pavement sections for maintenance purposes.

Application/Use: The models developed in this study can be used to evaluate the structural integrity of pavements on a network-level.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The models developed here allow a network level structural evaluation to be conducted where very limited information exists. This is beneficial in the pavement management and preservation programming arenas. The LTPP database provided the information that made the study possible.

Future Benefit: The models developed may be used in the years to come by pavement management staff at agencies that have limited condition data available.

Title: Statistical Analysis Between Roughness Indices and Roughness Prediction Model Using Neural Networks

Author(s): Oliveira de Souza, Ricardo; Neto, Silvrano Dantas; Muniz de Farias, Marcio

Date: 2006

Publisher: Federal Highway Administration; American Society of Civil Engineers

Abstract/Synopsis: This paper presents an analysis between the International Roughness Index (IRI) and the standard deviation of longitudinal roughness, as well as a neural network study developed to predict the critical level of roughness. Measured longitudinal profiles available in the Long-Term Pavement Performance (LTPP) program database were used. A total of 207 pavement sections in 42 States of the United States were used to do this analysis. Using suitable software, the IRI and the standard deviation of longitudinal roughness values were computed for every longitudinal pavement profile measured. Afterwards, there values were used in regression analysis and a high correlation was found between them ($R^2 = 0.93$). Neural network analysis correlated the IRI-computed values with the type of subgrade soil, pavement structure (layer thickness), climate, and traffic data of 157 pavement sections. The neural network could forecast the IRI with an extremely high correlation factor ($R^2 = 0.99$). Besides, the neural network provided a sensitivity analysis indicating the relative contribution of factors related to the structural number (49%), climate (31%), and traffic (20%). Multivariate linear and nonlinear statistic regressions were also performed to predict IRI, but no correlation was found.

Application/Use: This paper can be used by those interested in pavement roughness predictions.

Contribution: Improvement in Knowledge

Present Benefit: This paper provides insight on pavement roughness prediction using neural network algorithms. Predictions are useful in pavement management as well as pavement design.

Future Benefit: The LTPP database provides the means of evaluating new prediction models and techniques. This will be beneficial as new techniques are introduced as it allows error and variability estimates to be established.

Title: Use of LTPP Data to Verify the Acceptance Limits Developed for PennDOT Pavement Distress Data

Author(s): Ganesan, Venkatesa Prasanna Kumar; Stoffels, Shelley M; Arellano, Janice; Morian, Dennis A.

Date: 2006

Publisher: Federal Highway Administration; American Society of Civil Engineers

Abstract/Synopsis: State transportation agencies use various methods of pavement data collection. The major methods are manual, film-based, semi-automated, and automated collection. The Federal Highway Administration (FHWA) Long-Term Pavement Performance (LTPP) program has used both the manual method and the Pavement Distress Analysis System (PADIAS) film-based survey for its pavement data collection. The Pennsylvania Department of Transportation (PennDOT) replaced its former manual method with a semi-automated method. The project team at the Pennsylvania Transportation Institute developed a quality assurance plan for PennDOT for pavement data collection and rating. Initial acceptance limits were developed by the project team with the assistance of PennDOT. The manual distress data are compared with the PADIAS 4.2 distress data. This paper also summarizes the PennDOT quality assurance plan. The sources of variability affecting surface distress are also discussed. In this paper, the LTPP distress data are used to verify the PennDOT acceptance limits. The findings indicate that the proposed limits may require modification. Two types of modifications are attempted with the LTPP data, providing input to PennDOT's future decisions.

Application/Use: The findings from this paper will be used by PennDOT in adjusting and implementing acceptance limits for semi-automated distress collection.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Understanding the inherent variability in distress data and discrepancies between various data collection procedures is critical in proper use of distress data in pavement management. This paper provides insight into the expected variability, which aides PennDOT in establishing quality control specifications and acceptance limits. Through these means, the overall quality of distress data is improved.

Future Benefit: This will benefit PennDOT in the future as they continue collecting semi-automated distress data. Quality data improves network-level programming decisions and provides a better picture of the overall condition of the network.

Title: Digital Image Processing for Pavement Distress Analyses

Author(s): Teomete, Egemen; Amin, Viren R; Ceylan, Halil; Smadi, Omar G.

Date: 2005

Publisher: Iowa State University, Ames

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

Abstract/Synopsis: Local agencies have to collect distress data of their network system for building and implementing pavement management programs. Data collection for the whole network is expensive, time consuming, and dangerous, if pursued by traditional field surveys. Developments in computer technology, digital image acquisition, and image processing allow local agencies to use digital image processing for pavement distress analyses. In this project, pavement images obtained from the Long-Term Pavement Performance Program (LTPP) are used to detect horizontal and vertical cracks, crack lengths, and severity. The results are favorable for many images. Further development of the technique may allow adaptation to additional conditions in the images, such as more types of cracks, lane markings, etc.

Application/Use: The study may be useful to those interested in photographic distress data collection.

Contribution: Improvement in Knowledge

Present Benefit: LTPP has collected distress data using both manual and photographic survey techniques, providing a means of comparing the two methods. The images collected and stored as part of the program are extremely useful for evaluating new summarization techniques.

Future Benefit: As new techniques are introduced and variability information is desired for distress data collection methods, the benefit of distress data in the LTPP database will increase.

Title: The Effect of Faulting on IRI Values for Jointed Concrete Pavements

Author(s): Byrum, Christopher R; Perera, Rohan W.

Date: 2005

Publisher: Transportation Research Board

Conference Title: Eighth International Conference on Concrete Pavements

Abstract/Synopsis: This paper presents a study on the effects that faulting of joints and cracks in concrete pavements have on International Roughness Index (IRI) values for the pavements. Three methods for comparing faulting to IRI values for roadways are evaluated in this study. The first method is a parametric study on the effect that idealized faulted profiles consisting of rotated line segments having various slab lengths and fault sizes (a saw-tooth pattern) have on IRI values. The second method is a road profile based fault size estimation routine using data from non-contact moving road profilers. Profile based faulting estimates were obtained from over 1000 GPS-3 pavement profiles. The third fault measurement method evaluated is the official Long-Term Pavement Performance (LTPP) field measurement of faulting using the Georgia Faultmeter. This direct measurement method uses the Faultmeter placed over each joint to measure fault sizes. Faulting and IRI can be presented in the same units, m/km (in./mi) for comparison purposes. Based on this study, faulting along the roadway has gain of about 1.75 when converted to IRI. In other words for each 1.58 m/km (100 in./mi) of faulting present, about 2.76 m/km (175 in./mi) of IRI will develop, with gain increasing slightly with increasing fault spacing. The IRI gains measured for real pavement faulting matches the gain values calculated for the ideal saw-tooth patterns. Faulting data can be reliably obtained from relatively inexpensive road profile data that is being obtained for major roadways.

Application/Use: Relationships between faulting and pavement roughness can be used in pavement management applications.

Contribution: Improvement in Knowledge

Present Benefit: The ability to estimate faulting from roughness data is beneficial because roughness data can be collected more quickly and safely using inertial profilers as compared to direct faulting measurement techniques.

Future Benefit: The LTPP database provides a means of conducting comparison studies like this. Concrete pavements test sections monitored as part of the LTPP program have an extensive suite of data using various techniques and equipment. This level of information is not available from typical pavement management databases.

Title: Evaluation of the Cost Benefits of Continuous Pavement Preservation Design Strategies versus Reconstruction

Author(s): Smith, K.L; Titus-Glover, L; Darter, M.I.; Von Quintus, H.L; Stubstad, R.N; Hallin, J.P.

Date: September 2005

Publisher: Arizona Department of Transportation

Abstract/Synopsis: The Arizona Department of Transportation (ADOT) has traditionally employed continuous pavement preservation (consisting of a myriad of treatment options that cost-effectively address existing pavement problems) as part of an overall design strategy to maintain the highest levels of service for highway users. However, with concern about the effects of continual weakening of substructure material layers on preservation treatment performance and cost, ADOT sponsored a study to determine the cost-effectiveness of the continuous preservation approach as compared to a reconstruction strategy. Another goal of the study was to determine the break-even point for the continuous preservation and reconstruction strategies (i.e., after how many rehabilitation treatments does reconstruction becomes equally cost-effective as continuous preservation). Using inputs such as pavement performance/life estimated primarily through pavement survival analysis, best estimate unit costs derived from historical data, work zone-related user costs, and a specified analysis period and discount rate, the total life-cycle costs for each of four alternative strategies (one continuous preservation strategy, three reconstruction strategies) for each of 15 commonly occurring pavement scenarios in Arizona were determined and compared. The results of the analysis showed a consistent reduction in total life-cycle costs with a corresponding increase (from 0 to 2) in the number of rehabilitations between original construction and the first reconstruction event. Results also showed that for 9 of the 15 scenarios, total life-cycle costs associated with the third reconstruction alternative (i.e., two rehabilitations occurring prior to the first reconstruction event) were within 3 percent (sometimes higher, sometimes lower) of the total life-cycle costs of the continuous preservation strategy. Hence, the break-even point between the two strategies typically occurs after two to three cycles of rehabilitation

Application/Use: This report is directly applicable to the pavement management practices in Arizona.

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

Present Benefit: LTPP sections in Arizona were selected to represent some of the commonly occurring pavements in the state. In-service performance information from these sections was used to validate the M-E PDG. Cost benefits information for pavement preservation is critical to establishing rehabilitation schedules and preventative maintenance strategies.

Future Benefit: Future evaluations requiring long term performance information will benefit from the LTPP database. Additionally, GPS test sections represent the commonly constructed pavements within an agency and can be used to investigate performance expectations of typical structures.

Title: LTPP ProQual 2005 User Guide Documentation

Author(s): Macpherson, Donald; Olmedo, Chris; Merrill, Cory

Date: 2005

Publisher: FHWA, McLean, Virginia

Abstract/Synopsis: This report provides a description of the procedures used in the installation and operation of the ProQual 2005 software application including: installation and setup; preparation for field operations; field operations; transition from field to office operations; office operations; manual profile procedures.

This manual is supplemented by various other documents including:

- LTPP Manual for Profile Measurements and Processing, Version 4.1
- LTPP Profile Directives
- LTPP WIM Index Software Manual, Version 1.0

Application/Use: The procedures described in this guideline has been a reference for those interested in collecting pavement profile data using road profiler, Dipstick®, and rod/level devices.

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: The work conducted by LTPP in the area of profile data collection has significantly advanced the standard of practice. Improvements in data collection, equipment calibration, data review and data processing have been realized in these endeavors. The most recent profile protocol developed under LTPP defines the methodology to collect smoothness data for weigh-in-motion (WIM) sites.

Pavement roughness directly impacts the end user in perception, comfort, safety and operating costs. By accurately and consistently collecting profile data, highway officials can provide pavements with improved service to end users.

In particular, the software developed under LTPP has been extremely useful in reviewing profile data, making comparisons between runs, and identifying anomalous data.

Future Benefit: This processing software can be used in the future as agencies continue to collect profile data. Additional benefit will be realized in the areas of pavement management systems, M-E PDG calibration, and traffic data collection.

Title: Quantification of Smoothness Index Differences Related to Long-Term Pavement Performance Equipment Type.

Author(s): Perera, R. W; Kohn, S. D.

Date: 2005

Publisher: Soil and Material Engineers, Incorporated; Federal Highway Administration; Federal Highway Administration

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) Program was designed as a 20-year study of pavement performance. A major data collection effort at LTPP test sections is the collection of longitudinal profile data using inertial profilers. Three types of inertial profilers have been used since the inception of the LTPP program: (1) K.J. Law Engineers DNC 690 incandescent profilers; (2) K.J. Law Engineers T-6600 infrared-system profilers; and (3) International Cybernetics Corporation (ICC) laser profilers. The following analyses were performed for this research project: (1) investigate data collection characteristics and compare profile data collected by the different inertial profilers; (2) compare International Roughness Index (IRI) values obtained by the different inertial profilers; (3) investigate factors that contribute to differences in IRI for data obtained from profilers and Dipstick (registered); and (4) identify problems with equipment functionality and current data collection and processing procedures. The analyses indicated good agreement of IRI values among the different inertial profilers that have been used in the LTPP Program.

Application/Use: This evaluation is used by those interested in understanding differences between various profile data collection techniques and equipment.

Contribution: Improvement in Knowledge

Present Benefit: This study provides insight on the differences in data collected between the various profile collection techniques and equipment employed by LTPP. This is beneficial in situations where techniques have changed over the course of monitoring. There is definite value in knowing that LTPP profile data does not vary based on data collection equipment.

Future Benefit: The LTPP database contains the data to make comparison studies such as this possible. Benefits will be realized as decisions are made from pavement management systems with consistent data, leading to better prioritization and proper scheduling of improvements.

Title: Transforming LTPP Distress Information for Use in MTC-PMS

Author(s): Dewan, Shameem A.

Date: 2005

Publisher: Federal Highway Administration; American Society of Civil Engineers

Abstract/Synopsis: The severities, types, and definitions of surface distresses used in the Strategic Highway Research Program (SHRP) database for Long-Term Pavement Performance (LTPP) sites are not the same as those used in the Metropolitan Transportation Commission Pavement Management System (MTC-PMS) system. Therefore, to use the LTPP distress data as inputs in the MTC-PMS software, the LTPP data must be transformed to match the MTC-PMS distress definitions. The objective of this paper is to describe a method to complete such transformations. Data conversion and use of converted data as inputs in the MTC-PMS were performed to develop a model for International Roughness Index (IRI) as a function of pavement condition information (the IRI model is intended for use in estimating user costs/benefits in the pavement management system). The condition information includes all MTC distress-severity combinations transformed from LTPP data, and corresponding deducts, percent load related deducts, percent nonload related deducts, and pavement condition index (PCI) values calculated using MTC-PMS software. The paper first presents the differences in definitions of distresses and severities in the two systems. It describes the selection of appropriate LTPP distress types to be transformed to generate required MTC distress data. Then the data transformation techniques for different distress types and severities from the LTPP system to the MTC system are explained. It was found that several types of manipulations were required to conduct the transformation of different distresses. These manipulations were performed based on the differences in definition for distresses and severities in the two systems. An IRI model was eventually developed using the transformed distress data and the output from MTC-PMS software.

Application/Use: This can be used by those interested in predicting pavement roughness based on MTC distress conditions.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Pavement roughness contributes directly to user perception as well as user costs. The ability to accurately predict the accumulation of roughness is beneficial to pavement engineers scheduling improvements and selecting candidate projects. Proper selection and timing can result in a cost-effective improvement strategy while improving the overall condition of the network (and reducing user costs).

Future Benefit: The LTPP database provides roughness and distress data that can be used to develop prediction models for PMS. Prediction capabilities can be used to make better informed decisions on improvements by allowing the consequences of decisions to be estimated.

Title: Wavelet Analysis and Interpretation of Road Roughness

Authors: Wei, Liu; Fwa, T. F; Zhe, Zhao

Date: February 2005

Publisher: Journal of Transp. Engrg., Volume 131, Issue 2, pp. 120-130 (February 2005)

Abstract/Synopsis: Road roughness indices such as the International Roughness Index, Quarter-car Index, and root-mean-square vertical acceleration are useful as indicators of the level of pavement serviceability performance. Each of these summary roughness statistics offers a convenient index for monitoring the trend of pavement roughness deterioration with time. However, they do not retain the actual contents of pavement surface roughness. Such detailed roughness information may be useful for maintenance operations, detection of pavement surface distresses, and detailed analysis of the trend of pavement roughness deterioration. This paper presents an application procedure based on wavelet theory to offer supplementary information to a roughness index and provide additional information on the characteristics of the roughness profile of interest. The procedure is able to identify the characteristics of a pavement roughness profile in both the frequency and distance domains. This study proposes methods of roughness data processing using different wavelet transformation and analysis techniques to extract useful information for pavement maintenance management. Numerical examples based on measured roughness profiles of the Long Term Pavement Performance (LTPP) database are presented to illustrate the types of useful information derivable with the proposed method of analysis. It is demonstrated that using appropriately selected analysis methods and wavelet parameters, detailed roughness features of interest to pavement engineers not currently available from summary roughness statistics can be obtained together with summary roughness statistics as part of the roughness survey report for highway agencies.

Application/Use: This study is valuable to those involved in selecting and designing pavements, including rehabilitation alternatives. The analysis conducted as part of the study is also applicable to pavement management.

Contribution: Cost Savings; Improvement in Knowledge.

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 analyses.

Title: Collection and Interpreting Long-Term Pavement Performance Photographic Distress Data: Quality Control - Quality Assurance Processes

Author(s): Rada, G R; Simpson, A. L; Hunt, J. E.

Date: 2004

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1889

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) program is making use of photographic technology to provide, first, detailed, distress-specific condition data for use in the development and validation of pavement performance models and, second, a permanent, objective, high-resolution record of pavement condition over the full length and width of the sections in the program. Because high-quality distress data are critical to the success of the LTPP program, numerous quality control-quality assurance (QC-QA) processes have been implemented over the life of the program. Those processes address data quality before the start of data collection, during data collection, during data interpretation, after data interpretation, and after the uploading of data to the LTPP database. Some of the processes are a direct result of advance planning, based on past experience, while others are the result of lessons learned in the course of the program. Some were implemented early in the program, while others were introduced well into the program. The Distress Identification Manual, distress rater accreditation workshops, time series review, database checks, data studies and analyses, and feedback reports are just a few of the elements that make up the full suite of QC-QA processes. A detailed summary of the QC-QA processes associated with the LTPP photographic distress data is presented.

Application/Use: This paper can serve two purposes. It is useful for those interested in utilizing LTPP photographic distress data. The QC-QA process established by LTPP can also be implemented by those collecting and analyzing photographic distress data.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: Pavement management is dependent on quality distress data. Erroneous data can lead to ineffective treatment schedules, improper segment prioritization and inaccurate budgets. The QC-QA procedures documented in this paper provide a means of reducing inconsistent data and improving the data system. This can improve network-level conditions and lead to better informed decisions.

Future Benefit: The use of photographic distress data collection techniques will increase in the future. As these techniques are implemented, the QC-QA processes documented in this paper will be beneficial in ensuring that quality data is collected.

Title: LTPP Manual for Profile Measurements and Processing, Version 4.1

Author(s): Perera, R.W., Kohn, S.D., and Rada, G.R.

Date: 2004

Publisher: FHWA, McLean, Virginia

Abstract/Synopsis: This manual describes operational procedures to be followed when measuring pavement profiles for the Long Term Pavement Performance (LTPP) Program using the International Cybernetics Corporation (ICC) road profiler, Face Company Dipstick®, and the rod and level. Field testing procedures, data collection procedures, calibration of equipment, record keeping, and maintenance of equipment for each of the profiling methods are described in this manual. This manual also describes procedures to be followed in the office when processing the profile data that were collected in the field.

This manual is supplemented by various other documents including:

- LTPP ProQual 2005 User Guide
- LTPP Profile Directives
- LTPP WIM Index Software Manual, Version 1.0

Application/Use: The procedures described in this guide has been a reference for those interested in collecting pavement profile data using road profiler, Dipstick®, and rod/level devices.

Contribution: Improvement in Knowledge; Advancement in Technology; Implementation/Usage.

Present Benefit: The work conducted by LTPP in the area of profile data collection has significantly advanced the standard of practice. Improvements in data collection, equipment calibration, data review and data processing have been realized in these endeavors. The most recent profile protocol developed under LTPP defines the methodology to collect smoothness data for weigh-in-motion (WIM) sites.

Pavement roughness directly impacts the end user in perception, comfort, safety and operating costs. By accurately and consistently collecting profile data, highway officials can provide pavements with improved service to end users.

The data collected and stored in the LTPP database has been instrumental in modeling the progression of roughness over time. Additionally, the data has allowed researchers to study contributing factors in the rate of roughness accumulation.

Future Benefit: These guidelines will be used in the future as agencies continue to collect profile data. Additional benefit will be realized in the areas of pavement management systems, M-E PDG calibration, and traffic data collection.

Title: ProVAL

Date: September 2004

Publisher: FHWA

Abstract/Synopsis: FHWA developed the Pavement Profile Viewer and Analyzer (ProVAL) software to conduct the work described in the report LTPP Profile Variability (FHWA-RD-00-113). Based on the ProQual software created for the LTPP program, ProVAL enables the user to easily compare longitudinal profile data that has been obtained from multiple profile data collection runs on the same or different dates. ProVAL provides users with the analytic capabilities to compute summary indices, such as the International Roughness Index (IRI) and power spectral density (PSD), and includes several display functions. The intent is to provide pavement engineers with a tool that will help them understand what is really going on in the pavement, to support sound decisions regarding rehabilitation and repair, and to promote effective quality control of pavement profile data.

Application/Use: ProVAL has been used by researchers and practitioners to evaluate profile data in many different formats.

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

Present Benefit: The ability to apply various filters and to analyze data in various formats has made ProVAL extremely beneficial in evaluating profile data for pavement management. Additionally, ProVAL has been used in construction applications to identify areas of noncompliance in smoothness specifications. Grinding simulations can also be evaluated in these areas to determine the improvement in ride.

Future Benefit: ProVAL will continue to add benefit to the pavement community, especially considering its ability to evaluate profile data in a variety of processes. Moving forward, ProVAL will be beneficial in the pavement management, construction, performance modeling, and traffic data collection arenas.

Title: Slurry Seal / Micro-Surface Mix Design Procedure

Date: March 2004

Publisher: California Department of Transportation

Abstract/Synopsis: Despite the widespread use of slurry seals and micro-surfacing, current tests and design methods are primarily empirical and are not related to field performance. There is very limited knowledge on the relationships among certain test parameters, environmental factors, and mix performance in the field. Thus, there is a need to develop new mix design procedures, guidelines, and specifications for slurry seal and micro-surfacing that address performance needs of the owners and users, the design and application needs of the suppliers, and improve the reproducibility of the test methods used for the mix designs. The current International Slurry Seal Association (ISSA) procedures for Slurry Seal Mix Design (A105) and Micro-surfacing (A143) and the corresponding American Society for Testing and Materials (ASTM) Standards D3910 and D6372 have their origin in the 1980's before the widespread use of micro-surfacing and the use of polymer modified emulsions in slurry seals. These test methods and design procedures remain in use today because there is no test method or mix design procedure that specifically addresses micro-surfacing and the adequate representation/characterization of its performance indicators. Recent Texas Transportation Institute (TTI) studies documented the problems associated with using the existing methods for micro-surfacing and suggested the development of a comprehensive mix design and analysis procedure. While differences exist between slurry seal and microsurfacing applications (i.e., traffic volume, application thickness, and curing mechanisms), the similarities of the tests currently used indicate that the two systems must be studied together.

Application/Use: This is directly applicable to pavement management as well as pavement maintenance engineers.

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

Present Benefit: Many aspects of the LTPP program were utilized in this study. The SPS-3 experiment was specifically tailored to investigating preventative maintenance treatments, including slurry seals. Results from studies conducted on the SPS-3 projects were incorporated into this study. The Distress Identification Manual developed by LTPP was recommended as a tool for evaluating treatments from a surface condition perspective. Additionally, the experimental design and test site layout from the SPS-3 project were recommended for use in developing pilot projects for field validation in this slurry seal/microsurfacing project. All of this readily available information from the LTPP program provided significant value to the study at hand.

Future Benefit: Products and findings from the LTPP program can be used in a variety of projects. While the findings and products from LTPP are of significant value to researchers, other aspects of the program, including the experimental design, data collections techniques, and documentation procedures, provide benefit as well.

Title: Use of Artificial Neural Networks for Predicting Rigid Pavement Roughness

Author(s): Teomete, Egemen; Bayrak, Mustafa Birkan; Agarwal, Manish

Date: 2004

Publisher: Iowa State University, Ames

Conference Title: 2004 Transportation Scholars Conference

Abstract/Synopsis: This paper focuses on analyzing the Long Term Pavement Performance (LTPP) database to predict the international roughness index (IRI) in rigid pavements using artificial neural networks (ANNs). Large number of input parameters such as pavement layer data including the initial IRI value, age, faulting, traffic data, and transverse cracking data for 3 different severity levels (low, medium, and high) were used to predict the IRI values for jointed Portland cement concrete (JPCC) pavements. Substantial amounts of pavement performance data queried from 83 pavement sections that belong to 9 states were used in developing the ANN pavement roughness prediction models. The developed ANN models were able to successfully predict the measured IRI values with coefficient of multiple determination values of 0.84 for the training data set and 0.81 for the testing data set. Results showed that the selection criteria for the testing sets are very important when evaluating the performance of the ANN models. It was demonstrated that ANNs are capable of mapping the complex, nonlinear relationship between the large number of pavement input parameters and the pavement roughness index of IRI value. Such models can be used to predict and forecast the pavement roughness index for pavement management system applications.

Application/Use: This paper can be used by those interested in pavement roughness predictions.

Contribution: Improvement in Knowledge

Present Benefit: Pavement roughness predictions are useful in pavement management as well as pavement design. Accurate predictions can be used to make cost-effective decisions on improvement timing and budget. This paper is also useful in evaluating artificial neural network algorithms.

Future Benefit: The LTPP database will contribute to future research by providing data necessary to evaluate new prediction techniques. As part of this process, bias, error, and sensitivity studies can also be conducted using the LTPP database. This improved prediction techniques along with quantified variability will benefit the pavement community in a multitude of areas.

Title: Automated Pavement Analysis in Missouri Using Ground Penetrating Radar

Author(s): Cardimona, S; Willeford, B; Webb, D; Hickman, S; Wenzlick, J; Anderson, N.

Date: 2003

Publisher: University of Missouri, Rolla; Missouri Department of Transportation; Federal Highway Administration

Abstract/Synopsis: Current geotechnical procedures for monitoring the condition of roadways are time consuming and can be disruptive to traffic, often requiring extensive invasive procedures (e.g., coring). Ground penetrating radar (GPR) technology offers a methodology to perform detailed condition assessment of existing roadways, with the added advantage over other techniques of being rapid and cost-effective. This project and report were split into four different sections based on the type of roadway being surveyed. The first section presents the results of a GPR survey over portions of Interstate 44 near Springfield, Missouri. The goal of this survey was to evaluate concrete pavement layer thickness and continuity within the specific study regions. The second section applies GPR techniques to a survey along Interstate 70 across the state of Missouri. Goals of this survey were threefold: 1) determine layer thicknesses every tenth mile; 2) update history information related to types of pavements that make up I70 across Missouri; and 3) to note regions where the radar signal appears anomalous. The third section applies GPR techniques to 35 test pavements of the Strategic Highways Research Program LTTP sites across the state of Missouri. The result is a correlation of GPR reflection character and GPR-derived layer thickness estimates with design information for each test pavement. In the last section of the report, GPR surveys were performed over 42 miles of secondary highways to determine the thickness of the asphalt pavement and also to determine if indications of potential maintenance problem areas could be identified. Asphalt surface layering proved to be the easiest to image, creating a strong signal in the GPR data. Not as consistently clear is the concrete-to-base rock interface where the dielectric contrast between these two media is not always strong enough to create a high amplitude reflected signal. It was also determined by correlation of GPR data and coring that anomalous areas could be characterized, especially to recognize pavement where the asphaltic cement was stripping from the aggregate.

Application/Use: The study is directly applicable those interested in using GPR data to collect layer information

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: The LTPP database provides material property and layer thickness data for test sections across the country. With this information, evaluations can be performed comparing GPR results with known layer information. Variability, error, and bias can then be quantified.

Future Benefit: The future benefit of this study and the availability of layer thickness information in the LTPP database can advance GPR technology. GPR technology has the potential to provide huge benefits in acquiring inventory information for pavement management, pavement evaluation, and design purposes.

Title: Distress Identification Manual for the Long-Term Pavement Performance Program (Fourth Revised Edition)

Author(s): Miller, John S; Bellinger, William Y.

Date: 2003

Publisher: FHWA, Office of Infrastructure Research and Development, McLean, VA

Abstract/Synopsis: Accurate, consistent, and repeatable distress evaluation surveys can be performed by using the Distress Identification Manual for the Long-Term Pavement Performance Program. Color photographs and drawings illustrate the distresses found I three base pavement types; asphalt concrete-surface; jointed (plain and reinforced) portland cement concrete; and continuously reinforced concrete. Drawings of the distress types provide a reference to assess their severity. Methods for measuring the size of distresses and for assigning severity levels are given. The manual also describes how to conduct the distress survey, from obtaining traffic control to measuring the cracks in the pavement. Sample forms for recording and reporting the data are included. The manual also tells how to calibrate and operate fault measurement devices.

This manual is supplemented by various other documents including:

- Pocket DIMS
- LTPP Distress Directives

Application/Use: This manual provides all of the necessary definitions and guidelines to collect consistent surface distress data. Numerous State and local agencies have implemented the techniques in this manual for collecting network level and project level condition data.

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

Present Benefit: The distress manual established by LTPP ensures accurate and consistent surface condition information is collected. Inaccurate data can result in improper selection of rehabilitation strategies and inadequate pavement designs. Improvements in the accuracy and consistency of condition data result in cost savings through proper selection of rehabilitation strategies and pavement structure designs.

The guidelines and protocols have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedure without expending significant effort developing a new protocol. The LTPP manual can also be used as a training tool for new surveyors.

Future Benefit: The benefit of the LTPP distress manual will increase as additional agencies collect condition information as part of their pavement management systems.

Title: Distress Data Consolidation Final Report

Author(s): Simpson, A. L; Daleiden, J. F.

Date: 2003

Publisher: Fugro-BRE, Incorporated; Federal Highway Administration

Abstract/Synopsis: Pavement distress is an important indicator of pavement performance. The Long-Term Pavement Performance (LTPP) program has been collecting distress information on more than 2,000 test sections located across North America since 1989. However, these surveys were performed using three different methodologies--two photographic and one manual. Additionally, over the years, distress definitions and measurement techniques were revised in an attempt to improve consistency in data collection. The primary objective of the research reported here was to produce a comprehensive consolidated distress data set to reconcile differences between data collected using these different methodologies. After thorough review, two-thirds of the LTPP distress data were considered to be in "good shape" and could be included in the consolidated data set with no further effort. The other one-third of the data will require additional review by the agencies that performed the data collection. Overall, the discrepancies found between surveys were independent of distress methodology. The data sets from these different data collection methods could be combined without concern about a consistent bias existing in the data. Of the discrepancies that were observed, 17 percent could be attributed to human error, 6 percent to data collection methodology, 36 percent to the strategies used in this review, and 41 percent were unidentifiable.

Application/Use: The results from this study can be not only be used as a planning tool for the LTPP program but also by those interested in using distress data from the LTPP database.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: The study provides valuable information on distress data quality in the LTPP database. In addition, the evaluation provides an understanding of the differences observed between the three data collection methodologies.

Future Benefit: This study will be useful in combining the data into one consolidated table. It will also be beneficial in identifying discrepancies and improving data quality as part of the consolidation effort. The methodology used to review the data will be beneficial in improving data quality in LTPP as well as in state highway agency databases.

Title: Flexible Pavements - Results of Vicroads Pavement Performance Monitoring Program

Author(s): Papacostas, A; Bowman, A.

Date: 2003

Publisher: American Society of Civil Engineers

Journal Title: ARRB Transport Research, Limited

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

Abstract/Synopsis: In the late 1990's, VicRoads reestablished its long term Strategic Pavement Monitoring Program with the principal objective of reporting general trends in pavement condition using roughness, rutting, pavement deflection and visual condition as the principle indicators of pavement performance. This information can then be used to develop pavement performance prediction models suitable for inclusion in HDM4, recently implemented by VicRoads. In addition, it is anticipated that the monitoring data will also enable Austroads pavement design and overlay design procedures to be further refined. The program incorporates monitoring of heavily trafficked unbound granular pavements at 9 sites varying in age from 10 - 23 years with cumulative in-service traffic loadings as high as 2 x 10 7 ESAs. These pavements are surfaced with a sprayed seal and typically incorporate up to 400 mm of high quality crushed rock placed over lower quality crushed rock and select fill materials. Considerable data is now available which clearly confirms the excellent performance of these pavements, particularly in relation to pavement roughness and rutting. Trends in the data confirm that these pavements will continue to provide satisfactory long-term performance. Also included within the program are 5 deep strength asphalt pavement sites that were established initially under the Strategic Highway Research Program (SHRP) Long-Term Pavement Performance (LTPP) studies. Monitoring of the 5 sites, which are all located along the Western Ring Road, began in 1994. Deep strength asphalt pavements in Victoria typically consist of not less than 175 mm of asphalt overlying a high quality cement treated subbase. In expansive subgrade environments, a thick non-expansive capping layer is placed beneath the cement treated subbase. Trends in roughness, rutting and pavement deflection are now available and this data may ultimately assist with establishing performance based specification criteria. The pavement monitoring program also now incorporates assessment of the performance of pavement rehabilitation and surfacing treatments in various locations throughout Victoria. The treatments include cementitious stabilization, granular resheets, and asphalt regulation combined with geotextile reinforced seals. This new focus is a significant expansion from past pavement monitoring programs that concentrated largely on newly constructed pavements.

Application/Use: Data collected as part of the LTPP program will assist pavement engineers in selecting cost-effective design features.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Long term monitoring has allowed evaluations of deep strength asphalt concrete pavement to be conducted.

Future Benefit: The results from this study will be beneficial in determining proper applications for deep strength asphalt concrete pavement.

Title: PCC Joint Faulting Measurements at the Mn/ROAD Project

Author(s): Burnham, Tom

Date: April 2003

Publisher: Minnesota Department of Transportation

Abstract/Synopsis: Fault measurements are being taken at the Mn/ROAD project to establish long-term trends that can be used to calibrate models in new mechanistic-empirical design methods. The wide range of variables built into the test sections will result in a fairly comprehensive set of data that can be used to develop new models, or calibrate existing ones.

This document outlines the history of transverse joint fault measurements taken on the PCC cells at the Mn/ROAD project. It will describe both the current testing scheme and the history of changes.

Application/Use: The results from faulting data collection can be used in the design and management of jointed concrete pavement.

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

Present Benefit: This document illustrates how LTPP-developed data collection techniques can be used by State Highway Agencies and other organizations for performance monitoring. Faulting measurements taken at Mn/ROAD follow protocols established by the LTPP program. This is just one example of the many data collection guidelines and procedures developed by LTPP that are in use across the country and abroad.

Future Benefit: Guidelines established through the LTPP program will continue to be used by the pavement community, adding to the benefit provided by the program. Pavement monitoring and materials testing techniques developed within LTPP provide benefits to every aspect of pavement engineering and research.

Title: Prediction of Longitudinal Roughness Using Neural Network

Author(s): Farias, M. M; Neto, SAD; Souza, R. O.

Date: 2003

Publisher: Universidade do Minho, Portugal

Conference Title: Maintenance and Rehabilitation of Pavements and Technological Control

Abstract/Synopsis: Longitudinal roughness is the major cause of discomfort for passengers and the main variable when computing rideability and serviceability indices of pavements in several countries. Therefore it is important to predict when the road will achieve a critical level of roughness in order to allocate funds fir necessary maintenance and rehabilitation. In this paper, International Roughness Index (IRI) values were obtained for a profile database of the Long-Term Pavement Performance (LTPP) program, including 42 states of the USA. Later neural networks were used to predict this index having input parameters related to the type of sub-grade soil pavements structure (layer thickness), climate and traffic. A neural network was able to forecast IRI with an extremely high correlation factor (R2=0.99). Besides, neural network provided a sensitivity analysis indicating relative contribution factors related to the structural number (49%), climate (31%), and traffic (20%). Multivariate linear and nonlinear statistic regressions were also performed and could not find any correlation at all.

Application/Use: This paper can be used by those interested in pavement roughness predictions.

Contribution: Improvement in Knowledge

Present Benefit: This paper provides insight on pavement roughness prediction using neural network algorithms. Predictions are useful in pavement management as well as pavement design.

Future Benefit: The LTPP database provides the means of evaluating new prediction models and techniques. This will be beneficial as new techniques are introduced as it allows error and variability estimates to be established.

Title: Application Notes: FWD Calibration Centers Ensure States Get Quality Data

Author(s): Richter, Cheryl

Date: 2002

Publisher: FHWA, Office of Infrastructure Research and Development, McLean, VA

Abstract/Synopsis: In the late 1980s, the Long Term Pavement Performance (LTPP) program developed FWD calibration procedures. Adopted by the American Association of State Highway and Transportation Officials (AASHTO) as a provisional standard, these procedures are the only nationally accepted means of ensuring that FWD information is as accurate as it can be. In the early 1990s, FWD calibration centers were opened in cooperation with State DOTs in Minnesota, Nevada, Pennsylvania, and Texas. The State DOTs manage the centers, and in three of the States, DOT personnel supervise the day-to-day operations and calibrations. The Texas Transportation Institute, through an agreement with the State DOT, operates the FWD calibration center in Texas. The States provide the space and staffing resources for the calibration centers, while the Federal Highway Administration (FHWA) donates the equipment used in the calibration procedures.

Other documents on the FWD Calibration Centers include:

- SHRP/LTPP FWD Calibration Protocol
- Guidelines for Users of the SHRP FWD Calibration Centers
- Falling Weight Deflectometer Relative Calibration Analysis, FWDCAL Version 3.0
- Product Brief: Working With Your FWD Calibration Center Videotape

Application/Use: The calibration centers have been used by public agencies as well as private companies who own and operate FWDs.

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

Present Benefit: Development of the FWD calibration protocol, including the methodology as well as design and construction of the calibration apparatus, was the direct result of LTPP, and served as the foundation for the new calibration protocol.

Significant benefits are associated with better quality FWD data. Accurate information results in more cost-effective pavement designs and leads to appropriate rehabilitation strategy selections.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach. With this move, the accuracy of deflection data will become even more critical to proper pavement design.

Title: Benefiting from LTPP - A State's Perspective

Author(s): Hoffman, G.

Date: 2002

Publisher: Federal Highway Administration

Journal Title: Public Roads Vol. 65 No. 6

Abstract/Synopsis: For more than a decade, the U.S. Federal Government, the States, and Canadian provinces have invested in the Long-Term Pavement Performance Program (LTPP), a 20-year pavement research project. During its first 10 years, LTPP gathered, processed, and analyzed data describing the structure, service conditions, and performance of more than 2,500 pavement test sections in North America. This article provides a discussion of the values and benefits of LTPP to date from the perspective of the author's experience with the Program in the state of Pennsylvania.

Application/Use: This article is useful in providing state highway agencies examples of how the LTPP program can be used in many aspects of their operation.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The LTPP program has a wide variety of products that can be used by state highway agencies. This includes data collection/equipment protocol, performance data from across the country, as well as many research results. This information can supplement ongoing research at the state-level or can be implemented directly. In either case, cost savings can be realized by tapping the LTPP resource.

Future Benefit: The LTPP program will continue to add benefit as new research needs arise. In particular, local calibration and validation of the M-E PDG will rely heavily on LTPP data.

Title: Issues in Pavement Smoothness: A Summary Report

Author(s): Perera, R. W; Kohn, S. D.

Date: 2002

Publisher: National Cooperative Highway Research Program; Soil and Materials Engineers, Incorporated

Journal Title: NCHRP Web Document 42

Abstract/Synopsis: Pavement smoothness has been recognized as one of the measures of pavement performance. Several Long-Term Pavement Performance (LTPP) studies have addressed certain aspects of pavement smoothness, including roughness development, measurement methods, and modeling. To advance the state of practice and knowledge of pavement smoothness, a workshop on pavement smoothness was held from August 26-28, 2001, in Irvine, California as part of National Cooperative Highway Research Program (NCHRP) Project 20-51(01). Participants included individuals from state highway agencies, the Federal Highway Administration (FHWA), asphalt concrete and portland cement concrete paving industries, academia, consulting firms, and research organizations. The workshop began with a series of presentations that covered a variety of topics related to pavement smoothness. These topics included findings from LTPP data analysis studies, equipment used for measuring smoothness, findings from a FHWA survey of state practices, contractors' perspective on pavement smoothness, and state highway agencies perspective on issues related to pavement smoothness. After the presentations, workshop participants reviewed, in facilitated group discussions, the subjects of equipment and measurements, data analysis, and specifications and use. Through these discussions and a consensus-building process, workshop participants identified and prioritized nine primary issues related to pavement smoothness that require concerted efforts for advancement. Workshop participants then recommended strategies to address each of the nine issues. Workshop participants also identified groups within the private and public sectors that could play an active role in implementing these strategies. The information provided in this document should serve as a guide to those concerned with pavement smoothness in identifying, sponsoring, or pursuing parts of this extensive effort and thus help achieve the expected benefits from such measurements.

Application/Use: This document provides and excellent source for researchers interested in pavement smoothness issues.

Contribution: Advancement in Technology; Lessons Learned.

Present Benefit: The work conducted by LTPP in the area of profile data collection has significantly advanced the standard of practice. Improvements in data collection, equipment calibration, data review and data processing have been realized in this endeavor. The most recent profile protocol developed under LTPP defines the methodology to collect smoothness data for weigh-in-motion (WIM) sites.

The roughness of the road directly impacts the end user in perception, comfort, safety and operating costs. By accurately and consistently collecting profile data, highway officials can provide pavements with improved service to end users.

The data collected and stored in the LTPP database as been instrumental in modeling the progression of roughness over time. Additionally, the data has allowed researchers the opportunity to study the contributing factors in the rate of this accumulation.

Through work under LTPP, WIM smoothness has been identified as a key component in the calibration and accuracy of WIM equipment. This has resulted in software that assists in evaluating and selecting WIM locations.

Future Benefit: The guidelines developed will be used in the future as agencies continue to collect profile data. Additional benefit will be realized in the areas of pavement management systems, M-E PDG, and traffic data collection.

Title: LTPP Data Analysis: Factors Affecting Pavement Smoothness

Author(s): Perera, R. W; Kohn, S. D.

Date: 2002

Publisher: Transportation Research Board

Journal Title: NCHRP Research Results Digest No. 264

Abstract/Synopsis: This digest highlights the factors affecting pavement smoothness, identified in National Cooperative Highway Research Program (NCHRP) Project 20-50(08/13), on the basis of the data available from the Long-Term Pavement Performance (LTPP) studies. The research, completed in August 2001, provided preliminary conclusions regarding the factors affecting pavement smoothness of different types of new and rehabilitated pavement structures. Data related to pavement structure and features, rehabilitation techniques, climatic conditions, traffic levels, layer materials and properties, pavement distress variables, and other factors that may contribute to changes in pavement were extracted from the LTPP data tables and compiled in a project-specific database to facilitate the analysis. The International Roughness Index (IRI) was adopted as the measure of pavement smoothness. This digest provides a summary of the work performed in this research.

Application/Use: This information provides researchers with a broad perspective on factors affecting pavement smoothness.

Contribution: Advancement in Technology; Implementation/Usage.

Present Benefit: The work conducted by LTPP in the area of profile data collection has significantly advanced the standard of practice. Improvements in data collection, equipment calibration, data review, and data processing have been realized in this endeavor. The most recent profile protocol developed under LTPP defines the methodology to collect smoothness data for weigh-in-motion (WIM) sites.

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Title: LTPP Distress Identification Manual Sets a Standard for States: Illinois, Michigan, Mississippi, Missouri, Nevada, and Oklahoma Use Manual as a Baseline for Identifying and Quantifying Distresses

Date: 2002

Publisher: Federal Highway Administration

Journal Title: Application Notes

Abstract/Synopsis: State departments of transportation (DOTs) rely on accurate distress reports to plan and implement pavement projects. The Long Term Pavement Performance (LTPP) program's "Distress Identification Manual" uses drawings, text, and color photographs to clearly show common types of distress found in asphalt cement, jointed portland cement concrete, and continuously reinforced concrete pavements. Developed under the Strategic Highway Research Program, the manual is currently being updated and reissued by the Federal Highway Administration's LTPP program. This Application Note briefly comments on use of the manual by the DOTs of Illinois, Michigan, Mississippi, Missouri, Nevada, and Oklahoma as a baseline for identifying and quantifying distresses.

Application/Use: This manual provides all of the necessary definitions and guidelines to collect consistent surface distress data. Numerous state and local agencies have implemented the techniques in this manual for collecting network level and project level condition data.

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

Present Benefit: The distress manual established by LTPP ensures accurate and consistent surface condition information is collected. Inaccurate data can result in improper selection of rehabilitation strategies and inadequate pavement designs. Improvements in the accuracy and consistency of condition data result in cost savings through proper selection of rehabilitation strategies and pavement structure designs.

The guidelines and protocol have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedure without expending significant effort developing a new protocol. The LTPP manual can also be used as a training tool for new surveyors.

LTPP has also advanced technology in the areas of rut depth measurement using Dipstick® devices and faulting measurement using the modified Georgia Faultmeter.

Future Benefit: The benefit of the LTPP distress manual will increase as additional agencies collect condition information as part of pavement management systems.

Title: Utilizing the Long-Term Pavement Performance Database in Evaluating the Effectiveness of Pavement Smoothness

Author(s): Ksaibati, K; Mahmood, S. A.

Date: 2002

Publisher: Mountain-Plains Consortium

Abstract/Synopsis: State highway agencies (SHAs) in the United States use smoothness specifications to insure that they are providing the public with quality roads. Monetary incentives/disincentive policies based on the initial roughness values are used by the SHAs to encourage contractors to build smoother roads. To justify the extra costs associated with smoothness specifications, it is important to demonstrate that smoother roadways do stay smooth over time. This research study was conducted at the University of Wyoming to examine if the initial roughness of a pavement section has any effects on its long-term performance. A large number of test sections from the Long-Term Pavement Performance (LTPP) database were included in the study. The statistical tests performed indicate that asphalt and concrete pavements with low initial smoothness stay smooth over time. This study also emphasized the importance of utilization of the LTPP database.

Application/Use: This paper can be used by those interested in post-construction smoothness and its effect on long term roughness accumulation.

Contribution: Improvement in Knowledge

Present Benefit: Quantifying the relationship between initial smoothness and progression of roughness over time allows highway agencies to adjust specifications and optimize long term performance. The amount of data available in the LTPP database allows this type of study to be conducted on a large dataset, over a variety of in situ conditions, creating robust results.

Future Benefit: The inventory and performance data in the LTPP database will be valuable to researchers as similar future studies and evaluations are conducted.

Title: Adequacy of Rut Bar Data Collection

Date: 2001

Publisher: Federal Highway Administration

Journal Title: TechBrief

Abstract/Synopsis: The importance of timely corrective action for rutted pavements, coupled with the need for safe and efficient data collection, has led many State highway agencies to use automated survey vehicles to collect the data needed to assess and monitor the extent and severity of pavement rutting. Typically, these devices measure the distance from a reference point on the survey vehicle to the pavement surface at three or five points across the pavement width. These data are then used to compute an estimate of the depth of pavement rutting. Recent Long Term Pavement Performance (LTPP) data analysis has provided information on the repeatability and accuracy of the rut statistics obtained with these devices. Key findings from the LTPP data analysis are presented in this Tech Brief.

Application/Use: The results from this study provide information on the accuracy and variability of rutting data that can be used by state highway and other agencies collecting and analyzing the data.

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: Rutting information can be collected and used as part of a pavement management system. Error, variability, and bias are important aspects of data used to make decisions on improvement selection and timing. Agencies can use the findings from this study to improve these decision making process.

Future Benefit: The availability of quality rutting index data will continue to provide value as researchers conduct future studies dealing with rutting data.

Title: Assessing Variability of Surface Distress Surveys in Canadian Long-Term Pavement Performance Program

Author(s): Goodman, S. N.

Date: 2001

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1764

Abstract/Synopsis: In 1997 the Canadian Long-Term Pavement Performance (C-LTPP) project capitalized on an opportunity to have surface distress surveys completed twice at more than half of its test sections to provide some insight as to the variability between different raters. The major findings of that investigation are presented. Because only two distress surveys for each test section were available for comparison, traditional variance analysis techniques were not applicable. Instead, a technique involving an "agreement index," also known as "Cohen's weighted kappa statistic," was used to directly compare the levels of agreement between the surveys. The kappa statistic considers the likelihood of chance agreement and also allows the introduction of penalty values for individual cases of disagreement. The analysis results indicated that the level of agreement based on crack type was very high; less agreement was observed for severity level. Agreement increased significantly with increased data aggregation, indicating that less variability will be present for network-level analyses than for project-level analyses. The effect of rater experience was also investigated, although no firm conclusions could be made with the available data. Recommended methods for reduction of the variability of future distress surveys included reduction of the number of severity levels from five to three, reduction of the number of individual agency raters, more frequent training of raters, and the use of rating teams. In general, the results of the C-LTPP project distress variability analysis were in agreement with previous studies, including the recent study completed by the U.S. LTPP program.

Application/Use: This study is directly applicable to pavement management as well as researchers using distress data.

Contribution: Improvement in Knowledge

Present Benefit: Distress data is a key component in pavement management. Variability studies can be used to determine methods of reducing inconsistencies. Additional benefit is realized when distress data is used to make improvement decisions and scheduling treatment activities. The LTPP program has collected sufficient data through accreditation workshops to study variability, error, and bias. Additionally, LTPP has developed methods that reduce variability between raters, which has improved the quality of data reported in the LTPP database.

Future Benefit: Distress data will continue to be a key factor in pavement management systems. The methodology developed as part of the LTPP program can be implemented by local agencies. This eliminates the need for the agency to develop their own protocols and

manual, resulting in cost savings. Variability studies conducted under the LTPP program will also be beneficial to agencies developing improvement strategies based on distress data.

Title: Characterization of Transverse Profiles

Author(s): Simpson, A. L.

Date: 2001

Publisher: Fugro-BRE, Incorporated; Federal Highway Administration

Abstract/Synopsis: A study of the transverse profile data currently being collected under the Long Term Pavement Performance (LTPP) project was undertaken. The data were collected by three processes: (1) Dipstick (registered trademark); (2) a photographic method; and (3) straightedge used to collect rut depths. This study examined several indices for the purposes of quantifying and qualifying the transverse profiles. It is recommended that five indices be added to the National Information Management System. These indices include the area of the rut below a straight line connecting the end points of the transverse profile, the total area below the straight lines connecting the maximum surface elevations, the maximum depth for each wheelpath between a 1.8-m straightedge placed across the wheelpath and the surface of the pavement, and the width of the rut based on a 1.8-m straightedge. These indices were studied in order to determine t

Title: Key Findings from LTPP Distress Data

Date: 2001

Publisher: Federal Highway Administration

Journal Title: TechBrief

Abstract/Synopsis: Within the Long Term Pavement Performance (LTPP) program, two approaches to pavement distress data collection have been used: manual distress surveys and photographic surveys. In both approaches, the type, severity, and extent of the distress observed on the pavement are determined and recorded by trained personnel using the definitions and measurement and rating criteria provided in LTPP's distress identification manual. Differences between the two survey methods, when examined, suggest that some reconciliation may be needed before the data obtained with them may be combined for use in pavement performance analysis. For this reason, a study was undertaken to pursue this reconciliation. The findings of this study have some important implications for future work with the LTPP distress data and for agencies collecting similar distress data for their own applications. The most important finding of this investigation is that there is no systematic difference in the distress data that is attributable to the method of survey. Thus, no reconciliation of data differences due to distress survey methods is needed prior to combining photographic and manual distress data for use in subsequent analysis. It was also found that the majority of the distress data reflect rational time trends and are, therefore, suitable for use in future performance analysis. Finally, the methodology applied to evaluate the LTPP distress data is very promising as a quality control tool. It is anticipated that this methodology will be used to enhance LTPP quality control measures.

Application/Use: The results from this study can not only be used as a planning tool for the LTPP program but also as a resource to those interested in using distress data from the LTPP database.

Contribution: Improvement in Knowledge

Present Benefit: The study provides valuable information on distress data quality in the LTPP database. In addition, the evaluation provides an understanding of the differences observed between the three data collection methodologies.

Future Benefit: This study will be useful in combining the data into one consolidated table. It will also be beneficial in identifying discrepancies and improving data quality as part of the consolidation effort. The methodology used to review the data will be beneficial in improving data quality in LTPP as well as in state highway agency databases.

Title: Survey of Current Practices of Using Falling Weight Deflectometers (FWD)

Author(s): Nazef, Abdenour; Choubane, Bouzid

Date: September 2001

Publisher: Florida Department of Transportation

Abstract/Synopsis: In May of 2001, the Florida Department of Transportation (FDOT) distributed a survey questionnaire to the 51 State Departments of Transportation (DOTs), and to 3 Canadian provinces including British Columbia, Ontario, and Quebec. The objective was to assess the current practices of using the Falling Weight Deflectometer (FWD) by these highway agencies, and to gather some related facts and figures of interest to FWD users. This report provides a summary of the survey results based on the responses received from the user agencies.

Application/Use: This is directly applicable to pavement evaluation, pavement design, pavement management, all of which make use of FWD data.

Contribution: Improvement in Knowledge; Advancement in Technology; Implementation/Usage.

Present Benefit: The results of this survey reveal the number of agencies utilizing LTPP-developed procedures to calibrate FWD equipment. Accurate FWD data is essential to proper pavement evaluation and cost-effective design and LTPP has made significant contributions to the advancement of FWD in terms of calibration, maintenance, data collection, and QC.

Future Benefit: The use of FWD equipment continues to grow and is now a pavement evaluation tool not only for use in pavement design but also pavement management applications. The advancements made by the LTPP program will have a lasting effect on the accuracy and quality of FWD data.

Title: Analysis by High-Speed Profile of Jointed Concrete Pavement Slab Curvatures

Author(s): Byrum, C. R.

Date: 2000

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1730

Abstract/Synopsis: A high-speed pavement profile analysis method that detects curvature present in the wheelpaths of jointed concrete pavement slabs is presented. This technique can be used to analyze slab curvatures present in pavements and caused by curling and warping forces. The Federal Highway Administration Long-Term Pavement Performance (LTPP) program has obtained high-speed elevation profiles for the jointed concrete pavements in the study. This profile analysis method reads an LTPP profile and detects imperfections in the road curvature profile, which typically are joints and cracks. It then analyzes the slab regions (intact slab segments) between these numerical imperfections for the presence of curvature. The result of a profile analysis is a road profile index--the curvature index--which represents the average slab curvature present along the wheelpaths for the profile. This profile analysis method was applied to more than 1,100 LTPP GPS3 profiles. The range of the slab curvatures encountered is described, and some key factors related to apparent locked-in curvatures (related to warping and construction) are discussed. The amount of locked-in curvature in slabs significantly affects slab behavior and long-term pavement performance. Curvature information should be available to pavement rehabilitation engineers making fix type and funding decisions for pavements. This new analysis method could be implemented rapidly in routine pavement profile analysis and pavement management systems.

Application/Use: The findings from this study can be used in pavement management applications.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The analysis procedure developed in this study can be extremely useful to pavement managers. Understanding the condition of slabs and sources of deterioration is essential in making cost-effective rehabilitation decisions.

Future Benefit: Understanding the conditions of rigid pavements will continue to provide benefit through better decisions. These will lead to better performing pavements and overall optimization of resources.

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, and for that 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, which 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 Profile Variability

Author(s): Evans, L. D; Eltahan, A.

Date: 2000

Publisher: ERES Consultants, Incorporated; Federal Highway Administration

Abstract/Synopsis: A study has been conducted to evaluate the quality and variability of the International Roughness Index (IRI) data in the Long Term Pavement Performance (LTPP) database. All LTPP profiles collected between June 1989 and October 1997 were visually reviewed for saturation spikes, lost lock, shifted starts, wrong location, out of study, and other equipment- and operator-related problems. Noted problems are identified in the report. Repair, replacement, or deletion of these files was completed in conjunction with this study. Remaining or replaced good IRI data were used for analysis of variability. Analysis of variance focused on the run-to-run and visit-to-visit IRI variability in the LTPP sections studied. Mean IRI values for these asphalt concrete (AC), portland cement concrete (PC), and AC/PC overlaid sections ranged from 0.5 to 4.3 m/km. Based on the upgraded data set, confidence limits were developed for expected variability between repeated profile testing runs and for the expected change in IRI between subsequent visits. Additional analysis is also presented regarding the effects of saturation spikes, shifted profiles, and wheelpath testing location on IRI. Study was also completed on the effect of the number of runs collected at a site, the effect of moist pavement surfaces, and the results of small changes in the coefficients used to compute IRI. Recommendations of the study address the methods used for field profile collection, office review methods, Information Management System (IMS) database design, and profile calibration.

Application/Use: This study was used by LTPP for internal planning, but is also applicable to pavement management.

Contribution: Improvement in Knowledge; Advancement of Technology.

Present Benefit: The study has provided benefit by identifying and correcting problems thereby improving the quality of the LTPP database. Additionally, the work has documented the inherent variability in inertial profiler data collection. This and other findings from the study will be beneficial to agencies collecting profile data and may provide information on methods to improve consistency and reduce variation.

Future Benefit: Roughness plays an important role in highway agency pavement management systems because it directly effects user perception and user costs. Therefore, understanding the nature of roughness data and the variability in the data collection techniques will continue to provide benefit as agencies strive to improve overall network conditions.

Title: NDT Approach to Monitoring PCC Deterioration Due to D-Cracking in Highway Pavements

Author(s): Kumapley, R. K; Kumapley, N. K.

Date: 2000

Publisher: Technomic Publishing Company, Incorporated

Conference Title: Structural Materials Technology IV - An NDT Conference

Abstract/Synopsis: Durability cracking (D-cracking) is a pavement distress that is widespread in the mid-western, northern, and eastern United States, and it is one of the predominant distresses monitored by visual inspection under the Long-Term Pavement Performance (LTPP) Project. The nondestructive procedure presented in this paper for monitoring D-cracking was found to be a good supplement of the LTPP procedure for monitoring D-cracking in the test sections. The procedure involves the use of the ratio of deflections at the slab edge to the deflections at the slab center, DEF ratio. Case studies on monitoring D-cracking in two test sections in the North Central LTPP Region are used to illustrate the use of the DEF ratio. This procedure may be useful to highway agencies for monitoring D-cracking progression and deterioration of joints, cracks, and shoulder edges of jointed plain concrete pavement.

Application/Use: The results from this paper are applicable to FWD analysis and concrete materials engineers.

Contribution: Improvement in Knowledge

Present Benefit: The LTPP database provides both surface distress and FWD data for rigid pavements. This information was necessary for this study to be conducted. Correlating FWD data to materials related deterioration is useful to pavement engineers in identifying the mechanisms of failure. This can also be used to select rehabilitation alternatives.

Future Benefit: The LTPP data source will continue to benefit pavement research. The LTPP database affords the opportunity to refine existing analysis procedures or develop new methodology.

Title: Variability of Pavement Distress Data from Manual Surveys

Date: 2000

Publisher: Federal Highway Administration

Journal Title: TechBrief

Abstract/Synopsis: Several measures have been carried out in the Long Term Pavement Performance (LTPP) Program to ensure uniform distress data collection and interpretation. However, no systematic evaluation has been done to quantify the variability (bias and precision) associated with both the manual and film-derived pavement distress data. In view of this, a study was undertaken to assess the variability of the LTPP distress data, consisting of the assessment of manual distress data variability, assessment of film-derived distress data variability, and assessment of the agreement between manual distress data and film-derived distress data. This TechBrief summarizes findings from the full report related to variability in manually collected pavement distress data.

Application/Use: The results from this study can not only be used as a planning tool for the LTPP program but also as a resource to those interested in using distress data from the LTPP database.

Contribution: Improvement in Knowledge

Present Benefit: The study provides valuable information on distress data quality in the LTPP database. In addition, the evaluation provides an understanding of the differences observed between the three data collection methodologies.

Future Benefit: This study will be useful in combining the data into one consolidated distress table. It will also be beneficial in identifying discrepancies and improving data quality as part of the consolidation effort. The methodology used to review the data will be useful in improving data quality in LTPP as well as in state highway agency databases.

Title: Assessment of LTPP Friction Data

Authors: Titus-Glover, L; Tayabji, S. D.

Date: 1999

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 make them longer lasting. As part of the condition monitoring of the LTPP test sections, friction data are being collected on a regular basis at each test site. Friction data collection is the responsibility of the specific highway agency under whose jurisdiction the pavements are located. The LTPP data collection guidelines for friction data recommend using the ASTM E-274 (AASHTO T242) procedure as the preferred method for obtaining data. The ASTM E-274 procedure uses a locked-wheel skid tester in a trailer assembly. Friction test results are reported as Skid Numbers (SNs). This report provides an assessment of the availability, characteristics, and quality of the friction data collected as part of the LTPP study. Also, the availability of related pavement characteristics data was assessed. The report also contains recommendations for adjustments and refinements to current procedures for the collection of friction and related data. The LTPP database provides a one-stop source of reasonably good friction data collected in a systemic manner from a wide range of pavements subjected to a wide range of traffic loading and environmental conditions. The friction data will be of use for analyzing why some pavement surfaces retain good friction characteristics with time and why some surfaces show rapid deterioration in friction over time.

Application/Use: The results from this study can be used in pavement design and pavement management to improve safety

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The friction data collected at LTPP test sections can be beneficial in understanding surface characteristics of pavements. The friction data is collected along with other material properties, which can be used for correlation studies. Ensuring adequate friction on pavement surfaces is a major safety consideration in all pavement applications.

Future Benefit: The friction data in the LTPP database provides information that can be used in future studies evaluating pavement surface characteristics.

Title: Characterization of Transverse Profile

Authors: Simpson, A. L.

Date: 1999

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1655

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) program currently being conducted by the Federal Highway Administration is collecting transverse profile data on each of the asphalt-surfaced test sections included in the study. These data have been collected since monitoring was begun on these sections in 1989. A study was undertaken to provide indexes that summarize these x-y profiles. A study was conducted to recommend profiles to be included in the LTPP database in which six indexes were recommended to be included in the National Information Management System (NIMS). These six indexes and how they relate to each other are examined in this paper.

Application/Use: The results of this study were used to populate the LTPP database with rutting indices. This can be used by those interested in rutting data in the LTPP database.

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: This study offers benefit through multiple avenues. First, the availability of rut indices improves the usability of rut data in the database. Secondly, the evaluation of these indices over time improves the quality of data reported in the database. The study also provides some insight into the contribution of climatic and in situ conditions on rutting accumulation.

Future Benefit: The availability of quality rutting index data will continue to provide value as researchers conduct future studies involving rutting data.

Title: Study of LTPP Distress Data Variability, Volume I

Authors: Rada, G. R; Wu, C. L; Bhandari, R. K; Shekharan, A. R; Elkins, G. E; Miller, J. S.

Date: 1999

Publisher: Law PCS; Federal Highway Administration

Abstract/Synopsis: Reliable distress data for pavement performance model development and validation, and other pavement engineering products, are critical to the success of the Long-Term Pavement Performance (LTPP) program. Confidence in distress data requires a measure of error because of the bias and precision components of its variability. No systematic evaluation has been performed to quantify the bias and variability associated with both the manual and PASCO film-based distress data. In view of this, this study was undertaken by the Federal Highway Administration (FHWA) to assess the variability of the LTPP distress data, including those in the Information Management System (IMS) and those currently being collected using either photographic or manual methods. This main volume of the report contains sources of data used in the analyses, evaluation of manual distress data, evaluation of film-derived distress data, comparisons of data obtained from these two methods, and conclusions and recommendations.

Application/Use: This report can be used as an internal planning tool for LTPP, but is also applicable to pavement management.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: Pavement condition data is the driving factor in the majority of pavement management systems currently in use. Network level decisions on maintenance and rehabilitation are typically directly related to the distress data. Therefore, quantifying error and understanding bias in distress data is beneficial in improving the pavement management process. Additionally, comparisons between manual and photographic techniques can be used by agencies in determining the most appropriate data collection method for their system.

Future Benefit: By understanding the sources of variability, the results from the study can be used to modify existing data collection procedures, adding quality control measures, and improve training activities. Improving existing techniques will reduce variability and provide the means of making well-informed decisions.

Title: Study of LTPP Distress Data Variability, Volume II: Appendix A, Appendix B, and Appendix C

Authors: Rada, G. R; Wu, C. L; Bhandari, R. K; Shekharan, A. R; Elkins, G. E; Miller, J. S.

Date: 1999

Publisher: Law PCS; Federal Highway Administration

Abstract/Synopsis: Reliable distress data for pavement performance model development and validation, and other pavement engineering products, are critical to the success of the Long-Term Pavement Performance (LTPP) program. Confidence in distress data requires a measure of error because of the bias and precision components of its variability. No systematic evaluation has been performed to quantify the bias and variability associated with both the manual and PASCO film-based distress data. In view of this, this study was undertaken by the Federal Highway Administration (FHWA) to assess the variability of the LTPP distress data, including those in the Information Management System (IMS) and those currently being collected using either photographic or manual methods. This second volume of the report contains all tables and figures developed in this study.

Application/Use: This report can be used as an internal planning tool for LTPP, but is also applicable to pavement management.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: Pavement condition data is the driving factor in the majority of pavement management systems currently in use. Network level decisions on maintenance and rehabilitation are typically directly related to the distress data. Therefore, quantifying error and understanding bias in distress data is beneficial in improving the pavement management process. Additionally, comparisons between manual and photographic techniques can be used by agencies in determining the most appropriate data collection method for their system.

Future Benefit: By understanding the sources of variability, the results from the study can be used to modify existing data collection procedures, add quality control measures, and improve training activities. Improving existing techniques will reduce variability and provide the means of making well-informed decisions.

Title: Working with Your FWD Calibration Center Videotape

Date: 1999

Publisher: Federal Highway Administration

Journal Title: Product Brief

Abstract/Synopsis: The Strategic Highway Research Program and the Long Term Pavement Performance (LTPP) program developed a set of standardized falling weight deflectometer (FWD) calibration procedures and also set up four regional FWD calibration centers. To help highway agencies better understand FWD calibration procedures, LTPP produced a videotape in 1997 that explains the how and why of LTPP's FWD calibration procedures. This Product Brief describes the FWD videotape and explains who can benefit from it.

Application/Use: The calibration centers have been used by public agencies as well as private companies who own and operate FWDs. Over 500 calibrations have been performed.

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

Present Benefit: Development of the FWD calibration protocol is the direct result of LTPP. This includes development of the methodology as well as design and construction of the calibration apparatus. Significant benefits are associated with better quality FWD data. Accurate information results in more cost-effective pavement designs and leads to appropriate rehabilitation strategy selections and design decisions.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design, particularly as pavement design moves to a mechanistic-empirical approach. With this move, the accuracy of deflection data will become increasingly critical to proper pavement design.

Title: Assessment of Long-Term Pavement Performance Plan Wall Projection-Based Distress Data Variability

Authors: Shekharan, A. R; Rada, G. R; Elkins, G. E; Bellinger, W. Y.

Date: 1998

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1643

Abstract/Synopsis: In the Long-Term Pavement Performance (LTPP) program, 35-mm black and white, continuous-strip photographs are used as a permanent record of pavement distress development for archival purposes and to quantify the distress severity and extent for pavement performance analysis. The traditional method of interpreting distress from LTPP film utilizes a relatively small image projected onto a digitizing tablet. From quality control checks performed on the interpreted data, it was found that some low severity types of distress, identified from larger magnified images projected onto a wall or projection screen, could not be seen in the smaller image used for distress interpretation. The variability in distresses interpreted directly off of the large format, wall-image projection was assessed through analysis of interpretations performed on six asphalt concrete and six portland cement concrete pavement sections used in the LTPP distress rater accreditation workshops. The data set included distress ratings from eight individuals, four two-person rater teams, and an experienced rater team. Also available were distress ratings performed in the field by the experienced rater team, which are used as reference values which represent the best estimate of ground-truth. Statistical tests show that the film-interpreted distresses from individual raters exhibit much larger variability than those from the rating teams. The most significant contributor to this finding is outlier observations in which one of the individual raters had significantly different ratings than the rest of the group. The spread in the rating teams was much lower. The film interpreted distresses from the experienced group correlated very well with the field-derived reference values.

Application/Use: This paper can be used to by those interested in the inherent variability of distress data.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Distress data is an essential part of most pavement management systems. Because distress data is the driving factor in improved decisions and timing, it is essential to quantify variability and develop techniques to reduce erroneous data. The LTPP database provides an extensive database with multiple data collection techniques, which allows for these types of distress data evaluations. Benefits can be realized in the form of improved treatment selections and more cost-effective pavement management.
Future Benefit: The results from this study can be used in the future by agencies that are developing or improving distress data collection protocols. It will also be helpful in accounting for inherent variability in pavement improvement selection protocols.

Title: Establishment of a Falling Weight Deflectometer Calibration Facility

Authors: Hossain, M.

Date: 1998

Publisher: Kansas State University, Manhattan; Kansas Department of Transportation

Abstract/Synopsis: The Strategic Highway Research Program (SHRP) developed a protocol for calibration of Falling Weight Deflectometers (FWDs) which is now being administered by the Long Term Pavement Performance (LTPP) Division of the Federal Highway Administration (FHWA). The calibration procedure for FWDs recommended by SHRP consists of two parts: (1) Reference Calibration, and (2) Relative Calibration. Reference Calibration requires permanent facilities similar to those established by LTPP in Reno, Nevada, Harrisburg, Pennsylvania, Minneapolis, Minnesota, and College Station, Texas. Relative Calibration can be performed almost anywhere, using equipment provided by the FWD manufacturer. Since the center closest to Kansas is in Minneapolis, and considerable time is required for travel and calibration (usually a week), a local facility was considered to be very beneficial by the Kansas Department of Transportation. The FWD Reference Calibration facility for the Dynatest model FWD has been developed at Kansas State University and is available for calibration of FWDs in the surrounding area. The facility was established in accordance with the SHRP/LTPP FWD calibration protocol. The calibration center became operational in the spring of 1998. An independent quality assurance visit by PCS/LAW Engineering of Beltsville, Maryland has confirmed that the equipment and setup are working correctly.

Application/Use: The calibration centers have been used by public agencies as well as private companies who own and operate FWDs. Over 500 calibrations have been performed.

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

Present Benefit: Development of the FWD calibration protocol is the direct result of LTPP. This includes development of the methodology as well as design and construction of the calibration apparatus. Significant benefits are associated with better quality FWD data. Accurate information results in more cost-effective pavement designs and leads to appropriate rehabilitation strategy selections.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach. With this transition, the accuracy of deflection data will become critical to the proper pavement design.

Title: Investigation of Development of Pavement Roughness

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

Date: 1998

Publisher: Soil and Materials Engineers, Incorporated; Federal Highway Administration

Abstract/Synopsis: The Long-Term Pavement Performance (LTPP) program was designed as a 20-year study of pavement performance. The LTPP program consists of two programs: (1) General Pavement Studies (GPS) that use in-service test sections in either their original design phase or in their first overlay phase and (2) Specific Pavement Studies (SPS) that investigate the effect of specific design features on pavement performance. A major data collection effort at these test sections is the collection of longitudinal profile data along the wheel paths, which is performed annually. This report describes an investigation that was carried out to study the change in roughness at the test sections using the profile data. At the time this analysis was carried out, profile data were generally available for four years in the database. This report describes: (1) investigation of time-sequence roughness data collected at GPS test sections to study trends in development of roughness; (2) comparison between International Roughness Index and Ride Number; (3) development of models to predict changes in roughness; (4) investigation of roughness characteristics of new flexible and rigid pavements built for the SPS program; (5) investigation of roughness characteristics of flexible and rigid pavements that were subjected to different rehabilitation strategies under the SPS program; and (6) recommendations for quality assurance and profiling frequency for the test sections.

Application/Use: This study is valuable to those involved in selecting and designing pavements, including rehabilitation alternatives. The trend analysis conducted as part of the study is also applicable to pavement management.

Contribution: Cost Savings; Improvement in Knowledge.

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: "Off-The-Wall" Pavement Distress Variability Study

Authors: Daleiden, J. F; Simpson, A. L.

Date: 1998

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1643

Abstract/Synopsis: Variability of pavement surface distress data collection has always been an area of significant concern. When conducting evaluations of distress data manually (with raters observing pavements in question, interpreting what they see, and recording on paper) the process is subject to human errors. To minimize the impact of such human errors on these important pavement performance data, sophisticated equipment has been developed to eliminate as much of the human intervention as possible. Such technology is not without its own limitations of precision and bias. With both methodologies being used for the collection of surface distress data for the long-term pavement performance (LTPP) program, questions regarding precision and bias have been identified. In attempting to define the variability of the data for incorporation in stochastic analyses, it has become apparent how diverse and complex these distress data truly are. To adequately quantify the precision and bias, a detailed experiment was designed to evaluate the errors inherent in the different distress data collection methodologies. The facet of the experiment reported targets the variability of human distress surveyors and the biases associated with conducting surveys from film, using a slightly different projection system. Specifically, a collection of surveyors was assembled to establish the variability associated with experienced raters versus novice raters, engineers versus engineering technicians, and teams versus individuals.

Application/Use: This paper can be used to by those interested in the inherent variability of distress data.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Distress data is an essential part of most pavement management systems. Because distress data is the driving factor in improving decisions and timing, it is essential to quantify variability and develop techniques to reduce erroneous data. The LTPP database provides an extensive database with multiple data collection techniques, which allows for these types of distress data evaluations. Benefit can be realized in the form of improved treatment selections and more cost-effective pavement management.

Future Benefit: The results from this study can be used in the future by agencies that are developing or improving distress data collection protocols. It will also be helpful in accounting for inherent variability in pavement improvement selection protocols.

Title: Update of Long-Term Pavement Performance Manual Distress Data Variability: Bias and Precision

Authors: Rada, G. R; Wu, C. L; Elkins, G. E; Bhandari, R. K; Bellinger, W. Y.

Date: 1998

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1643

Abstract/Synopsis: Pavement distress surveys based upon field interpretation and manual mapping and recording of the distress information on paper forms has been used in the Long-Term Pavement Performance (LTPP) program to collect important pavement condition and distress data. Although this manual method was used in the past as a backup to the 35-mm black and white photographic-based method, recently the use of manual distress survey methods has increased in intensity and coverage. To promote uniformity and consistency of distress data collection, one of the early LTPP efforts was to develop standard definitions, measurement procedures and data collection forms. Various quality control and quality assurance functions have also been implemented to provide for high quality data. However, despite these efforts, manual surveys are still based upon a single rater's subjective classification of distresses present in the field. Recognizing that rater variability exists, a study was undertaken by the Federal Highway Administration to assess the level of variability between individual distress raters and to address the potential precision and bias. Results from nine LTPP distress rater-accreditation workshops conducted during the period of 1992 to 1996 were used as the source of data. Analyses of those data led to numerous observations and conclusions regarding the bias and precision of LTPP distress data. Because LTPP distress data are to be used in the development of pavement performance prediction models, it is believed that the level of variability found in this study should be reduced to increase its potential usage in the development of such models. A number of recommendations to improve the variability associated with manual distress surveys data are included.

Application/Use: This paper can be used by those interested in the inherent variability of distress data.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Distress data is an essential part of most pavement management systems. Because distress data is the driving factor in improved decisions and timing, it is essential to quantify variability and develop techniques to reduce erroneous data. The LTPP database provides an extensive database with multiple data collection techniques, which allows for these types of distress data evaluations. Benefits can be realized in the form of improved treatment selections and more cost-effective pavement management.

Future Benefit: The results from this study can be used in the future by agencies that are developing or improving distress data collection protocols. It will also be helpful in accounting for inherent variability in pavement improvement selection protocols.

Title: Analysis of LTPP Profile Data for Jointed Concrete Pavement Sections

Authors: Moody, E. D.

Date: 1997

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1570

Abstract/Synopsis: Incremental changes to a pavement-surface profile have long been considered a primary measure of pavement performance. As a result, the Long-Term Pavement Performance (LTPP) program of the Strategic Highway Research Program has allocated considerable resources for collecting accurate profile data on all general pavement studies (GPS) sites annually. As of June 1995, the profiles of the rigid pavement sites had been measured an average of four times, with many sites having been measured seven times. The data are collected and processed in the field, generating several statistical measures of pavement profile for each wheelpath, including the international roughness index (IRI), present serviceability index (PSI), slope variance, and root-mean-square vertical acceleration (RMSVA) at selected wavelengths. The focus of this analysis is on the primary profile statistic, the IRI. The profile data were downloaded from the National Inventory Management System (NIMS) and extensively analyzed using selected statistical techniques. The objective of this effort was to conduct a thorough analysis of the response variable, the IRI. The analysis included univariate, bivariate, and multivariate analytical techniques to determine which prediction variables are useful for predicting the IRI. Although many of the primary independent variables had significant correlations with the IRI, others did not. Various measures of traffic had particularly poor correlations with the IRI. Several regression models are also presented along with advantages and limitations of the prediction and response variables. The results of a detailed analysis of the within-year and year-to-year variability in IRI measurements are also included. The coefficient of variation in year-to-year measurements averaged 4.2 percent for the jointed plain concrete pavement (JPCP) sections (GPS-3) and 3.8 percent for the jointed reinforced concrete pavement (JRCP) sections (GPS-4). This degree of variability in year-to-year profile measurements tended to overshadow any absolute increase in IRI that may have been occurring in these sections. An analysis was then performed on every section to determine exactly which sections had statistically significant increases in IRI over time. Approximately 44 percent of the jointed concrete pavement sections exhibited statistically significant increases in IRI over time.

Application/Use: This paper is directly applicable to those involved in pavement management systems using roughness data.

Contribution: Improvement in Knowledge

Present Benefit: The results from this analysis provide valuable information on the nature of roughness data collected using inertial profilers. Variability and bias information is very important and is a critical consideration when developing decision trees and treatment timing based on roughness. The LTPP database provides sufficient data to allow a robust analysis of variability inherent in roughness data.

Future Benefit: This information will continue to be useful as agencies further develop and refine pavement management systems. The LTPP database will also be beneficial in developing and evaluating prediction models.

Title: Assessment of Long-Term Pavement Performance Program Manual Distress Data Variability: Bias and Precision

Authors: Rada, G. R; Bhandari, R K; Elkins, G. E; Bellinger, W. Y.

Date: 1997

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1592

Abstract/Synopsis: The use of manual survey methods within the Long-Term Pavement Performance (LTPP) program for the collection of distress data has drastically increased both in intensity and in coverage over the past couple of years. Because these surveys are conducted by individual raters whose biases can lead to variability between raters, it was hypothesized that distress data variability existed and that it could potentially be quite large. Thus, the purpose of the presented study was to quantify manual distress data variability, with special emphasis on the bias and precision of the data. Results from seven LTPP program distress rater accreditation workshops conducted during the period from 1992 to 1995 were used as the only source of data. On the basis of analyses of these data, both the apparent bias and the precision for the common distress type-severity level combinations were quantified. It was also concluded from this study that individual rater variability for any given distress type-severity level combination is typically large and increases as the distress quantity increases; however, when all distress type-severity level combinations are viewed in terms of a single composite number such as the pavement condition index value, there is excellent agreement between the individual raters, the group mean, and the ground truth value, and individual rater variability is also quite small. Because LTPP program distress data are to be used in the development of pavement performance prediction models, improvements in variability are highly desirable to ensure that they serve their intended purpose. Recognizing that the LTPP program distress raters are experienced individuals, such improvements are not envisioned to come through additional training. It is the authors' contention that the only way of achieving the desired improvement is through the conduct of group consensus surveys.

Application/Use: This study is directly applicable to pavement management as well as assisting researchers using distress data.

Contribution: Improvement in Knowledge; Lessons Learned.

Present Benefit: Distress data is a key component in pavement management. Variability studies can be used to determine methods of

Future Benefit: Distress data will continue to be a key factor in pavement management systems. The methodology developed as part of the LTPP program can be implemented by local agencies. This eliminates the need for the agency to develop their own protocol and manual, resulting in cost savings. Variability studies conducted under the LTPP program will also be useful to agencies developing improvement strategies based on distress data.

Title: Capabilities of Multimedia Pavement Distress Identification Training

Authors: Lake, A. I; Van Dam, T. J; Zimmerman, K. A.

Date: 1997

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1592

Abstract/Synopsis: In recent years the interactive training capabilities available through multimedia technology have dramatically influenced the way in which technical material is taught. These interactive training programs feature training approaches combining graphics, audio, and video in an electronic environment that allows the user to create an individualized training process customized to each person's level of understanding and expertise. Procedural changes in collecting pavement distress information and in the pavement condition rating process itself have created an opportunity for the Illinois Department of Transportation (IDOT) to develop a training package for its pavement distress identification program. This package demonstrates the capabilities of multimedia-based training within the pavement distress identification arena. The compact disc-based tutorial has been created for IDOT using Folio VIEWS multimedia production software and other application software. The information contained in the program is from the Condition Rating Survey (CRS) distress manual and the Long-Term Pavement Performance (LTPP) program distress identification manual. Both distress identification procedures (CRS and LTPP) are presented in full detail, using text and graphics, to accommodate a greater number of users. The development of the training tutorial is documented, and some of the capabilities of interactive training tools are demonstrated.

Application/Use: The LTPP Distress Identification Manual provides all of the necessary definitions and guidelines to collect consistent surface distress data. This is an example of how Illinois DOT has implemented the techniques established in the manual for collecting network level and project level condition data.

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

Present Benefit: The distress manual established by LTPP ensures that accurate and consistent surface condition information is collected. Inaccurate data can result in improper selection of rehabilitation strategies and inadequate pavement designs. Improvements in the accuracy and consistency of condition data result in cost savings.

The guidelines and protocols have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedures without expending significant effort on developing new protocols. The LTPP manual can also be used as a training tool for new surveyors.

Future Benefit: The benefit of the LTPP distress manual will increase as additional agencies collect condition information as part of their pavement management systems.

Title: LTPP Data Analysis: Frequently Asked Questions About Joint Faulting with Answers from LTPP

Date: 1997

Publisher: Federal Highway Administration

Journal Title: LTPP TechBrief

Abstract/Synopsis: This Long-Term Pavement Performance (LTPP) data analysis was intended to examine, in a practical way, the LTPP data base and to identify the site conditions and design features that significantly affect transverse joint faulting. Key products developed as part of this research were (1) answers to frequently asked questions regarding design features and site conditions that lead to "good" (better than expected) and "poor" (worse than expected) performance of jointed concrete pavements relative to joint faulting and (2) guidelines to assist highway agencies on what works and what does not work in the design of transverse joints to control joint faulting. This TechBrief presents key findings of this research.

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

Contribution: Cost Savings; Lessons Learned.

Present Benefit: There are many factors that contribute to pavement performance. This study attempts to sort out attributes relative to joint faulting 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 sufficient data to develop additional conclusions and findings.

Title: Prediction of Pavement Remaining Life

Authors: Vepa, T. S; George, K. P; Shekharan, A. R.

Date: 1996

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1524

Abstract/Synopsis: The evaluation of remaining life is necessary to make optimal use of the structural capacity of in-service pavements. It simply represents the useful life left in the pavement until a failure condition is reached. Knowledge of remaining life facilitates decision making in regard to strategies for reconstruction-rehabilitation of roads, thereby leading to the efficient use of existing resources. Several methods proposed or used by various agencies to estimate the remaining lives of pavements are reviewed. They are classified under two categories: functional and structural. Making use of the Mississippi Department of Transportation pavement management system data base, survivor curves are developed for seven classes of flexible pavements with from thin to thick structures. By using these survivor curves a novel method for estimating remaining life is proposed. The reasonableness of the selected methods is examined by putting them to use in calculating the remaining lives of each of eight rigid and flexible pavement sections, all of them from the Mississippi global positioning system sections of the Strategic Highway Research Program - Long-Term Pavement Performance (LTPP) project. With the structural details, falling weight deflectometer deflection data, and the distress information compiled from the LTPP information management system data base, the authors use two and four methods for rigid and flexible pavements, respectively, to determine the remaining lives. The remaining lives calculated by two methods for rigid pavements are comparable. Three of four methods for flexible pavements also generated comparable remaining lives. The authors were encouraged by the results and recommend that the survivor curve approach be explored further for network-level remaining life calculations. The reliabilities of various techniques currently available for the remaining life calculation are discussed.

Application/Use: This study is applicable to pavement management as well as pavement design.

Contribution: Improvement in Knowledge

Present Benefit: The LTPP database has provided a source of in-service performance data that was used to evaluate six remaining life models. By doing this, pavement managers and designers using remaining life analysis techniques can select the best method for a given application and can also benefit from the reliability analysis reported in this study.

Future Benefit: The LTPP database will continue to be used to evaluate existing models as well as to develop new prediction tools. The large number of in-service pavements that comprise the LTPP database makes it well-suited for the development of robust and comprehensive predictive models.

Title: Pavement Management System - Phase II. Final Report

Authors: George, K. P.

Date: 1995

Publisher: Mississippi University; Mississippi Department of Transportation; Federal Highway Administration

Abstract/Synopsis: Initiated by the Mississippi Department of Transportation (MDOT) in 1991, this study has the objective of establishing a statewide system for managing pavements. The tasks undertaken to accomplish this objective are described in this report. For the purpose of monitoring pavement condition, a distress manual is prepared, using the SHRP-LTPP Distress Manual as a guide. Assisted by a contractor, the monitoring data were collected in 1991 and 1993. The condition interface program developed as a part of the study helps to organize/reduce the field data in a useable format. By pooling the consensus opinion of MDOT engineers, a composite index -- designated pavement condition rating (PCR) -- is put in place to rate and compare pavements. Monitoring data including distresses and roughness are the inputs in maintenance strategy selection algorithms. Designated as decision trees, these algorithms are developed based on the consensus opinion (aided by heuristic rules) of MDOT engineers from maintenance, construction and research divisions. Incorporating various computational steps, such as for data reduction, life cycle cost and vehicle operating cost, a user-friendly PC computer program, designated MPB program, is implemented. Additionally, this program prioritizes the PMS sections in the network employing two approaches: first, based on agency cost -- highest cost first -- and second, relying on functional classification, traffic and PCR. Resulting from the MPB analysis is a list of PMS sections at the district level that would form the annual work program.

Application/Use: This is directly applicable to pavement management in Mississippi.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: This paper illustrates how an LTPP product—in this case the LTPP Distress Identification Manual—can be used by a SHA to implement new data collection activities. Mississippi DOT was able to reduce development costs by using the LTPP manual.

Future Benefit: The LTPP program has contributed significantly to advancing data collection technology and procedures. These techniques will continue to benefit SHAs as they routinely collect data on their pavement network.

Title: Quality Standards for Reliable Pavement Roughness Evaluation

Authors: Henderson, B; Phang, W. A; Richter, C.

Date: 1995

Publisher: Transportation Research Board

Journal Title: Conference Proceedings 1 Vol. 2

Conference Title: Third International Conference on Managing Pavements

Abstract/Synopsis: A pavement management system (PMS) requires reliable data to project maintenance needs and evaluate the success or failure of various maintenance options. Assessments of ride quality, based on either response-type roughness measurements or longitudinal profile measurements, are often used to characterize pavement conditions and predict future needs in a PMS. To successfully determine changes in pavement roughness, the measurement equipment must provide accurate repeatable results and be stable over time. Records of pavement profile taken at intervals form a basis on which changes in roughness can be deduced, whether by calculation of International Roughness Index (IRI) or some other roughness characteristic or statistic. For this reason, measurements of longitudinal profile are a key component of the long-term monitoring effort conducted by the Strategic Highway Research Program (SHRP) Long-Term Pavement Performance (LTPP) studies. For the SHRP/LTPP program the K.J. Law profilometer was selected because of its well-tested record and ability to provide rapid measurements of longitudinal profile on highway pavements. The backup device for the SHRP program is the Face Technologies "dipstick," which can also be used as a reference for the dynamic calibration check on the profilometer. A description is given of PROQUAL, a suite of computer programs developed by SHRP for field quality assurance and subsectioning of profile data, inputting, checking, and analyzing profile data before uploading to the Regional Information Management System and then finally the National Information Management System (RIMS/NIMS). The software also provides procedures for the dynamic calibration of the profilometer and processing longitudinal and transverse data collected with the dipstick. Statistical criteria are used in the field data collection process to determine adequacy of the data with respect to repeatability. Data that do not fit the requirements are discarded, and a minimum data set is declared accepted. IRI, root-mean-square vertical acceleration, Mays output, and slope variance values are calculated; profiles are stored. Examples of data from the SHRP program collected over 4 years are used to demonstrate with confidence the reliability of the data collected as part of the LTPP program. There is also a discussion of how the procedures and software developed for the SHRP program may be transferred to other agencies.

Application/Use: The procedures described in this paper have been a reference for those interested in collecting pavement profile data using road profiler, Dipstick®, and rod/level devices.

Contribution: Improvement in Knowledge; Advancement in Technology; Implementation/Usage.

Present Benefit: The work conducted by LTPP in the area of profile data collection has significantly advanced the standard of practice. Improvements in data collection, equipment calibration, data review and data processing have been realized in this endeavor. The most recent profile protocol developed under LTPP defines the methodology to collect smoothness data for weigh-in-motion (WIM) sites.

Pavement roughness directly impacts the end user in perception, comfort, safety and operating costs. By accurately and consistently collecting profile data, highway officials can provide pavements with improved service to end users. The data collected and stored in the LTPP database as been instrumental in modeling the progression of roughness over time. Additionally, the data has allowed researchers the opportunity to study the contributing factors in the rate of this accumulation.

Future Benefit: The guidelines developed will be used in the future as agencies continue to collect profile data. Additional benefit will be realized in the areas of pavement management systems, M-E PDG, and traffic data collection.

Title: Evaluation of Strategic Highway Research Program—Long-Term Pavement Performance Surface Distress Data Collection Procedures

Authors: Daleiden, J. F; Simpson, A. L.

Date: 1994

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1435

Abstract/Synopsis: Surface distress is commonly perceived to be one of the primary indicators of pavement performance. As such, the collection of these data for the Long-Term Pavement Performance (LTPP) program is a significant aspect of this overall effort—so significant in fact that there have been substantial efforts to develop a distress identification manual and guidelines for the measurement and recording of these distresses. Elaborate accreditation procedures also have been implemented to provide for the most uniform and consistent data possible. To further ensure that adequate observations of these data are obtained, two methods of data collection were utilized. The primary method of distress data collection for the LTPP program is from the digital analysis of 35-mm film taken of each test section on a routine basis. As a backup, manual surveys were conducted, as needed. From studies of the distress data collected to date, several observations were made. The first, and probably most significant, observation was that relatively few of these test sections have much distress. Second, some types of the distress occur more commonly than others. A variety of potential reasons for the limited occurrence of these distresses are considered in detail. The third observation is that there are distinct differences in the distress data collected from these two methods of distress data collection. Possible reasons for why these differences exist are discussed in detail. It is important to recognize these differences to ensure that the data are not misinterpreted. These limitations and distinctions are not intended to imply superiority of one methodology over the other. Instead, the studies should serve to document where additional research may be warranted to improve both methodologies. These studies also highlight the importance of not relying too heavily on either method of distress data collection alone.

Application/Use: This paper is useful for those interested in pavement distress data collected as part of the LTPP program.

Contribution: Improvement in Knowledge

Present Benefit: The LTPP program has devoted significant effort to establishing protocols and guidelines for the collection of quality distress data. This effort included the development of the LTPP Distress Identification Manual along with accreditation workshops. Not only have these met the objective of providing quality data in the LTPP database, but they also have been adopted by SHAs for distress data collection. Additionally, this paper documents the differences between the two distress data collection methods adopted by LTPP: manual and digital. Comparisons between the two have been rigorously documented in this and many other publications.

Future Benefit: The distress data collected as part of LTPP will be a long lasting legacy to the pavement community. Prediction models, new design methodologies and improved pavement management procedures all require extensive quality distress data.

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: SHRP-LTPP Monitoring Data: Five-Year Report

Authors: Rada, G. R.

Date: 1994

Publisher: Strategic Highway Research Program

Abstract/Synopsis: The overall objective of the Strategic Highway Research Program Long-Term Pavement Performance (SHRP-LTPP) study was to increase pavement life by investigation of various designs of pavement structures and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. The establishment of a national long-term pavement performance database to support LTPP analyses and future research needs was recognized as a major specific objective of the study. This report summarizes the LTPP monitoring data collection activities for inclusion in the National Pavement Performance Database. The pavement condition monitoring data include identification of surface distress, profile measurements, deflection testing results, and surface friction measurements. The report also describes traffic, climate, maintenance, rehabilitation, and seasonal monitoring and data collection. Other results and products of the 5-year pavement condition monitoring activity are listed.

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

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

Present Benefit: Findings from status or summary reports can provide significant insight into the early activities of the LTPP 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 similar nature. One such example is the Long Term Bridge Performance program, which was recently initiated.

Title: Accreditation for the Long-Term Pavement Performance Studies Pavement Distress Raters

Date: 1993

Publisher: Strategic Highway Research Program

Abstract/Synopsis: This report describes the Strategic Highway Research Program's efforts to monitor surface distress on the test sections under the Long Term Pavement Performance (LTPP) program. To achieve its objectives, SHRP is making use of the photographic distress survey technology which provides for high resolution 35 mm black and white photographs and photographic transverse profile measurements. Manual distress surveys are used as a backup data collection method. By its definition, the latter cannot have the detail and consistency of the photographic survey, and will be rater-dependent. An accreditation process has therefore been established by SHRP to provide a means of ensuring the quality and consistency of distress data collected for the LTPP program by regional coordination office raters. This report describes the accreditation process and its implementation to date including its basis, components, and grading system. Two workshops conducted by SHRP are also described. Recommendations are made for improving the overall process and its implementation.

Application/Use: This paper is useful for those interested in pavement distress data collected as part of the LTPP program.

Contribution: Improvement in Knowledge

Present Benefit: The LTPP program devoted significant effort to establishing protocols and guidelines for the collection of quality distress data. This effort included the development of the LTPP Distress Identification Manual along with accreditation workshops. Not only have these met the objective of providing quality data in the LTPP database, but they also have been adopted by SHAs for distress data collection. Additionally, this paper documents the differences between the two distress data collection methods adopted by LTPP: manual and digital. Comparisons between the two have been rigorously documented in this and many other publications.

Future Benefit: The distress data collected as part of LTPP will be a long lasting legacy to the pavement community. Prediction models, new design methodologies, improved pavement management procedures all require extensive quality distress data.

Title: Accreditation of Strategic Highway Research Program Long-Term Pavement Performance Pavement Distress Raters

Authors: Rada, G. R; Miller, J. S; Bellinger, W. Y; Rogers, R. B.

Date: 1993

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1410

Abstract/Synopsis: Distress surveys are one element of the monitoring effort currently under way by the Strategic Highway Research Program (SHRP) for the Long-Term Pavement Performance (LTPP) study. Because accurate data are vital to the success of the LTPP study, SHRP has developed and implemented an accreditation process to ensure the quality of distress data collected from manual surveys. The purpose of SHRP's accreditation process is to provide a means for ensuring, to the extent possible, the quality and consistency of distress data being collected by the raters. The process consists of two parts, a written examination and a two-part field survey examination, and is being administered in a workshop situation. Although the process is still in its early stages, it is SHRP's intent that all distress data for the LTPP study be collected by raters who have successfully completed the accreditation. The SHRP accreditation process and the results of its implementation to date are discussed.

Application/Use: This report can be used by those interested in developing a distress data collection program.

Contribution: Improvement in Knowledge; Implementation/Usage.

Present Benefit: The LTPP program has significantly contributed to accurate distress data collection. The program has developed a distress identification manual, developed accreditation workshops, established data collection protocols, produced quality control measures, and performed numerous data studies. An NHI training course based on the LTPP protocols was developed and delivered around the country to SHA distress personnel. All of these efforts provide value to the pavement community and can be used to collect quality distress data for use in pavement management and design.

Future Benefit: As evidenced by the NHI course, the accreditation workshop developed by LTPP can be modeled by agencies to train new surveyors and to "calibrate" experienced raters. Improving the accuracy and quality of data leads to better informed decisions for treatment selection and timing. Additionally, accurate distress data is essential for proper pavement design. Accreditation workshops can be used to reduce erroneous data, which can lead to costly improper pavement decisions.

Title: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity. FWDCheck Version 2.00. Volume III - Program Listing

Date: 1993

Publisher: Strategic Highway Research Program

Abstract/Synopsis: Nondestructive deflection testing using falling weight deflectometers is one element of the monitoring effort underway by the Strategic Highway Research Program (SHRP) for the Long Term Pavement Performance (LTPP) study. SHRP has implemented several measures to ensure the quality of deflection data. Equipment calibration and field data checks have been built into the FWD data acquisition software. A computer program, called FWDSCAN verifies the integrity, completeness and compliance with the established test patterns of the field data. A computer program called FWDCHECK has been developed to analyze deflection data for test section homogeneity, the degree to which test pit data is representative of the section, the presence of data outliers within the section, and overall reasonableness from a structural capacity viewpoint. This report focuses on the FWDCHECK program and consists of three separate volumes: technical documentation; user's guide; and program listing.

Application/Use: This document can be used by those interested in FWD data processing using LTPP protocols to collect network-level, project-level, or research quality FWD data.

Contribution: Improvement in Knowledge; Advancement in Technology; Implementation/Usage.

Present Benefit: The protocols established by LTPP have aided agencies in collecting FWD data. Data obtained by these procedures can be used to determine the structural condition of pavements, which is useful for both pavement management and design. The calibration protocol established by LTPP ensures accurate loading and deflection data are obtained from FWD equipment. Inaccurate data can result in improper selection of rehabilitation strategies and inadequate structural pavement designs. Improvements in the accuracy and consistency of FWD data collection result in cost savings through proper selection of rehabilitation strategies and pavement structure designs.

Additional cost savings are realized when consideration is given to the reduced start up time required by an agency implementing FWD data collection. The guidelines and protocol have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedure without expending significant effort developing new protocols.

The software developed by LTPP to convert and review FWD data is an additional benefit to the pavement community as it allows outliers and erroneous data to easily be identified.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design operations, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach.

Title: Design Specifications and Implementation Requirements for a Texas Long-Term Pavement Performance Program. Interim Report

Authors: Saeed, A; Hudson, W. R; Dossey, T; Weissmann, J.

Date: 1993

Publisher: Texas University, Austin; Texas Department of Transportation

Abstract/Synopsis: This report summarizes the requirements for development of a long-term pavement performance (LTPP) program for the State of Texas. This work is part of a project sponsored by the Texas Department of Transportation to develop distress prediction models for rigid pavements which are to be incorporated in the Texas pavement management information system (PMIS) currently under development. As in other pavement management systems, test sections are identified for which distress data can be collected to develop the required models. An experiment design which keeps in view the existing LTPP and Center for Transportation Research (CTR) experiment designs is described. The recommended experiment designs meet the current pavement design standards, latest research criteria, and climatic and geographic needs of Texas. The experiment design is followed by a discussion of the type of data which should be collected. The data items to be collected are divided into two categories, (1) inventory data items and (2) monitoring data items. Inventory data item sources are also identified. The human and financial resources required to establish the database and maintain and monitor it periodically are also evaluated.

Application/Use: This is directly applicable to pavement research in Texas.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: Significant effort and coordination took place in developing the LTPP structure, experimental design, and strategic plan. This report provides an example of how an agency can use the LTPP program as a model for implementing a research program on a local level.

Future Benefit: Establishing a national, long-term research program requires significant planning and coordination. Documentation describing the design and implementation of the LTPP program will be extremely beneficial to future endeavors of similar nature. One such example is the Long Term Bridge Performance program, which was recently initiated.

Title: Distress Interpretation from 35mm Film for the LTPP Experiments

Date: 1993

Publisher: Strategic Highway Research Program

Abstract/Synopsis: Distress surveys are one element of the monitoring effort currently underway by the Strategic Highway Research Program (SHRP) for the Long Term Pavement Performance (LTPP) study. In this study, photographic distress survey technology is being used which provides for high resolution 35mm black and white photographs and photographic transverse-profile measurements. The reduction of the distress data from film is through a computer assisted interpretation process. Film interpretations and quality assurance (QA) are performed under the supervision of experienced engineers and technicians. Further QA is performed at regional coordination offices by personnel knowledgeable of the actual conditions at the sites. This report presents a detailed description of the film distress interpretation procedure for the SHRP LTPP study.

Application/Use: This report can be used by those interested in the film interpretation method employed by LTPP for distress data collection purposes.

Contribution: Improvement in Knowledge

Present Benefit: This document provides valuable information on the photographic distress data collection, interpretation, and quality control techniques employed by the LTPP program. This is valuable for those using the data as well as SHAs interested in collecting similar data.

Future Benefit: The LTPP program fully documented differences between photographic and manual distress data collection techniques. This information is extremely valuable for SHAs looking to collect distress data for network level pavement management systems. Variability, bias, and error all affect the decision process of a pavement management system. This information has been reported by LTPP and will be used by SHA's to gain insight into the nature of distress data.

Title: Falling Weight Deflectometer Relative Calibration Analysis

Date: 1993

Publisher: Strategic Highway Research Program

Abstract/Synopsis: Nondestructive deflection testing with Falling Weight Deflectometers (FWDs) is a critical element of the pavement monitoring effort for the Long-Term Pavement Performance (LTPP) testing of the Strategic Highway Research Program. The deflection testing must be conducted consistently and with accurately calibrated FWDs. This is a report of the FWDCAL software, which was developed to help ensure that. One aspect of this is the monthly relative calibration of the FWD deflection measurement system. The details are described of how a data set is obtained which can be analyzed to (1) determine a multiplier for each sensor; and statistically partition the measurement errors in the data to the major sources of error, as a check on the acceptability of the calibration data. The FWDCAL software is described which was developed to perform these analyses.

Application/Use: LTPP protocols for FWD data collect can be used by agencies interested in collecting network-level, project-level, or research quality FWD data.

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

Present Benefit: The protocols established by LTPP have provided benefit to agencies in collecting FWD. Data obtained by these procedures can be used to determine the structural condition of pavements, which is beneficial for pavement management and design. The calibration protocol established by LTPP ensures accurate loading and deflection data are obtained from FWD equipment. Improvements in the accuracy and consistency of FWD data collection result in cost savings through proper selection of rehabilitation strategies and pavement structure designs.

Additional cost savings are realized when consideration is given to the reduced start up time required by an agency implementing FWD data collection. The guidelines and protocols have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedure without expending significant effort developing a new protocol. The software developed by LTPP to convert and review FWD data is another benefit to the pavement community as it allows outliers and erroneous data to be easily identified.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach.

Title: High-Tech Deflectometers Aid PMS

Authors: Harrington-Hughes, K.

Date: 1993

Publisher: Scranton Gillette Communications, Incorporated

Journal Title: Roads & Bridges Vol. 31 No. 7

Abstract/Synopsis: The use of the falling weight deflectometer (FWD) and its help in making pavement management decisions are discussed. Although in use for some time, there are gaps in its technology and in the interpretation of its results. The Strategic Highway Research Program's Long Term Pavement Performance (LTPP) program has found ways to reduce or overcome these problems. Techniques have been developed that allow machine-dependent readings, adjustments for seasonal differences, and reliable back-calculation. Products have also been developed that improve the consistency and reliability of the FWD instruments. The calibration of an FWD is discussed, and regional centers to perform calibrations are noted. Software (FWDSCAN) has been developed to perform analysis in the field. Software (FWDCHECK) has been developed to interpret the data collected in the field.

Application/Use: This is directly applicable to FWD data collection.

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

Present Benefit: Efforts conducted under the LTPP program resulted in significant advancements in FWD data collection, maintenance, and calibration. All guidelines and protocols were aimed at improving the quality and consistency of FWD data. Accurate FWD information is vital to cost-efficient pavement designs as well as to proper analysis of existing pavement structures. Improved FWD data results in cost savings through optimized design and analysis.

Future Benefit: FWD data is now an integral part of pavement analysis/design and is getting more use in pavement management. Protocols established by LTPP have become agency standards and will continue to benefit the pavement community for years to come.

Title: Pacific Rim Trans Tech Conference Proceedings. Volume II. Design Implications for Concrete Pavement from LTPP Analyses

Authors: Owusu-Antwi, E; Darter, M. I; Ahmad, R.

Date: 1993

Publisher: American Society of Civil Engineers

Conference Title: Pacific Rim TransTech Conference. ASCE Third International Conference on Applications of Advanced Technologies in Transportation Engineering.

Abstract/Synopsis: The results are presented of a first evaluation of the AASHTO (American Association of State Highway and Transportation Officials) rigid pavement design equation using the data in the Strategic Highway Research Program's Long-Term Pavement Performance (LTPP) database. The study examined the adequacy of the design equation for predicting the number of axle loads required to bring about a given loss in serviceability. Comparisons were made of the 80-kN equivalent single axle loads predicted using the design equation for the SHRP test sections located across the U.S. and Canada. The study results show how the LTPP database can be used in a full scale evaluation of the AASHTO design equation.

Application/Use: This is directly applicable to rigid pavement design using the 1993 AASHTO design guide.

Contribution: Cost Savings; Improvement in Knowledge.

Present Benefit: The LTPP database provides pavement layer information along with traffic and performance data. This information is an excellent source of comparing pavement design to actual performance. The results from this study can be used to gain insight into the rigid pavement design methodology in the 1993 AASHTO design guide, and can be used to make more cost-efficient designs.

Future Benefit: The LTPP database will continue to be an excellent source of evaluating both current and future pavement design procedures. The development of the M-E PDG relied heavily on the LTPP database. Further use of the LTPP database will be necessary in calibrating the M-E PDG models to local conditions.

Title: Photographic Pavement Distress Record Collection and Transverse Profile Analysis

Author(s): Gramling, W. L; Hunt, J. E.

Date: 1993

Publisher: SHRP, Washington, DC

Abstract/Synopsis: The Strategic Highway Research Program's Long Term Pavement Performance study required permanent, high resolution, pavement distress records. To meet this need, SHRP chose PASCO USA's automated ROADRECON Survey systems to obtain permanent, high resolution, records of pavement surface distress and transverse profile. This report documents the methods used to calibrate the survey systems and develop quality control procedures. It also summarizes the survey operations, and support system development performed prior to June 1991.

Application/Use: LTPP established guidelines and quality control procedures for the collection of photographic pavement distress data collection. The collection of both manual and photographic distress data allowed comparisons between the two techniques.

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

Present Benefit: The development and improvement of photographic distress data collection is beneficial in many ways. The work conducted as part of the LTPP program advanced technology and improved knowledge in this arena. The data collected using the established guidelines provided a means for evaluating the collected data for accuracy, bias, and variability. Improving the automated data collection techniques has an added benefit of improved safety as compared to performing manual distress surveys.

Future Benefit: As automated and photographic distress data collection becomes more frequently used, the work conducted under LTPP will become more valuable.

Title: Data Readability and Completeness FWDScan Version 1.30 Program Background and User's Guide

Date: 1992

Publisher: Strategic Highway Research Program

Abstract/Synopsis: Nondestructive deflection testing using falling weight deflectometers is one element of the monitoring effort underway in the Strategic Highway Research Program's (SHRP) Long-Term Pavement Performance (LTPP) study. SHRP has implemented several measures to ensure the quality of deflection data, including equipment comparison and calibration. The quality of the data is also ensured by a computer program called FWDScan which verifies the integrity, completeness, and compliance with the established test pattern of the field data after it is delivered to the SHRP regional office. This report focuses on the FWDScan program. The details of the program are described, and a complete printout of the computer source code is included.

Application/Use: FWDScan can be used by agencies interested in collecting network-level, project-level, or research quality FWD data.

Contribution: Improvement in Knowledge; Advancement in Technology; Implementation/Usage.

Present Benefit: The protocols established by LTPP have provided benefit to agencies collecting FWD data. Data obtained by these procedures can be used to determine the structural condition of pavements, which is beneficial for pavement management and design. The calibration protocol established by LTPP ensures accurate loading and deflection data are obtained from FWD equipment. Improvements in the accuracy and consistency of FWD data collection result in cost savings through proper selection of rehabilitation strategies and pavement structure designs.

Additional cost savings are realized when consideration is given to the reduced start up time required by an agency implementing FWD data collection. The guidelines and protocols have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedures without expending significant effort developing new protocols.

The software developed by LTPP to convert and review FWD data is an additional benefit to the pavement community as it allows outliers and erroneous data to be easily identified. The FWDScan program can be used in the field to ensure complete and quality datasets have been collected before leaving the site.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach.

Title: Effects of Buffers on Falling Weight Deflectometer Loadings and Deflections (with Discussion)

Authors: Lukanen, E. O.

Date: 1992

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1355

Abstract/Synopsis: Falling weight deflectometers (FWDs) apply a load to the pavement surface that is generated by dropping a mass onto a hit bracket. The resulting impact generates the force that is transmitted to the pavement through a contact plate. A spring set between the falling mass and the hit bracket buffers the impact by decelerating the mass. The greater the deceleration, the greater the force generated. The amount of force generated is a function of the stiffness of the spring set, the amount of mass, and its velocity when it strikes the spring set, plus any dampening that may be part of the system. The Dynatest Model 8000E FWD is used for monitoring pavement sections in the Strategic Highway Research Program (SHRP) Long-Term Pavement Performance (LTPP) study. During the course of the study, several buffer changes were made. To evaluate the effects the buffers have on the loads and deflections, tests were conducted using each buffer set on three pavement structures near the SHRP North Central Regional Office. The results show the various buffer shapes had an effect on the test results. The differences observed are not considered significant for routine production testing but are expected to be relevant in research work involving viscoelastic materials (asphalt) and dynamic deflection analysis.

Application/Use: This study is directly applicable to FWD data collection and analysis.

Contribution: Lessons Learned; Advancement in Technology.

Present Benefit: Understanding the effect of buffer shapes on deflection data obtained from FWD equipment is extremely valuable to pavement analysis and design. Changes in deflection data can impact the type of rehabilitation selected, as well as structural pavement design results. Therefore, this study provides insight into potential variability in FWD data and how it can be minimized. Consistent FWD data will result in cost-effective pavement designs.

Future Benefit: FWD data will continue to be used as a pavement evaluation tool and agencies have started using FWD data on a network-level for pavement management purposes. Therefore, understanding various components that effect results will continue to provide benefit.

Title: Strategic Highway Research Program Falling Weight Deflectometer Quality Assurance Software

Authors: Rada, G. R; Rabinow, S. D; Witczak, M. W; Richter, C. A.

Date: 1992

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1377

Abstract/Synopsis: Nondestructive deflection testing using falling weight deflectometers (FWDs) is one element of the monitoring effort currently under way by the Strategic Highway Research Program (SHRP) for the Long-Term Pavement Performance (LTPP) study. Because accurate data are vital to the success of the LTPP study, SHRP has implemented a number of measures to ensure the quality of deflection data. They include equipment comparison and calibration, standardized field testing procedures and field data checks, and quality assurance software. SHRP FWD quality assurance software is the focus--specifically the FWDSCAN and FWDCHECK computer programs. Program FWDSCAN has been developed to verify the integrity and completeness of the FWD deflection data after they have been delivered to the SHRP regional offices. Program FWDCHECK has been developed to analyze deflection data for test section homogeneity, the degree to which test pit data are representative of the section, the presence of data outliers within the section, and overall reasonableness from a structural capacity viewpoint.

Application/Use: The operational guidelines describe can be used by agencies interested in collecting network-level, project-level, or research quality FWD data.

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: The protocols established by LTPP have provided value to agencies collecting FWD data. Data obtained by these procedures can be used to determine the structural condition of pavements, which is beneficial for pavement management and design. The calibration protocol established by LTPP ensures accurate loading and deflection data are obtained from FWD equipment. Improvements in the accuracy and consistency of FWD data collection result in cost savings through proper selection of rehabilitation strategies and pavement structure designs.

Additional cost savings are realized when consideration is given to the reduced start up time required by an agency implementing FWD data collection. The guidelines and protocols have already been established, refined, and documented. Therefore, agencies can tailor the LTPP procedures without expending significant effort developing new protocols.
The software developed by LTPP to convert and review FWD data is an additional benefit to the pavement community as it allows outliers and erroneous data to be easily identified.

Future Benefit: The FWD data collection, maintenance, and calibration guidelines established by LTPP will continue to benefit pavement management and design, particularly as pavement design moves from a purely empirical to a mechanistic-empirical approach.

Title: Non-Destructive Testing in SHRP's Long-Term Pavement Performance Studies

Authors: Richter, C. A; Witczak, M. W.

Date: 1991

Publisher: Thomas Telford Limited

Conference Title: Highway Research: Sharing the Benefits. The United States Strategic Highway Research Program

Abstract/Synopsis: The monitoring effort undertaken as a part of the Long Term Pavement Performance (LTPP) Studies of the Strategic Highway Research Program includes three types of nondestructive pavement testing: longitudinal profile measurement, photographic distress and cross-profile measurements, and deflection testing. A significant effort has been made to ensure the collection of uniform, high quality data. Substantial progress has been made, with first round data collection in all three areas essentially complete for nearly 800 General Pavement Studies (GPS) sections.

Application/Use: This paper documents the first round of non-destructive pavement testing for LTPP GPS test sections.

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

Present Benefit: This document illustrates the resources devoted by the LTPP program in developing protocols that ensure quality data collection. These procedures are available—through user's manuals, processing software, and quality control algorithms—for use on an agency level. In using the established methodologies, agencies realize reduced startup costs. Quality data collection has significant benefit in terms of appropriate decisions made using the data.

Future Benefit: The LTPP methodologies will continue to be useful to agencies performing non-destructive testing. Additional benefit will be realized in using the data collected at LTPP and other sites for research or pavement management services.

Title: Using Strip Films to Record Pavement Distress in the Strategic Highway Research Program: Long-Term Pavement Performance Study

Authors: de Solminihac, H; Roper, H.

Date: 1991

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1311

Abstract/Synopsis: The system recommended by the researchers to the Long-Term Pavement Performance (LTPP) studies of the Strategic Highway Research Program for the collection and storage of surface distress data is described. Specifically, the distress acquisition system, film interpretation system, quality assurance plan, certification procedure for Pavement Distress Analysis System operators, and finally, how the system benefits the LTPP study are described. There are several advantages to using this system: it is semiautomatic and provides a permanent record of the pavement surface; in addition, work is performed exclusively at night, ensuring that there will be minimum traffic interference. Films provide additional information for the LTPP studies; that is, a complete picture of each site is available at the office. Such a capability allows the engineers not only to analyze pavement distress, but to perform quality control of the test sites as well (e.g., inspecting the locations of the weigh-in-motion and automatic vehicle counters sites). In addition, this information can be used later to interpret the data analysis output. Although the system is limited in some respects, these limitations can be overcome through operator experience and use of supplemental information available from the site.

Application/Use: This paper can be used by those interested in collecting photographic pavement distress data for network or project level analysis.

Contribution: Improvement in Knowledge; Advancement in Technology.

Present Benefit: The LTPP program has expended significant effort in establishing data collection protocols, quality control measures, and data processing techniques for pavement distress. These techniques can be employed by agencies wishing to collect similar data. With this information, the start-up costs for a distress data collection program would be reduced.

Future Benefit: As technology advances and new photographic/automated techniques become available, the procedures established by the LTPP program will continue to provide benefit to the pavement community.

Title: Condition Surveys in the Strategic Highway Research Program Long-Term Pavement Performance Study and Pavement Condition Rating for Pre-Overlay Conditions (Abridgment)

Authors: Goulias, D. G; Castedo, H; Hudson, W. R.

Date: 1990

Publisher: Transportation Research Board

Journal Title: Transportation Research Record No. 1276

Abstract/Synopsis: The long-term pavement performance (LTPP) research study, a component of the Strategic Highway Research Program (SHRP), represents a $50 million effort to collect field observations of pavement structures from across the United States and Canada. The procedures to be used for rating the condition of LTPP test sections before overlay are discussed. The methods should be used in classifying the condition of a test section as "good" or "bad," and such information is needed as an input variable to the asphalt concrete overlays on asphalt and concrete pavement factorial experiments. These experiments were defined for recruiting in-service test sections for inclusion in the SHRP LTPP study. The distress-monitoring approach being adopted for the long-term monitoring of in-service SHRP pavement sections is then described. The categories and types of distress data to be collected periodically are described, together with uniform and practical distress definitions and monitoring procedures. Finally, information on the contents of survey forms and maps to be used during the process is provided.

Supplemental: This paper appears in Transportation Research Record No. 1276, Maintenance Management 1990: Proceedings of a Workshop, Jackson, Mississippi, July 25-27, 1990.

Application/Use: This paper can be used by those interested in LTPP distress data collection or interested in the methodology of assigning test sections in the experimental matrix for rehabilitation projects.

Contribution: Improvement in Knowledge

Present Benefit: At the beginning of the program, considerable effort was allocated to the development of each experiment design. This paper illustrates how the rehabilitation experiments were categorized. Additionally, the effort in establishing a consistent distress data collection protocol is also documented. The framework and structure of the LTPP program can be applied to many other studies, resulting in reduced startup costs.

Future Benefit: The LTPP database will continue to be a go-to resource for pavement performance information. As such, background information on experimental design and data collection protocol will continue to benefit the pavement community.

Title: Performance Monitoring and Data Acquisition for Pavement Performance Evaluation. Proceedings of Strategic Highway Research Program and Traffic Safety on Two Continents, Gothenburg, Sweden, 27-29 September 1989

Authors: Richter, C. A.

Date: 1990

Publisher: National Swedish Road & Traffic Research Institute; Statens VAEG-OCH Transportforskningsinstitut

Abstract/Synopsis: The Long Term Pavement Performance (LTPP) studies undertaken by the Strategic Highway Research Program (SHRP) require an extensive data collection effort. More than 1000 in-service pavement test sections, located in the United States and Canada, will be monitored when all aspects of the LTPP studies are under way. At present, the initial round of data collection on the General Pavement Studies (GPS) test sites identified to date is well underway, and work is progressing rapidly on the remaining portions of the LTPP program. The SHRP test sections were selected to represent the full range of pavement design practice and climatic conditions present in most of North America. No two test sections are exactly alike in terms of materials, climatic conditions, traffic etc. SHRP's data acquisition effort must provide for quantitative measures of the performance of each test section, and the factors which influence that performance. The data collected will include pavement profile and distress data for monitoring pavement performance, pavement deflection data, to help define the structural characteristics of the pavement, and monitor variations therein, a wide array of pavement materials data, traffic data, and data describing any maintenance and rehabilitation performed on the test section throughout the duration of the SHRP monitoring effort. This paper will discuss the data acquisition requirements for SHRP's Long Term Pavement Performance studies, and SHRP's efforts to meet those requirements. Equipment calibration and other quality assurance measures will be among the topics discussed, as will SHRP's efforts to balance the data requirements against data collection cost.

Application/Use: This early report can be used by those interested in establishing a comprehensive research database.

Contribution: Improvement in Knowledge; Advancement in Technology; Implementation/Usage.

Present Benefit: Significant effort, planning, and coordination took place in the development of LTPP's data acquisition standards. The large number of data elements and records stored in the LTPP database made the development of standards a critical component of the LTPP structure. The documentation on this process will prove useful to others interested in implem im

will be extremely beneficial to future endeavors of similar nature. One such example is the Long Term Bridge Performance program, which was recently initiated.