Technical Publications Catalog

October 2007 – September 2008

Turner-Fairbank Highway Research Center
Research, Development and Technology

FHWA-HRT-09-019

U.S. Department of Transportation
Federal Highway Administration

Table of Contents

Introduction

The Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center (TFHRC) is pleased to present our third *Technical Publications Catalog*. This is a comprehensive listing of our research documents published from October 2007 through September 2008, and includes listings of fact sheets, flyers, product briefs, reports, summaries, and TechBriefs, available both in print from our Federal Highway Administration (FHWA) Product Distribution Center and online at www.tfhrc.gov/techpubcat/index.htm.

This catalog is an indispensable transportation research resource for engineers, transportation specialists, policymakers, information specialists, and other interested groups. Three preceding volumes cover earlier research publications:

- October 1998 – September 2003
- October 2003 -- September 2006, and
- October 2006 -- September 2007

Readers can immediately access most publications online or order a copy from the source listed.

I hope you find this a useful addition to your reference library. Questions or comments about this publication can be directed to Martha Soneira at martha.soneira@fhwa.dot.gov, or (202) 493-3468.

Gary L. Henderson
Acting Associate Administrator
Research, Development, and Technology

and

Michael Trentacoste
Acting Associate Administrator
Research, Development, and Technology

1 Administration

Directories

Organizational and Expertise Directory, Fall 2007
FHWA-HRT-08-021

The Turner-Fairbank Highway Research Center (TFHRC) is a federally owned and operated research facility in McLean, Virginia. TFHRC is the home of the Federal Highway Administration's (FHWA's) Office of Research, Development, and Technology. The *Organizational and Expertise Directory* lists areas of specialties and shows where to locate and contact individuals.
http://www.tfhrc.gov/about/orgdirectory/08021/index.htm

Organizational and Expertise Directory, Winter 2007
FHWA-HRT-08-037

The Turner-Fairbank Highway Research Center (TFHRC) is a federally owned and operated research facility in McLean, Virginia. TFHRC is the home of the Federal Highway Administration's (FHWA's) Office of Research, Development, and Technology. The *Organizational and Expertise Directory* lists areas of specialties and shows where to locate and contact individuals.
http://www.tfhrc.gov/about/orgdirectory/08037/index.htm

Organizational and Expertise Directory, Spring 2008
FHWA-HRT-08-054

The Turner-Fairbank Highway Research Center (TFHRC) is a federally owned and operated research facility in McLean, Virginia. TFHRC is the home of the Federal Highway Administration's (FHWA's) Office of Research, Development, and Technology. The *Organizational and Expertise Directory* lists areas of specialties and shows where to locate and contact individuals.
http://www.tfhrc.gov/about/orgdirectory/08054/index.htm

Fact Sheet

Priority, Market-Ready Technologies and Innovations: 2008 List
FHWA-HRT-08-036

This Priority, Market-Ready Technologies and Innovations' fact sheet lists recently completed projects, which encompasses construction and project management, finance, geotechnical and hydraulics, operations, pavements and materials, planning, structures, and safety and design.
FHWA Research Library (printed copies available)

Summary

Lab Clips
FHWA-HRT-08-022

As the research facility for the Federal Highway Administration, the Turner-Fairbank Highway Research Center (TFHRC) coordinates an ambitious program of innovative research and development, and technology and innovation deployment that addresses the safety, infrastructure, and operational needs of the National Highway System.

These Lab Clips provide a brief overview of individual TFHRC laboratories, their current activities, and laboratory managers. Laboratory fact sheets, available separately, describe each facility in more technical detail and include information such as research purpose, resources, current projects, accomplishments, and partnerships. For the most up-to-date information about our research, please visit the TFHRC Web site at www.tfhrc.gov. To schedule an onsite tour of our laboratories, e-mail us at TFHRC.tours@fhwa.dot.gov.
FHWA Research Library and http://www.tfhrc.gov/about/08022/index.htm

2 Environment

None to report

3 Human Factors

None to report

4 Operations

Fact Sheet

Adaptive Control Software Lite (ACS-Lite)
FHWA-HRT-08-027

This Priority, Market-Ready technologies and Innovations fact sheet presents the Adaptive Control Software Lite (ACS-Lite). A major problem that contributes to traffic congestion is ineffective signal timing. A solution to decreasing traffic congestion is by adjusting traffic signal timing according to current traffic conditions. Adaptive Control Software-Lite improves the efficiency of traffic signals and prolongs the effectiveness of traffic signal timing by updating phase splits and offsets in response to current traffic

conditions. The benefits can be reductions in travel time up to 35 percent, delay up to 29 percent, and fuel consumption up to 7 percent.
FHWA Research Library and http://www.fhwa.dot.gov/crt/lifecycle/08027.pdf

Flyer

Office of Operations R&D
FHWA-HRT-08-030

This flyer presents major contributions in the following areas: (1) Traffic Analysis Toolbox, (2) Adaptive Control Systems, (3) ACS Lite, (4) Traffic Estimation and Prediction System, (5) Strategic Work Zone Analysis Tools, (6) Strategic Work Zone Analysis Tools, (7) Traffic Management Tools—Handbook, (8) Integrated Corridor Management, (9) Exploratory Advanced Research Program, (10) Weather-Related Impacts on Traffic Operations Study, (11) Cooperative Intersection Collision Avoidance Systems Initiative, (12) ITS Applications for Communications, (13) Clear Roads Pooled Fund Research Program, (14) Base Stations for the Nationwide Differential Global Positioning System, and (15) High Accuracy NDGPS.
FHWA Research Library

5 Pavements

Fact Sheet

Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS)
FHWA-HRT-08-033

This Priority, Market-Ready Technologies and Innovations fact sheet presents Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS). State transportation agencies are increasingly shifting their focus from constructing new highways to rehabilitating and reconstructing existing facilities. Highway rehabilitation projects often cause congestion, safety problems, and road accessibility issues. The CA4PRS software identifies optimal rehabilitation strategies that balance the construction schedule with inconvenience to drivers and transportation agency costs. CA4PRS helps agencies, contractors, and consultants prepare strategies for highway projects by: (1) estimating working days and CPM schedules, (2) developing construction staging plans; (3) supplementing traffic management plans; and (4) outlining incentives and cost (A) + schedule (B) contracts.
FHWA Research Library and http://www.fhwa.dot.gov/crt/lifecycle/ca4prs.cfm

Flyer

LTPP 2007 Year in Review
FHWA-HRT-08-039

This flyer lists and briefly describes the Long Term Pavement Performance (LTPP) program 2007 accomplishments. They are: LTPP Standard Data Release #21, Materials Action Plan, LTPP Data Collection, LTPP Customer Support Service Center, Profiler Rodeo Held at MnROAD Site, two LTPP data analysis studies, and four currently underway; one LTPP-related Pooled Fund Study and three underway. The LTPP products completed and those expanded are listed, and two new Products Workshops.
http://www.fhwa.dot.gov/pavement/ltpp/pubs/08039/

Newsletters

LTPP Newsletter, Volume 4, Issue 1, Winter 2008
FHWA-HRT-08-055

This newsletter highlighted this year's Long-Term Pavement Performance (LTPP) State Coordinators' Meeting. At this year's 87th Annual Transportation Research Board (TRB) Meeting, we held our annual LTPP State Coordinators' Meeting. This was the 20th year of gathering with our partners to provide updates and information on the activities of the LTPP program. Although we had a very diverse audience from State personnel to university professors and students to consultants, we recognize that many of our key supporters were unable to attend. Those key supporters are our LTPP State Coordinators. As a result, we decided to dedicate this edition of the newsletter to highlight the discussions of the meeting.
http://www.fhwa.dot.gov/pavement/ltpp/news/08055.cfm

LTPP Newsletter, Volume 4, Issue 3, Summer 2008
FHWA-HRT-08-072

The Mechanistic-Empirical Pavement Design Guide (M-E PDG) represents a major change from the way pavement design has been done in the past. The designer first considers site and construction conditions in proposing a trial design for a new pavement or rehabilitation. The trial design is then evaluated for adequacy through the prediction of key distresses and roughness. If the design does not meet desired performance criteria, it is revised and the evaluation process is repeated as necessary. Thus, the designer has the flexibility to consider different design features and materials for the prevailing site conditions. As such, the M-E PDG is not a design tool but a very powerful and comprehensive pavement analysis tool. This publication describes how Texas is using Long-Term Pavement Performance (LTPP) data to calibrate the M-E PDG Permanent Deformation Models.
http://www.fhwa.dot.gov/pavement/ltpp/news/08072.cfm

TechBrief

Phosphoric Acid as an Asphalt Modifier Guidelines for Use: Acid Type
FHWA-HRT-08-061

This TechBrief discusses the selection of acid type, how phosphoric acid is produced commercially, and the experimental validation of the stiffening effect of different phosphoric acid grades. A dynamic shear rheometer was used to determine the stiffness of Boscan asphalt. A chart is included which shows the stiffness of AAK-1 modified with phosphoric acid.
http://www.fhwa.dot.gov/pavement/asphalt/pubs/08061/

Technical Reports

Long Term Pavement Performance Project Laboratory Materials Testing And Handling Guide
FHWA-HRT-07-052

The Long Term Pavement Performance (LTPP) Laboratory Material Testing Guide was originally prepared for laboratory material handling and testing of material specimens and samples of asphalt materials, portland cement concrete, aggregates, and soils under the supervision of the Strategic Highway Research Program. This version of the Guide has been updated to provide a historical reference document for analysts of the LTPP data. It provides the basis for the quality control program used in performing the laboratory testing, the protocols used in testing the material samples, and the guidelines for handling these samples in the laboratory. Additionally, this document provides the guidelines used for identifying the pavement structure based on the material properties of the sampled layers.
http://www.fhwa.dot.gov/pavement/ltpp/pubs/07052/index.cfm

LTPP Computed Parameter: Moisture Content
FHWA-HRT-08-035

A study was conducted to compute in situ soil parameters based on time domain reflectometry (TDR) traces obtained from Long Term Pavement Performance (LTPP) test sections instrumented for the seasonal monitoring program (SMP). Ten TDR sensors were installed in the base and subgrade layers at each of the 70 SMP test sites monitored as part of the LTPP program. A comprehensive description of a new method developed as part of the study to estimate moisture content, dry density, reflectivity, and conductivity of the soil from TDR traces is provided in the report. This new method utilizes transmission line equations and micromechanics models calibrated to site-specific conditions for each site/layer combination. Background information on existing empirical methodologies used to estimate subsurface moisture content from TDR traces is also documented. The results were compared to previous methods as well as ground truth data to evaluate the ability of the new model to predict soil parameters. The transmission line equation and micromechanics method was found to provide accurate results and was used to interpret over 270,000 TDR records stored in the LTPP

database. A computer program (MicroMoist) was developed to aid in the computation of soil parameters based on TDR trace data and calibration information. Details on the program are provided along with descriptions of the tables developed to store the computed values in the LTPP Information Management System database.
http://www.fhwa.dot.gov/pavement/ltpp/pubs/08035/

6 Safety

Fact Sheet

USLIMITS
FHWA-HRT-08-028

This Priority, Market-Ready Technologies and Innovations fact sheet address speeding. Speeding is a significant threat to public safety and warrants priority attention. The management of speed through appropriate speed limits is an essential element of highway safety. USLIMITS is a Web-based expert advisor system designed to assist practitioners in determining appropriate speed limits in speed zones.

The benefits of USLIMITS are: (1) Increases the likelihood of consistent speed limits among similarly zones roads. (2) It encourages consistent speed limits for specific road and traffic characteristics. (3) It also improves the consistency of speed limits within states and between states. (4) USLIMITS reduces the speed differences within the traffic stream, leading to reduction in crashes. (5) IT serves as a tool for public awareness and education and in responding to public and political concerns. (6) And it also supports the integrity of speed enforcement and adjudication.
FHWA Research Library and http://www.fhwa.dot.gov/crt/lifecycle/08028.pdf

TechBriefs

Drivers' Evaluation of the Diverging Diamond Interchange
FHWA-HRT-07-048

The Federal Highway Administration (FHWA) has been advocating novel intersection designs as a way to promote intersection safety while meeting the often conflicting demands for increasing capacity, decreasing congestion, and minimizing the cost of new infrastructure. One of these novel designs is the diverging diamond interchange (DDI).

The DDI design accommodates left-turning movements at signalized, grade-separated interchanges of arterials and limited-access highways while eliminating the need for left-turn phasing. On the arterial, traffic crosses over to the left side of the roadway between the nodes of the interchange. Two-phase traffic signals are installed at the crossovers. Once on the left side of the arterial roadway, vehicles can turn left onto limited-access ramps without stopping and without conflicting with through traffic.

FHWA invited representatives of its Missouri Division Office and MoDOT to visit the Turner-Fairbank Highway Research Center to preview their proposed Highway Driving Simulator design. The proposed changes, method, participants, procedures and findings are spelled out in the TechBrief.
http://www.tfhrc.gov/safety/pubs/07048/index.htm

Safety Evaluation of STOP AHEAD Pavement Markings
FHWA-HRT-08-045

This document is a technical summary of the Federal Highway Administration report, *Safety Evaluation of STOP AHEAD Pavement Markings.*
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/08045/index.htm

Safety Evaluation of Center Two-Way Left-Turn Lanes on Two-Lane Roads
FHWA-HRT-08-046
This document is a technical summary of the Federal Highway Administration report, *Safety Evaluation of Center Two-Way Left-Turn Lanes on Two-Lane Roads.*
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/08046/index.htm

Safety Evaluation of Increasing Retroreflectivity at STOP Signs
FHWA-HRT-08-047
This document is a technical summary of the Federal Highway Administration report, *Safety Evaluation of Increasing Retroreflectivity of STOP Signs.*
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/08047/index.htm

Safety Evaluation of Flashing Beacons at Stop-Controlled Intersections
FHWA-HRT-08-048

This document is a technical summary of the Federal Highway Administration report, *Safety Evaluation of Flashing Beacons at Stop-Controlled Intersections.*
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/08048/index.htm

Surrogate Safety Assessment Model (SSAM)
FHWA-HRT-08-049

This document is a technical summary of the Federal Highway Administration report, *Surrogate Safety Assessment Model and Validation: Final Report*, FHWA-HRT-08-051.
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/08049/index.htm

Surrogate Safety Assessment Model (SSAM)—Software User Manual
FHWA-HRT-08-050

This document presents guidelines for the installation and use of the Surrogate Safety Assessment Model (SSAM) software. For more information regarding the SSAM application, including discussion of theoretical background and the results of a series of evaluation tests, see the corresponding FHWA research report entitled *Surrogate Safety Assessment Model and Validation: Final Report*, FHWA-HRT-08-051.
http://www.tfhrc.gov/safety/pubs/08050/index.htm

Technical Reports

Shared-Use Path Level of Service Calculator–A User's Guide

FHWA-HRT-05-138

Shared-use paths are becoming increasingly busy in many places in the United States. Path designers and operators need guidance on how wide to make new or rebuilt paths and whether to separate the different types of users. The current guidance is not very specific, has not been calibrated to conditions in the United States, and does not accommodate the range of modes found on a typical U.S. path. The purpose of this project was to develop a level of service (LOS) estimation method for shared-use paths that overcomes these limitations. The research included the development of the theory of traffic flow on a path, an extensive effort to collect data on path operations, and a survey during which path users expressed their degree of satisfaction with the paths shown on a series of videos.

Based on the theory developed and the data collected, the researchers developed an LOS estimation method for bicyclists that requires minimal input and produces a simple and useful result. The method requires only four inputs from the user: One-way user volume in the design hour, mode split percentages, trail width, and presence or absence of a centerline. Factors involved in the estimation of an LOS for a path include the number of times a typical bicyclist meets or passes another path user and the number of those passes that are delayed. The method considers five types of path users when calculating adult bicyclists' LOS, including other adult bicyclists, child bicyclists, pedestrians, runners, and in-line skaters.

This report provides step-by-step instructions on how to use the LOS procedure and spreadsheet calculation tool, which can be downloaded from the Turner-Fairbank Highway Research Center Web site at www.tfhrc.org. Other products of the effort include FHWA-HRT-05-137 *Evaluation of Safety, Design, and Operation of Shared-Use Paths: Final Report,* which documents the research and the spreadsheet calculation tool and is the basis of FHWA-HRT-05-139 *Evaluation of Safety, Design, and Operation of Shared-Use Paths* TechBrief.
http://www.tfhrc.gov/safety/pedbike/pubs/05138/

Interchange Safety Analysis Tool (ISAT): User Manual

FHWA-HRT-07-045

This User Manual describes the usage and operation of the spreadsheet-based Interchange Safety Analysis Tool (ISAT). ISAT provides design and safety engineers with an automated tool for assessing the safety effects of geometric design and traffic control features at an existing interchange and adjacent roadway network. ISAT can also be used to predict the safety performance of design alternatives for new interchanges and prior to reconstruction of existing interchanges. The primary outputs from an analysis include: the number of predicted crashes for the entire interchange area, the number of predicted crashes by interchange element type (i.e., mainline freeway segments, ramps, ramp terminals and intersections, and crossroad roadway segments), the number of predicted crashes by year, and the number of predicted crashes by collision type.

This User Manual presents basic information for getting started with using ISAT, the general methodology that users will follow when conducting an analysis with ISAT, input requirements of the program, default data incorporated within the program and recommendations on when and how these default data should be updated by the user, output reports generated by ISAT, and general information on different applications for which ISAT can be applied. An example problem is also provided on the safety performance of a rural diamond interchange and surrounding roadway network, illustrating user inputs and generated output reports.
http://www.tfhrc.gov/safety/pubs/07045/index.htm

Model Minimum Inventory of Roadway Elements—MMIRE

FHWA-HRT-07-046

Safety data provide the key to making sound decisions on the design and operation of roadways, but deficiencies in many States' safety databases do not allow for good decisionmaking. The Federal Highway Administration, American Association of State Highway and Transportation Officials, and the National Cooperative Highway Research Program sponsored a scanning study of how agencies in the Netherlands, Germany, and Australia develop and use traffic safety information systems. That scan produced a report that included recommendations for advancing safety themes in the areas of strategy, efficiency, and utility.

A recently completed follow-on effort built on the scan team's final report and draft implementation plan by reviewing in detail the strategies suggested, providing action-related details to some of the critical strategies, and adding new strategies to help reach the team's goals. As noted in the White Paper, while considerable attention and effort has been devoted to the improvement in crash data, one of the primary safety databases, much less effort has been devoted to improvements in the second primary safety database–roadway inventory and traffic data. One of the five critical strategies detailed there involved improving safety data by defining *good inventory data*, and specifically recommended the development of a Model Minimum Inventory of Roadway Element (MMIRE) that would define the critical inventory and traffic data elements

needed by State and local jurisdictions to meet current safety analysis needs and data needs arising from a new generation of safety analysis tools. This current report presents a proposed MMIRE and documents the development process It also included a review of the proposed MMIRE elements in a workshop of safety data experts. A listing of high-priority and supplemental inventory and traffic elements are presented, along with proposed coding for each element.
http://www.tfhrc.gov/safety/pubs/07046/index.htm

Updates to Research on Recommended Minimum Levels for Pavement Marking Retroreflectivity to Meet Driver Night Visibility Needs

FHWA-HRT-07-059

This study was aimed at completing the research to develop and scrutinize minimum levels for pavement marking retroreflectivity to meet nighttime driving needs. A previous study carried out in the 1990s was based on the CARVE model developed at Ohio University and resulted in a table of minimum levels of pavement marking retroreflectiviy values. Since then, a newer, more powerful analytical tool, Tarvip, which was developed at the Operator Performance Lab of the University of Iowa, overcomes a lot of limitations of the CARVE model and uses updated data that reflect the current states of vehicles and roadways in the United States.

In this study, the Pavement Marking Visibility Module of the Tarvip model was validated by comparing field data from various studies to prediction results under similar conditions from Tarvip. Next, a comprehensive survey on the factors that affect pavement marking visibility and minimum R L levels was performed, with key factors identified, including pavement marking configuration, pavement surface type, vehicle speed, vehicle type, and presence of RRPMs. From these key factors, a methodology of using Tarvip to do a sensitivity analysis on factors modeled in it was developed. The plan was executed, and resulting R L values under typical conditions on United States roadways formed the basis of new recommendations. Finally, limitations of the recommendations were analyzed, and a plan for future research was presented.
http://www.tfhrc.gov/safety/pubs/07059/index.htm

Development of a Driver Vehicle Module (DVM) for the Interactive Highway Safety Design Model (IHSDM)

FHWA-HRT-08-019

The Federal Highway Administration is currently developing an integrated set of software tools to improve highway design, the Interactive Highway Safety Design Model (IHSDM). The IHSDM is a suite of software analysis tools for evaluating safety and operational effects of geometric design decisions on two-lane rural highways. The IHSDM provides highway project planners, designers, and reviewers in State and local departments of transportation and engineering consulting firms with a suite of safety evaluation tools to support these assessments. As currently implemented in the latest public release version, the IHSDM includes the following five components: (1) Policy Review Module, (2) Design Consistency Module, (3) Crash Prediction Module, (4) Traffic Analysis Module, and (5) Intersection Review Module. A sixth module, the Driver Vehicle Module (DVM), is a candidate for future release.

This report provides a complete technical description of the DVM. Specifically, it provides a description of the specification, verification, and calibration/validation of the DVM for the passenger vehicle and the heavy vehicle component, along with additional functionality enhancements.
http://www.tfhrc.gov/safety/pubs/08019/index.htm

Methods for Maintaining Traffic Sign Retroreflectivity

FHWA-HRT-08-026

In response to a Congressional directive, the FHWA has established minimum maintained traffic sign retroreflectivity levels that are incorporated into the *Manual on Uniform Traffic Control Devices* (MUTCD). One of the concerns expressed by agency personnel responsible for being in conformance with required minimums is the potential increase in tort exposure. The FHWA has developed retroreflectivity maintenance methods that, when implemented as intended, provide agencies with a flexible means of being in conformance with required minimum retroreflectivity levels and provide protection from potential tort claims. Other properly supported methods (i.e., through the completion of an engineering study) may be used to maintain signs at the required minimum retroreflectivity levels. Agencies can use the information in this report to help determine which retroreflectivity maintenance method or combination of methods best suits their needs.
http://safety.fhwa.dot.gov/roadway_dept/retro/hrt08026/index.htm

Minimum Retroreflectivity Levels for Blue and Brown Traffic Signs

FHWA-HRT-08-029

In 2003, the Federal Highway Administration published research recommendations for minimum maintained retroreflectivity (MR) levels for traffic signs. The recommendations included most sign types but not white-on-blue signs or white-on-brown signs. In addition, the 2003 recommended maintained retroreflectivity levels were based on conditions representing dark rural environments. This report describes the research activities and consequent findings related to the development of recommendations for MR levels for white-on-blue signs and white-on-brown signs. This report also includes an investigation related to MR levels needed for complex visual conditions that include glare from oncoming headlamps and fixed roadway lighting.

The research used a summary of the pertinent literature to develop an experimental plan to produce luminance thresholds that could be used with a previously developed analytical model to develop a set of recommendations for MR levels for white-on-blue signs and white-on-brown signs. The results for the white-on-blue signs and white-on-brown signs were integrated into one table that includes the current set of MR levels. Both legend and symbol signs were consolidated into the same recommendations because of similar requirements for luminance thresholds.
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/08029/index.htm

Safety Evaluation of Increasing Retroreflectivity of STOP Signs

FHWA-08-041

The Federal Highway Administration (FHWA) organized a Pooled Fund Study of 26 States to evaluate low-cost safety strategies as part of its strategic highway safety effort. One of the strategies chosen to be evaluated for this study was STOP signs with increased retroreflectivity. This strategy is intended to reduce the frequency of crashes related to driver unawareness of stop control at unsignalized intersections.

Geometric, traffic, and crash data were obtained at unsignalized intersections for 231 sites in Connecticut and 108 sites in South Carolina. In each case, the strategy was implemented as a blanket application of STOP signs with increased retroreflectivity. Empirical Bayes (EB) methods were incorporated in a before-after analysis to determine the safety effectiveness of increasing the sign retroreflectivity. There was a statistically significant reduction in rear-end crashes in South Carolina. Based on the results of the disaggregate analysis, reductions in crashes were found at three-legged intersections and at intersections with low approach volumes. The analysis also indicated a slight reduction in nighttime- and injury-related crashes in Connecticut and South Carolina, but the results were not statistically significant. It was determined that a sample size much larger than that available would be needed to detect a significant effect in these types of crashes. Given the very low cost of installing STOP signs with increased retroreflectivity, even with conservative assumptions, only a very modest reduction in crashes is needed to justify their use. Therefore, this strategy has the potential to reduce crashes cost-effectively, particularly at lower volume intersections.
http://www.tfhrc.gov/safety/pubs/08041/index.htm

Safety Evaluation of Installing Center Two-Way Left-Turn Lanes on Two-Lane Roads

FHWA-HRT-08-042

The Federal Highway Administration organized a Pooled Fund Study of 26 States to evaluate low-cost safety strategies as part of its strategic highway safety effort. One of the strategies chosen to be evaluated for this study was the installation of center two-way left-turn lanes on two-lane roads. This strategy is intended to reduce the frequency of crashes involving a turning vehicle, which could be classified as head on or rear end.

Geometric, traffic, and crash data were obtained for 78 sites (34.9 km (21.3 mi)) in North Carolina, 10 sites (9.7 km (6.0 mi)) in Illinois, 31 sites (10.95 km (6.8 mi)) in California, and 25 sites (21.25 km (13.2 mi)) in Arkansas. Empirical Bayes methods were incorporated in a before-after analysis to determine the safety effectiveness of installing the two-way left-turn lanes. There was a statistically significant reduction in total and rear-end crashes in each of four States whose installations were evaluated. Rural installations were found to be more effective in reducing crashes than urban ones in each of the four States.

Lower cost installations of TWLTLs can be a cost-effective treatment for two-lane rural locations, especially those with a high frequency of rear-end collisions involving a lead vehicle desiring to make a turn.

http://www.tfhrc.gov/safety/pubs/08042/index.htm

Safety Evaluation of STOP AHEAD Pavement Markings

FHWA-HRT-08-043

The Federal Highway Administration (FHWA) organized a Pooled Fund Study of 26 States to evaluate low-cost safety strategies as part of its strategic highway safety effort. One of the strategies chosen to be evaluated for this study was STOP AHEAD pavement markings. This strategy is intended to reduce the frequency of crashes related to driver unawareness of stop-control at unsignalized intersection. Geometric, traffic, and crash data were obtained at unsignalized intersections for 8 sites in Arkansas, 9 sites in Maryland, and 158 sites in Minnesota. To account for potential selection bias and regression-to-the-mean, an empirical Bayes before-after analysis was conducted to determine the safety effectiveness of installing STOP AHEAD pavement markings.

Results of the aggregate analysis indicate a statistically significant reduction in total crashes for Arkansas, Maryland, and the two States combined. The combined aggregate analysis indicates that at least a 15-percent reduction in total crashes can be expected conservatively. There is also a statistically significant reduction in right-angle and rear-end crashes for Arkansas. A reduction in injury crashes is shown for Arkansas and Maryland and is statistically significant at the ten percent level for the two States combined. The results for Minnesota were not included in the main analysis, but support the conclusion that this strategy is safety effective. The disaggregate analysis indicated that crash reductions are highly significant at three-legged intersections and significantly greater than reductions at four-legged intersections. The strategy was also more effective at intersections with all-way stop-control (AWSC). Given the low-cost of this strategy, even with conservative assumptions, a modest reduction in crashes is needed to justify their use. Based on the estimated safety effectiveness of STOP AHEAD pavement markings, the necessary crash reduction to obtain a 2:1 benefit-cost ratio is easily achieved. Therefore, this strategy has the potential to reduce crashes cost-effectively at unsignalized intersections, particularly at three-legged and AWSC intersections.
http://www.tfhrc.gov/safety/pubs/08043/index.htm

Safety Evaluation of Flashing Beacons at STOP-Controlled Intersections

FHWA-HRT-08-044

The Federal Highway Administration (FHWA) organized a pooled fund study of 26 States to evaluate low-cost safety strategies as part of its strategic highway safety effort. One of the strategies chosen to be evaluated for this study was flashing beacons. Three types of flashing beacons–intersection control beacons, beacons mounted on STOP signs, and actuated beacons–were considered collectively at stop-controlled intersections. This strategy is intended to reduce the frequency of crashes related to driver unawareness of stop control at unsignalized intersections.

Geometric, traffic, and crash data were obtained at stop-controlled intersections for 64 sites in North Carolina and 42 sites in South Carolina. Empirical Bayes methods were incorporated in a before-after analysis to determine the safety effectiveness of installing

flashing beacons, while accounting for potential selection bias and regression-to-the-mean effects. Overall, installation of flashing beacons in North Carolina resulted in statistically significant reductions in total, angle, and injury plus fatal crashes. The intersections in South Carolina experienced very little change following the introduction of flashing beacons. The combined results from both the States supports the conclusion that an angle crash reduction of a 13 percent and an injury and fatal crash reduction of 10 percent can be expected. The economic analysis based on the combined results for angle and nonangle accidents from both States indicates that standard flashing beacons and some of the actuated ones (i.e., the less expensive beacons) are economically justified, but that a benefit cost ratio of 2:1 may not be achievable for the more expensive actuated beacon types.
http://www.tfhrc.gov/safety/pubs/08044/index.htm

Surrogate Safety Assessment Model and Validation: Final Report

FHWA-HRT-08-051

Abstract Safety of traffic facilities is most often measured by counting the number (and severity) of crashes that occur. It is not possible to apply such a measurement technique to traffic facility designs that have not yet been built or deployed in the real world. This project has resulted in the development of a software tool for deriving surrogate safety measures for traffic facilities from data output by traffic simulation models. This software is referred to as SSAM—an acronym for the Surrogate Safety Assessment Model. The surrogate measures developed in this project are based on the identification, classification, and evaluation of traffic conflicts that occur in the simulation model. By comparing one simulated design case with another, this software allows an analyst to make statistical judgments about the relative safety of the two designs. An open-standard vehicle trajectory data format was designed, and support for this format has been added as an output option by four simulation model vendors/developers—PTV (VISSIM), TSS (AIMSUN), Quadstone (Paramics), and Rioux Engineering (TEXAS). Eleven “theoretical” validation tests were performed to compare the surrogate safety assessment results of pairs of simulated design alternatives. In addition, a field validation exercise was completed to compare the output from SSAM with real-world crash records. Eighty-three intersections from British Columbia, Canada were modeled in VISSM and simulated under AM-peak traffic conditions. The processed conflict results were then compared with the crash records in a number of different statistical validation tests. Last, sensitivity analysis was performed to identify differences between the SSAM-related outputs of each simulation model vendor’s system on the same traffic facility designs. These comparative analyses provide some guidance to the relative use of surrogate measures data from each simulation system. The SSAM software tool and user manual (FHWA-HRT08-050) are available to the public at no cost from FHWA.
http://www.tfhrc.gov/safety/pubs/08051/index.htm

Informational Report on Lighting Design for Midblock Crosswalks
FHWA-HRT-08-053

This report provides information on lighting parameters and design criteria that should be considered when installing fixed roadway lighting for midblock crosswalks. The information is based on static and dynamic experiments of driver performance with regard to the detection of pedestrians and surrogates in midblock crosswalks. Experimental condition variables included lamp type (high-pressure sodium and metal halide), vertical illuminance level, color of pedestrian clothing, position of the pedestrians and surrogates in the crosswalk, and the presence of glare. Two additional lighting systems, a Probeam luminaire and ground-installed LEDs, were also evaluated. The research found that a vertical illuminance of 20 lx in the crosswalk, measured at a height of 1.5 m (5 ft) from the road surface, provided adequate detection distances in most circumstances. Although the research was constrained to midblock placements of crosswalks, the report includes a brief discussion of considerations in lighting crosswalks colocated with intersections.
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/08053/index.htm

7 Structures

Fact Sheets

Hydraulics Laboratory Fact Sheet
FHWA-HRT-07-054

This fact sheet describes the purpose of the Hydraulics Laboratory, which is a facility used to conduct a variety of experiments pertaining to water. The Hydraulics Laboratory consists of a physical modeling facility and a numerical modeling facility that work in tandem; one extrapolates results, and the other verifies and calibrates the results. This article also describes the major components of the physical modeling facility, and lists several recent accomplishments. The laboratory staff consists of members who have expertise in fluid measurement techniques, including high-speed digital photography of illuminated flow sections using a high energy pulsed laser for 2-D and 3-D PIV.
FHWA Research Library and http://www.tfhrc.gov/structur/pubs/07054/index.htm

Structural Laboratory Fact Sheet
FHWA-HRT-07-060

This fact sheet describes the Structural Laboratory and its purpose, which is to support FHWA's strategic focus on improving mobility through analytical and experimental studies to determine the behavior of bridge systems under typical and extreme loading conditions. The fact sheet lists eleven recent activities, six current activities (Optimizing and evaluating ultra-high-performance concrete bridge girder performance; Developing modular steel bridge systems for rapid construction; Investigating the fatigue resistance of galvanized steel pole and sign structures; Evaluating the strength and creep

resistance of epoxy chemical anchor bolt systems under sustained loads; Developing design and performance specifications for the structural use of lightweight concrete in bridge decks and components; Assisting the National Transportation Safety Board investigation of the collapse of the I-35W Bridge), and future activities. The Structural Laboratory collaborates with other research institutions, AASHTO, individual States, and industry organizations to reduce cost and promote the implementation of research results.
FHWA Research Library and http://www.tfhrc.gov/about/struct.htm

Priority, Market-Ready Technologies and Innovations: Bridge and Tunnel Security

FHWA-HRT-08-031

This Priority, Market-Ready Technologies and Innovations fact sheet describes the problems owners and operators of highway structures have to protect a vulnerable transportation system. The use of an assessment tool is a method to ensure the security of critical bridges and tunnels. Successful applications: identifying and securing vulnerable bridge and tunnel components, and using a systematic risk management process for critical structures have proven useful. Deployment goal and deployment status is addressed.
FHWA Research Library and http://www.fhwa.dot.gov/crt/lifecycle/08031.pdf

Highways of the Future—A Strategic Plan for Highway Infrastructure Research and Development

FHWA-HRT-08-068

This *Highways of the Future—A Strategic Plan for Highway Infrastructure Research and Development* was developed in response to a need expressed by the staff of the Federal Highway Administration (FHWA) Office of Infrastructure Research and Development (R&D) for a coordinated plan that provides direction for future infrastructure research and a framework to support the reauthorization efforts in advance of the expiration of authority under Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This plan supports not only the mission of FHWA, but also serves as a reminder of the value added by addressing the Agency's strategic plan. This plan also demonstrates how the focus on highway infrastructure research, development, and technology deployment benefits the economy of the Nation.
http://www.tfhrc.gov/infrastructure/pubs/08068.htm

TechBriefs

TechBrief: Wind Induced Vibration of Stay Cables

FHWA-HRT-05-084

This techbrief is a summary of the complete report FHWA-HRT-06-083, *Wind Induced Vibration of Stay Cables.*

Cable-stayed bridges have been established as efficient and cost effective structural form in the 152-meter (m) to 472-m span range. Longer spans are being constructed employing increasingly longer stay cables. The stay cables are laterally flexible structural members with very low fundamental frequency and very little inherent damping. For this reason, the stay cables have been known to be susceptible to excitations, especially during construction, wind, and rain-wind conditions.

Early cable-stayed bridges were observed exhibiting large stay oscillations under certain environmental conditions. From field observations it became evident that these vibrations were occurring under moderate rain combined with moderate wind conditions, and hence were referred to as rain-wind vibrations. The formation of a water rivulet along the upper side of the cable and its interaction with the wind flow has been solidly established as the cause through many recent studies and wind tunnel tests. Exterior cable surface modifications that interfere with the formation of the water rivulets have been tried and proven to be very effective in the mitigation of the rain-wind vibrations.

At the time of the present investigation, it was evident that the rain-wind problem had been essentially solved at least for practical provisions for its mitigation. However, some further experimental and analytical work was needed to supplement the existing knowledge base on several other stay cable vibration issues in order to formulate adequate design guidelines.

The objectives of this project were to: (1) Identify gaps in current knowledge base; (2) Conduct analytical and experimental research in critical areas; (3) Study performance of existing cable-stayed bridges.; (4) Study current mitigation methods; (5) Develop procedures for aerodynamic performance assessment; and (6) Develop design and retrofit guidelines for stay cable vibration mitigation.
http://www.fhwa.dot.gov/bridge/pubs/05084/index.cfm

TechBrief: Multiple Corrosion Protection Systems for Reinforced Concrete Bridge Components

FHWA-HRT-07-044

This is the interim report on a Federal Highway Administration (FHWA) project that is fully documented in a separate report under the same title (FHWA-HRT-07-043).

Epoxy-coated reinforcement (ECR) is the principal concrete reinforcing material currently in use in the United States in corrosive environments. The purpose of this study is to evaluate methods for making ECR more corrosion resistant by using multiple corrosion protection strategies in bridge decks, as well as for bridge members in marine environments where abundant salt, moisture, and high temperatures are prevalent.

This research is being conducted using laboratory and field tests, the results of which will be used to compare the performance of the corrosion protection systems on the basis of chloride threshold, corrosion rate, life expectancy, and cost effectiveness. Fusion-bonded thermoset ECR currently is being evaluated in conjunction with

inorganic and organic corrosion inhibitors, bars coated with zinc prior to the application of epoxy, and chemical pretreatments and epoxy formulations that increase the adhesion of the epoxy coating to the reinforcing steel.
http://www.fhwa.dot.gov/bridge/pubs/07044/index.cfm

Analysis of an Ultra-High Performance Concrete Two-Way Ribbed Bridge Deck Slab

FHWA-HRT-07-055

This document is a technical summary of the unpublished Federal Highway Administration report, Analysis of an Ultra-High Performance Concrete Two-Way Ribbed Bridge Deck Slab, available through the National Technical Information Service.

This TechBrief highlights the design a process for an ultra-high performance concrete (UHPC) two-way ribbed prestressed bridge deck element.
FHWA Research Library and http://www.fhwa.dot.gov/bridge/pubs/07055/

Technical Reports

Manual for LS-DYNA Wood Material Model 143

FHWA-HRT-04-097

An elastoplastic damage model with rate effects was developed for wood and was implemented into LS-DYNA, a commercially available finite element code. This manual documents the theory of the wood material model, describes the LS-DYNA input and output formats, and provides example problems for use as a learning tool. Default material property input options are provided for southern yellow pine and Douglas fir. The model was developed for roadside safety applications, such as wood guardrail posts impacted by vehicles; however, it should be applicable to most dynamic applications.

The companion report to this manual is: Evaluation of LS-DYNA Wood Material Model 143 (FHWA-HRT-04-096)
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/04097/index.htm

Compilation and Evaluation of Results From High-Performance Concrete Bridge Projects, Volume I: Final Report

FHWA-HRT-05-056

In 1993, the Federal Highway Administration (FHWA) initiated a national program to implement the use of high-performance concrete (HPC) in bridges. The program included the construction of demonstration bridges throughout the United States. In addition, other States have implemented the use of HPC in various bridge elements. The construction of these bridges has provided a large amount of data on the use of HPC.

The first part of this project involved collecting and compiling information from each joint State-FHWA HPC bridge project and other HPC bridge projects. The compilation

is available on a CD-ROM and includes information on the benefits of HPC, costs, structural design, specified concrete properties, concrete mix proportions, measured properties, associated research projects, sources of data, and specifications. Information from 19 bridges in 14 States is included. A summary of the compiled information is provided in this final report.

The second part of this project involved a review of the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, the AASHTO *Standard Specifications for Highway Bridges*, the *AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications*, and the *AASHTO LRFD Bridge Construction Specifications* for provisions that directly impact the use of HPC. The detailed review is included in this report.

The third part of the project involved the development of proposed revisions to the AASHTO specifications where sufficient research results exist to support the revisions. Proposed revisions to 15 material specifications, 14 test methods, 30 articles of the standard design specifications, 17 articles of the LRFD design specifications, and 16 articles of the LRFD construction specifications are included in this report. In addition, a new materials specification for combined aggregates and a new test method for slump flow are proposed. Proposed revisions to the FHWA definition of HPC are also included.

The fourth part of the project involved the development of specific recommendations for needed research where sufficient results do not exist to support needed changes in the specifications. Six research problem statements related to concrete materials and four research problems related to structural design are recommended.
http://www.fhwa.dot.gov/bridge/pubs/05056/

Compilation and Evaluation of Results From High-Performance Concrete Bridge Projects, Volume II: Final Report

FHWA-HRT-05-057

In 1993, the Federal Highway Administration (FHWA) initiated a national program to implement the use of high-performance concrete (HPC) in bridges. The program included the construction of demonstration bridges throughout the United States. In addition, other States have implemented the use of HPC in various bridge elements. The construction of these bridges has provided a large amount of data on the use of HPC.

The first part of this project involved collecting and compiling information from each joint State-FHWA HPC bridge project and other HPC bridge projects. The compilation is available on a CD-ROM and includes information on the benefits of HPC, costs, structural design, specified concrete properties, concrete mix proportions, measured properties, associated research projects, sources of data, and specifications. Information from 19 bridges in 14 States is included. A summary of the compiled information is provided in this final report.

The second part of this project involved a review of the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, the AASHTO *Standard Specifications for Highway Bridges*, the *AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications*, and the *AASHTO LRFD Bridge Construction Specifications* for provisions that directly impact the use of HPC. The detailed review is included in this report.

The third part of the project involved the development of proposed revisions to the AASHTO specifications where sufficient research results exist to support the revisions. Proposed revisions to 15 material specifications, 14 test methods, 30 articles of the standard design specifications, 17 articles of the LRFD design specifications, and 16 articles of the LRFD construction specifications are included in this report. In addition, a new materials specification for combined aggregates and a new test method for slump flow are proposed. Proposed revisions to the FHWA definition of HPC are also included.

The fourth part of the project involved the development of specific recommendations for needed research where sufficient results do not exist to support needed changes in the specifications. Six research problem statements related to concrete materials and four research problems related to structural design are recommended.
http://www.fhwa.dot.gov/bridge/pubs/05057/

Wind-Induced Vibration of Stay Cables

FHWA-HRT-05-083

Cable-stayed bridges have become the form of choice over the past several decades for bridges in the medium- to long-span range. In some cases, serviceability problems involving large amplitude vibrations of stay cables under certain wind and rain conditions have been observed. This study was conducted to develop a set of consistent design guidelines for mitigation of excessive cable vibrations on cable-stayed bridges.

To accomplish this objective, the project team started with a thorough review of existing literature to determine the state of knowledge and identify any gaps that must be filled to enable the formation of a consistent set of design recommendations. This review indicated that while the rain/wind problem is known in sufficient detail, galloping of dry inclined cables was the most critical wind-induced vibration mechanism in need of further experimental research. A series of wind tunnel tests was performed to study this mechanism. Analytical and experimental research was performed to study mitigation methods, covering a range of linear and nonlinear dampers and crossties. The study also included brief studies on live load-induced vibrations and establishing driver/pedestrian comfort criteria.

Based on the above, design guidelines for mitigation of wind-induced vibrations of stay cables were developed.
http://www.fhwa.dot.gov/bridge/pubs/05083/index.cfm