Technical Publications Catalog

October 2006 – September 2007

Turner-Fairbank Highway Research Center
Research, Development and Technology

FHWA-HRT-08-023

U.S. Department of Transportation
Federal Highway Administration

Table of Contents

Introduction

This Turner-Fairbank Highway Research Center (TFHRC) third *Technical Publications Catalog* is a comprehensive listing of our research documents published from October 2006 through September 2007. The catalog 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, along with its two preceding volumes covering October 1998 – September 2003, and October 2003 -- September 2006, are indispensable transportation research resources for engineers, transportation specialists, policymakers, information specialists, and other interested groups. 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.

Dennis C. Judycki
Associate Administrator
Research, Development, and Technology

1 Administration

Directory

Organizational and Expertise Directory (October 2007)
FHWA-HRT-07-050

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 how to contact individuals.
http://www.tfhrc.gov/about/orgdirectory/index.htm

Summary

Office of Research, Development, and Technology Fiscal Year 2006 Research Project Status Summary
FHWA-HRT-07-049

This summary presents tables and charts which reflect the Federal Highway Administration (FHWA) Office of Research, Development, and Technology's (RD&T) fiscal year (FY) 2006 progress in conducting the program of research identified in the *Research, Development, and Technology Performance Plan: Fiscal Year 2006-2007* (**FHWA-HRT-06-037)**. FHWA is publishing this information as part of its commitment to hold themselves accountable publicly for carrying out its research plan. During FY 2006, researchers at the Turner-Fairbank Highway Research Center (TFHRC) conducted 127 research projects that support the Agency's strategic goals of *Safety, Mobility and Productivity, Global Connectivity, Environment, National Homeland Securit6y, and Organizational Excellence.* Of the total number of projects, 44 were completed by FY end, and 83 projects are ongoing. Eighty percent of the total number of projects were on schedule. For those research projects that were not on schedule in FY 2006, delays were due to staff changes and delayed availability of funds. Twelve projects in the original plan will not be conducted due to lack of funds and revised priorities. Fifteen projects that were unanticipated when the FY 2006/2007 performance plan was developed were added to the table. These 15 projects were identified as priorities based on stakeholder input following the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).
http://www.tfhrc.gov/about/07049/index.htm

2 Human Factors

Technical Reports

Enhanced Night Visibility Series, Volume VI: Phase II—Study 4: Visual Performance During Nighttime Driving in Fog
FHWA-HRT-04-137

Phase II—Study 4 was part of the Enhanced Night Visibility project, a larger research effort investigating drivers' visual performance during nighttime driving. Study 4 helped expand the knowledge of how current vision enhancement systems can affect detection and recognition of different types of objects during adverse weather, specifically for fog conditions. Thirty participants were involved in the study. A 6 by 3 mixed factorial design was used to investigate the effects of different types of vision enhancement systems and driver's age on detection and recognition of a pedestrian on the roadway. Subjective evaluations also were obtained for the different vision enhancement systems.

The analysis based on objective and subjective results revealed that the infrared thermal imaging system is the best configuration for detecting pedestrians in fog conditions. Halogen headlamps supplemented with ultraviolet A (UV–A) was a better configuration for detecting pedestrians than the halogen and high intensity discharge (HID) headlamps alone; however, the UV–A technology does not represent a dramatic improvement over the halogen and HID headlamps used in this research.
http://www.tfhrc.gov/safety/hsis/pubs/04137/index.htm

Enhanced Night Visibility Series, Volume XV: Phase III—Study 3: Influence of Beam Characteristics on Discomfort and Disability Glare
FHWA-HRT-04-146

The objective of this study was to evaluate the discomfort and disability glare produced by oncoming headlamps with varying beam intensity and distribution. Oncoming headlamps can be visually discomforting and disabling to drivers at night. In recent years, high intensity discharge (HID) headlamps have raised some concern because of their increased light output and brighter appearance than traditional halogen headlamps.

During the discomfort glare portion of this study, participants drove an experimental vehicle at 32 km/h (20 mi/h) past stationary glare headlamps. They were asked to rate their overall discomfort using the subjective deBoer scale. The disability glare portion involved drivers detecting a static pedestrian either near the road centerline or near the road edgeline while approaching different sets of glare headlamps. It was hypothesized that there would be significant differences in detection distance, illuminance at the driver's eye, and discomfort glare rating across the different glare headlamp, pedestrian position, adaptation level, and participant age combinations.

The main effect of glare headlamp was the only significant factor in the analysis for discomfort glare. The main effects of age, glare headlamp, and pedestrian location were all significant in the analysis for the disability glare portion. In addition, the interaction of pedestrian location and glare headlamp was significant. Overall, headlamps that had higher subjective discomfort ratings were the same lamps that had worse objective disability measures.

The conclusions of this research will be valuable to the consumer as well as the

manufacturers and designers of future headlamps in revealing how glare can affect drivers on the road at night. This information can help guide new designs to maximize forward visibility while minimizing glare.
http://www.tfhrc.gov/safety/hsis/pubs/04146/index.htm

Pedestrian and Bicyclist Intersection Safety Indices
FHWA-HRT-06-125

The primary objective of this study was to develop safety indices to allow engineers, planners, and other practitioners to proactively prioritize intersection crosswalks and intersection approaches with respect to pedestrian and bicycle safety. The study involved collecting data on pedestrian and bicycle crashes, conflicts, avoidance maneuvers, and subjective ratings of intersection video clips by pedestrian and bicycle experts. There were a total of 68 intersection crosswalks selected for the bicycle analysis included 67 intersection approaches from Gainesville, FL; Philadelphia, PA; and Portland and Eugene, OR.
FHWA Research Library and http://www.tfhrc.gov/safety/pedbike/pubs/06125/

Pedestrian and Bicyclist Intersection Safety Indices
FHWA-HRT-06-130

The primary objective of this study was to develop safety indices to allow engineers, planners, and other practitioners to proactively prioritize intersection crosswalks and intersection approaches with respect to pedestrian and bicycle safety. The study involved collecting data on pedestrian and bicycle crashes, conflicts, avoidance maneuvers, and subjective ratings of intersection video clips by pedestrian and bicycle experts. There were a total of 68 intersection crosswalks selected for the pedestrian analysis from the cities of Philadelphia, PA; San Jose, CA; and Miami-Dade County, FL. The bicycle analysis included 67 intersection approaches from Gainesville, FL; Philadelphia, PA; and Portland and Eugene, OR.

Prioritization models were developed based on expert safety ratings and behavioral data. Indicative variables included in the pedestrian safety index model included type of intersection control (signal or stop sign), number of through lanes, 85th percentile vehicle speed, main street traffic volume, and area type. Indicative variables in the bicycle safety models (for through, right-turn, and left-turn bike movements) included various combinations of: presence of bicycle lane, main and cross street traffic volumes, number of through lanes, presence of on-street parking, main street speed limit, presence of traffic signal, number of turn lanes, and others. Through this User Guide, practitioners will be able to use the safety indices to identify which crosswalks and intersection approaches have the highest priority for in-depth pedestrian and bicycle safety evaluations and subsequently use other tools to identify and address potential safety problems.
FHWA Research Library and http://www.tfhrc.gov/safety/pedbike/pubs/06130/

3 Operations

Fact Sheets

NGSIM Overview
FHWA-HRT-06-135

Traffic microsimulation models are becoming widely used and valuable tools in modeling existing and planned future transportation networks and conditions. These models can help transportation professionals make important decisions on such topics as new roadway alignments and configurations, new interchange configurations and locations, the addition of freeway auxiliary lanes, work zone management strategies and plans, operations and intelligent transportation system (ITS) strategies and plans, coordination and timing of traffic signals, and the addition of high-occupancy toll lanes.
FHWA Research Library and http://www.tfhrc.gov/about/06135.htm

Freeway Lane Selection Algorithm
FHWA-HRT-06-136

At the heart of the Next Generation SIMulaiton (NGSIM) program is the development of freely available driver behavior algorithms that represent the fundamental logic within microscopic traffic simulation models. A comprehensive survey of NGSIM stakeholder groups, coupled with an assessment of existing microsimulation systems and driver behavior algorithms, revealed a number of high-priority needs for algorithm development under the NGSIM program. As a result, researchers developed the Freeway Lane Selection algorithm as one of the first of several algorithms under the NGSIM program.
FHWA Research Library and http://www.tfhrc.gov/about/06136.htm

Interstate 80 Freeway Dataset
FHWA-HRT-06-137

To support the development of microscopic driver behavior algorithms, the Next Generation SIMulation (NGSIM) program is collecting detailed, high-quality traffic datasets. The NGSIM datasets represent the most detailed and accurate field data collected to date for traffic microsimulation research and development. The Interstate 80 freeway dataset was the first of several datasets collected under the NGSIM program.
FHWA Research Library and http://www.tfhrc.gov/about/06137.htm

Evolution of a Traffic Shockwave
FHWA-HRT-07-023

This brief narrative traces the evolution of a minor, lane-specific traffic shockwave using vehicle trajectory data from the first NGSIM dataset. This dataset tracks the exact position of all 4,733 vehicles that traversed a half mile freeway weaving section on Interstate 80 in Emeryville, California, over a 30-minute period.
FHWA Research Library

Lankershim Boulevard Dataset

FHWA-HRT-07-029

To support the development of algorithms for driver behavior at the microscopic level, the Next Generation SIMulation (NGSIM) program is collecting detailed, high-quality traffic datasets. NGSIM stakeholder groups identified the collection of real-world, vehicle trajectory data as important to understanding and researching driver behavior at a microscopic level. The NGSIM datasets represent the most detailed and accurate field data collected date for traffic microsimulation research and development. The Lankershim Boulevard dataset was one of several datasets collected under the NGSIM program.
FHWA Research Library and http://www.tfhrc.gov/about/07029.htm

US Highway 101 Dataset
FHWA-HRT-07-030

Researchers for the NGSIM program collected detailed vehicle trajectory data on southbound US 101, also known as the Hollywood Freeway, in Los Angles, California, on June 15, 2005. The study area was approximately 640 meters in length and consisted of five mainline lanes throughout the section. NG-VIDEO, a customized software application developed for the NGSIM program, transcribed the vehicle trajectory data from the video. This data provided the precise location of each vehicle within the study area every one-tenth of a second, resulting in detailed lane positions and locations relative to other vehicles.
FHWA Research Library and http://www.tfhrc.gov/about/07030.htm

Technical Report

Traffic Analysis Toolbox Volume I: Traffic Analysis Tools Primer
FHWA-HRT-04-038

This primer provides an overview of traffic analysis tools in the transportation analysis process. Different categories of traffic analysis tools are defined, and the challenges and limitations of using traffic analysis tools are presented. A specific comparison between Highway Capacity Manual analysis and traffic simulation-based analysis is provided. Criteria for selecting the appropriate type of traffic analysis tool are described. A list of traffic analysis tools within each category and their corresponding website links is provided in an appendix. This is the first volume in a series of volumes in the Traffic Analysis Toolbox.
FHWA Research Library and
http://ops.fhwa.dot.gov/trafficanalysistools/tat_vol1/vol1_primer.pdf

Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools
FHWA-HRT-04-039

This report provides an overview of the role of traffic analysis tools in the transportation analysis process and provides a detailed decision support methodology for selecting the appropriate type of analysis tool for the job at hand. An introduction to the role of traffic analysis tools and tool categories is provided. A set of criteria for selecting the

appropriate type of traffic analysis tools is described in detail and each tool category is scored as to its relevance to the criteria. This is the second volume in a series of volumes in the Traffic Analysis Toolbox.
FHWA Research Library and
http://www.ops.fhwa.dot.gov/trafficanalysistools/tat_vol2/Vol2_Methodology.pdf

Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software
FHWA-HRT-04-040

This report describes a process and acts as guidelines for the recommended use of traffic microsimulation software in transportation analyses. The seven-step process presented in these guidelines highlights the aspects of microsimulation analysis from project start to project completion. The seven steps in the process include: 1) scope project, 2) data collection, 3) base model development, 4) error checking, 5) compare model MOEs to field data, 6) alternatives analysis, and 7) final report. Each step is described in detail and an example problem applying the process is carried through the entire document. This is the third volume in a series of volumes in the Traffic analysis Toolbox.
FHWA Research Library and
http://ops.fhwa.dot.gov/trafficanalysistools/tat_vol3/vol3_guidelines.pdf

Volume II: Enhanced Night Visibility Series: Overview of Phase I and Development of Phase II Experimental Plan
FHWA-HRT-04-133

The focus of the Phase I effort was on the establishment of performance and design objectives to facilitate the deployment of ultraviolet A (UV–A) headlamps. This report describes the plan to develop UV–A headlamp specifications, evaluate fluorescent infrastructure materials, quantify glare and photobiological risks, expand the cost/benefit analysis, and demonstrate and implement the UV–A technology. It also includes a literature review that was conducted before the Phase II studies. As is often the case in large projects, some of the planned work eventually changed or was replaced to address more pressing issues. The later volumes of this report series detail what research occurred and why.
http://www.tfhrc.gov/safety/hsis/pubs/04133/index.htm

Traffic Detector Handbook: Third Edition—Volume I
FHWA-HRT-06-108

The objective of this Handbook is to provide a comprehensive resource for selecting, designing, installing, and maintaining traffic sensors for signalized intersections and freeways. It is intended for use by traffic engineers and technicians having responsibility for traffic sensors, whether in-roadway or over-roadway sensor. These two families of sensors have different characteristics and thus corresponding advantages and disadvantages that are discussed throughout the Handbook. Topics covered include sensor technology, applications, in-roadway sensor design, installation techniques, and maintenance. The sensor technology chapter discusses the operation and uses of inductive loop detectors, magnetic sensors and detectors, video image

processors, microwave radar sensors, laser radars, passive infrared and passive acoustic array sensors, and ultrasonic sensors, plus combinations of sensor technologies. The sensor application topics addresses safety, operational performance, multimodal issues, and physical and economic factors that the practitioner should consider.
FHWA Research Library and http://www.tfhrc.gov/its/pubs/06108/index.htm

Traffic Detector Handbook: Third Edition—Volume II
FHWA-HRT-06-139

The objective of this Handbook is to provide a comprehensive resource for selecting, designing, installing, and maintaining traffic sensors for signalized intersections and freeways. It is intended for use by traffic engineers and technicians having responsibility for traffic sensors, whether in-roadway or over-roadway sensors. These two families of sensors have different characteristics and thus corresponding advantages and disadvantages that are discussed throughout the Handbook. Topics covered include sensor technology, applications, in-roadway sensor design, installation techniques, and maintenance. The sensor technology chapter discusses the operation and uses of inductive loop detectors, magnetic sensors and detectors, video image processors, microwave radar sensors, laser radars, passive infrared and passive acoustic array sensors, and ultrasonic sensors, plus combinations of sensor technologies. The sensor application topics addresses safety, operational performance, multimodal issues, and physical and economic factors that the practitioner should consider. Appendixes include research, background papers, and implementation guidance. The information contained in this Handbook is based on the latest research available on treatments and best practices in use by the surveyed jurisdictions. References are provided for the student, practitioner, researcher, or decisionmaker who wished to learn more about a particular subject.
FHWA Research Library

4 Pavements

Flyer

LTPP 2006 Year in Review
FHWA-HRT-07-028

Improving the productivity and mobility of the national highway transportation system are key goals of the Federal Highway Administration (FHWA). During 2006, FHWA's Long-Term Pavement Performance (LTPP) program worked toward these goals through its efforts to provide answers to "how" and "why" pavements perform as they do. To better understand pavement performance, the LTPP program gathers and processes data describing the structure, service conditions, and performance of 2,513 pavement test sections in North America. Highway engineers use these data and data analysis findings to help make decisions that lead to more cost-effective and better performing pavements. This flyer describes 2006 accomplishments, LTTP products, and lists LTTP publications for 2006, and describes the future under SAFETEA-LU.

http://www.fhwa.dot.gov/pavement/ltpp/pubs/07028/

Newsletter

LTPP Newsletter Volume 3 , Issue 1 Winter 2007
FHWA-HRT-07-037

The latest edition of the world's largest pavement performance database is now available from the Federal Highway Administration's (FHWA) Long-Term Pavement Performance (LTPP) program. LTPP Standard Data Release (SDR) 21 can be obtained as a five CD-ROM set or on a single DVD-ROM. The SDR is in Microsoft® Access format.

Previously a utility software included as part of the LTPP SDR package, ESALCalc also is now available via DataPave Online.

Additional information included in this newsletter areTRB's annual meeting updates, and an announcement of Eric Weaver's new position.
http://www.fhwa.dot.gov/pavement/ltpp/news/07winternews.cfm

LTPP Newsletter Volume 3, Issue 2 Spring 2007
FHWA-HRT-07-047

The Federal Highway Administration (FHWA) sponsors the Transportation Pooled Fund (TPF) Program as a way for FHWA, interested States, and other organizations to partner when significant or widespread interest is shown in solving transportation-related problems. Partners may pool funds and other resources to solve these problems through research, planning, and technology transfer activities.

TPF studies cover a wide array of topics, from asphalt to work zones. Studies address pavement quality and composition, traffic monitoring and management, bridge design and repair, air quality, development of training modules, and safety for drivers, pedestrians, and construction crews as well as fish, deer, and bats. In many cases, the pooled fund process provides an effective mechanism to promote new technology. Technology transfer covers activities that lead to the adoption of a new technique or product. The TPF Program encourages States to include technology transfer activities in all pooled fund studies, but some projects focus solely on technology transfer.
A number of Long-Term Pavement Performance (LTPP)-related pooled fund studies have been completed or are now underway and are listed within this newsletter.
http://www.fhwa.dot.gov/pavement/ltpp/news.cfm

Technical Report

Long-Term Pavement Performance Program Falling Weight Deflectometer Maintenance Manual
FHWA-HRT-05-153

The Federal Highway Administration's Long-Term Pavement Performance (LTPP) program operates eight Dynatest Model 8000 FWDs to collect deflection data on in-

service pavement test sections across North America. LTPP has collected pavement deflection data in daily operations for 15 years, and in that time, the FWDs have had very little downtime. Continuous preventive maintenance is necessary to keep the complex hydraulic-electrical-mechanical FWDs operating under demanding conditions to collect high quality data and pass rigorous annual reference calibrations. The owner's manual from the manufacturer provides guidance on most repairs and troubleshooting; however, eventually FWDs require service beyond routine maintenance--in other words, the time comes for a complete overhaul. 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' information as a supplement to the Dynatest 8000 owner's manual. Maintenance guidelines are based on continuous operation of FWDs.
FHWA Research Library and http://www.fhwa.dot.gov/pavement/ltpp/pubs/05153/

Improving Pavements With Long-Term Pavement Performance: Products for Today and Tomorrow
FHWA-HRT-06-109

This report is a compilation of award-winning technical papers from the Third Annual International Contest on LTPP Data Analysis 2003-2004, various authors.
FHWA Research Library and
http://www.fhwa.dot.gov/pavement/ltpp/pubs/06109/index.cfm

Long-Term Pavement Performance (LTPP) Data Analysis Support: National Pooled Fund Study TPF-5 (013)
FHWA-HRT-06-121

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.
FHWA Research Library and
http://www.fhwa.dot.gov/pavement/ltpp/pubs/06121/index.cfm

Long-Term Pavement Performance Program Manual for Falling Weight Deflectometer Measurements
FHWA-HRT-06-132

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.
FHWA Research Library and
http://www.fhwa.dot.gov/pavement/ltpp/pubs/06132/index.cfm

The Use of Lithium to Prevent or Mitigate Alkali-Silica Reaction in Concrete Pavements and Structures
FHWA-HRT-06-133

Alkali-silica reaction (ASR) was first identified as a form of concrete deterioration in the late 1930's. Approximately 10 years later, it was discovered that lithium compounds can be used to control expansion due to ASR. There has recently been increased interest in using lithium technologies to both control ASR in new concrete and to retard the reaction in existing ASR-affected structures. This facts book provides information on lithium, its origin and properties, and on its applications. The mechanism of alkali-silica reaction is discussed together with methods of testing to identify potentially alkali-silica reactive aggregates. Traditional methods for minimizing the risk of damaging ASR are presented; these include the avoidance of reactive aggregates, controlling the levels of alkali in concrete and using supplementary cementing materials such as fly ash, slag and silica fume. The final two sections of the facts book discuss the use of lithium, first as an admixture for new concrete construction and second as a treatment for existing concrete structures affected by ASR.
FHWA Research Library and
http://www.fhwa.dot.gov/pavement/concrete/pubs/06133/index.cfm

Advanced Quality Systems: Guidelines for Establishing and Maintaining Construction Quality Databases
FHWA-HRT-07-019

The main objective of this study was to develop and present guidelines for State highway agencies (SHAs) in establishing and maintaining database systems geared towards construction quality issues for asphalt and concrete paving projects. To accomplish this, a literature search and review was performed on the subject matter, followed by a survey of construction quality practices at nine States and a more detailed review of practices at four of those nine States.
FHWA Research Library and
http://www.fhwa.dot.gov/pavement/concrete/pubs/07019/index.cfm

5 Safety

Fact Sheet

Lankershim Boulevard Dataset
FHWA-HRT-07-029

To support the development of algorithms for driver behavior at the microscopic level, the Next Generation SIMulation (NGSIM) program is collecting detailed, high-quality traffic datasets. NGSIM stakeholder groups identified the collection of real-world, vehicle trajectory data as important to understanding and researching driver behavior at a microscopic level. The NGSIM datasets represent the most detailed and accurate field

data collected to date for traffic microsimulation research and development. The Lankershim Boulevard dataset was one of several datasets collected under the NGSIM program.
http://www.tfhrc.gov/about/07029.htm

TechBrief

Pedestrian and Bicyclist Intersection Safety Indices
FHWA-HRT-06-129

The Pedestrian and Bicycle Intersection Safety Indices (Ped ISI and Bike ISI) are a set of models that enable users to identify intersection crossings and intersection approach legs that should be the greatest priority for undergoing indepth pedestrian and bicycle safety assessment. Using observable characteristics of an intersection crossing or approach leg, such as number of lanes and traffic volume, the tool produces a safety index score, with higher scores indicating greater priority for an indepth safety assessment. Each leg of an intersection may have different characteristics affecting pedestrian or bicyclist safety; therefore, the tool is intended to provide a rating of the safety of an individual crossing (Ped ISI) or approach leg (Bike ISI) rather than evaluating the intersection as a whole. A practitioner can use the tool to develop a prioritization scheme for a group of pedestrian crossings or bicyclist approaches. This method enables the practitioner to prioritize and proactively address sites that are the most likely to be a safety concern for pedestrians or bicyclists without having to wait for crashes to occur.
http://www.tfhrc.gov/safety/pedbike/pubs/06129/index.htm

Safety Assessment of Interchange Spacing on Urban Freeways
FHWA-HRT-07-031

In this research, we have studied the urban freeway interchange spacing problem from a safety perspective, and we have developed a valid fatal/injury crash prediction model using combined data from California and Washington State for urban freeways. These models quantify the sensitivity of crash rates to interchange spacing for fatal and injury crashes. A major value of the model is the ability to evaluate the impact of inserting new interchanges in existing urban freeway interchange spacings. The developed models should help decisionmakers quantify the safety impacts while conducting the cost-benefit analysis for projects involving construction of new interchanges or changes to existing interchanges. This evaluation is limited to freeway safety, and it excludes consideration of impact on surface streets and their intersections with new ramps.
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/07031/index.htm

Traffic Performance of Three Typical Designs of New Jersey Jughandle Intersections
FHWA-HRT-07-032

For this study, researchers used VISSIM simulations to model typical geometries over a wide distribution of traffic flow conditions for three NJJI design. Comparisons of NJJIs with conventional intersections for similar volume conditions revealed that NJJIs produced lower average intersection delays and higher intersection capacities for near-

saturated traffic conditions and similar traffic performance for undersaturated conditions. Practitioners can use statistical models documented in this study to assess average intersection delays, average number of stops per vehicle, and maximum queue lengths for three types of NJJIs.
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/07032/index.htm

Synthesis of the Median U-Turn Intersection Treatment, Safety, and Operational Benefits
FHWA-HRT-07-033

This synthesis summarizes the advantages and disadvantages of the MUTIT compared to conventional, at-grade signal-controlled intersections with left turns permitted from all approaches. The synthesis presents design guidelines including the location and design of the median crossovers on the major roads. Many of the guidelines presented in the synthesis are from the Michigan Department of Transportation, and address directional and bidirectional crossovers and widened areas called “loons” that facilitate the U-turn maneuver by larger vehicles and at roads with narrow medians. The synthesis also discusses application criteria for the MUTIT, and presents information on the capacity and crash experience at these intersections relative to traditional intersections.
FHWA Research Library and http://www.tfhrc.gov/safety/pubs/07033/index.htm

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

In recent years, 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). This study suggests that, where it is adopted, the DDI will deliver safety benefits. The prospective safety benefit combined with predicted operational benefits and reduced roadway width requirements for overpasses or underpasses should make the DDI an attractive interchange design alternative.
FHWA Research Library

Technical Report

Software Reliability: A Preliminary Handbook
FHWA-HRT-04-080

The overall objective of this handbook is to provide a reference to aid the highway engineer, software developer, and project manager in software verification and validation (V&V), and in producing reliable software. Specifically, the handbook:

1.) Demonstrates the need for V&V of highway-related software.
2.) Introduces the important software V&V concepts.
3.) Defines the special V&V problems for highway-related software.
4.) Provides a reference to several new software V&V techniques developed under this and earlier related projects to address the special needs of highway-related software:

- Wrapping, i.e., the use of embedded code to make a program self-verifying.
- SpecChek™, a V&V tool to check software with its specifications.
- Real-time computation of roundoff and other numerical errors.
- Phased introduction of new software to minimize failures.
- Helps the highway engineer, software developer, and project manager integrate software V&V into the development of new software and retrofit V&V into existing software.

The handbook emphasizes techniques that address the special needs of highway software, and provides pointers to information on standard V&V tools and techniques of the software industry.
http://www.tfhrc.gov/safety/pubs/04080/index.htm

Enhanced Night Visibility Series, Volume XI: Phase II—Cost-Benefit Analysis
FHWA-HRT-04-142

This volume of the Enhanced Night Visibility project is a cost-benefit analysis of the vision enhancement system (VES) and roadway marking technologies evaluated in the Phase II experiments of the Enhanced Night Visibility project. The cost-benefit analysis indicates that neither the ultraviolet-A (UV–A) headlamp nor the fluorescent pavement marking technologies are fully developed for implementation. Under the conditions simulated in the Virginia Smart Road tests, most of the combinations of experimental VESs and experimental marking materials show no net improvement in sight distance in comparison to the combination of halogen (i.e., tungsten-halogen) low-beam headlamps and a nonfluorescent pavement marking.

The best-performing VES configurations were the halogen low beam (HLB) and five UV–A + HLB. HLB serves as the benchmark, with both its estimated crash reduction benefit and its incremental cost defined to be zero. The slight overall benefit of five UV–A + HLB over HLB would lead to a positive crash savings, but its cost of implementation would result in a cost-benefit ratio of 0.001 and in negative net benefits of less than zero.

Among the pavement markings tested, the fluorescent paint generally performed worse than the fluorescent thermoplastic. Neither of the tested fluorescent pavement markings is forecast to generate positive benefits in comparison with the performance of the nonfluorescent pavement marking.
http://www.tfhrc.gov/safety/hsis/pubs/04142/index.htm

Users Manual for LS-DYNA Concrete Material Model 159
FHWA-HRT-05-062

An elasto-plastic damage model with rate effects was developed for concrete and implemented into LS-DYNA, a commercially available finite element code. This manual documents the theory of the concrete material model, describes the required input format, and includes example problems for use as a learning tool. A default material property input option is provided for normal strength concrete. The model was developed for roadside safety applications, such as concrete bridge rails and portable barriers impacted by vehicles, but it should also be applicable to other dynamic applications.

FHWA Research Library and http://ntlsearch.bts.gov/tris/record/tris/01052039.html

Evaluation of LS-DYNA Concrete
FHWA-HRT-05-063

An elastoplastic damage model with rate effects was developed for concrete and implemented into LS-DYNA, a commercially available finite element code. This manual documents the evaluation of the concrete material model, including the selection of the concrete model input parameters. The model is evaluated through correlations with test data; drop tower impact of 1/3-scale beams, bogie vehicle impact of full-scale reinforced beams, pendulum impact of bridge rails, and quasi-static loading of a safety-shaped barrier. Although the model was developed and evaluated for roadside safety applications, it should also be applicable to many dynamic problems.
FHWA Research Library

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

6 Structures

TechBrief

Wind Induced Vibration of Stay Cables

FHWA-HRT-05-084

This TechBrief is a summary of the complete report FHWA-HRT-05-083, Wind Induced Vibration of Stay Cables. At the time of the present investigation, it was evident that the rain-wind problem had been essentially solved 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.
FHWA Research Library

Freeze-Thaw Resistance of Concrete with Marginal Air Content
FHWA-HRT-06-118

Freeze-thaw resistance is a key durability factor for concrete pavements. Recommendations for the air void system parameters are normally 6 $\pm$ 1 percent total air and a spacing factor of $\leq$ 0.20 millimeter. However, it was observed that some concretes without these commonly accepted thresholds presented good freeze-thaw resistance in laboratory studies. This study evaluated the freeze-thaw resistance of several marginal air void mixes with two types of air-entraining admixtures, a Vinsol® resin and a synthetic admixture. To conduct the study, researchers used rapid cycles of freezing and thawing in plain water, with no deicing salts.
FHWA Research Library and http://www.fhwa.dot.gov/pavement/concrete/pubs/06118/

Guidelines for Establishing Maintaining Construction Quality Databases
FHWA-HRT- 07-020

The primary purpose of construction quality databases is to help State highway agencies assess the quality of materials production and placement, including the establishment of pay factors for quality. A secondary purpose is to support other agency activities, including performance analysis and improvements to current standards and specifications. These databases have become a critical component in construction quality assurance programs. The study upon which this TechBrief is based, Advanced Quality Systems: Guidelines for Establishing and Maintaining Construction Quality Databases provides a detailed description of an ideal construction quality database.
FHWA Research Library and http://www.fhwa.dot.gov/pavement/concrete/pubs/07020/

Strengthening Historic Covered Bridges to Carry Modern Traffic
FHWA-HRT-07-041

This document is a technical summary of the unpublished Federal Highway Administration report, *Strengthening Historic Bridges to Carry Modern Traffic*. This TechBrief describes research on the use of glass fiber reinforced polymer (GFRP) composites to strengthen wooden superstructure components of historic covered bridges. The research was conducted during the years 2000 to 2004.

FHWA Research Library and http://www.tfhrc.gov/structur/pubs/07041/index.htm

Multiple Corrosion Protection Systems for Reinforced Concrete Bridge Components
FHWA-HRT-07-044

This is the interim report on a Federal Highway Administration project that is fully documented in a separate report under the same title (FHWA-HRT-07-043). 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.
FHWA Research Library and http://ntlsearch.bts.gov/tris/record/tris/01055102.html

Current Provisions and Needed Research for Lightweight Concrete in Highway Bridges
FHWA-HRT-07-051

This document is a technical summary of the unpublished Federal Highway Administration (FHWA) report, *Synthesis of Research and Provisions Regarding the Use of Lightweight Concrete in Highway Bridges* which is available only through the National Technical Information Service (ww.ntis.gov) This TechBrief summarizes a synthesis report on completed research and current American Association of State Highway and Transportation Officials (AASHTO) provisions related to lightweight concrete used in highway bridges. The synthesis report is intended to provide a reference point for an FHWA research program aimed at addressing perceived shortcomings in the AASHTO specifications pertaining to lightweight concrete. The synthesis report also makes recommendations for future research efforts, focusing on the use of lightweight concrete in bridge structures.
FHWA Research Library and http://www.fhwa.dot.gov/bridge/pubs/07051/index.cfm

Technical Reports

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 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. 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. This project is composed of four parts. The first part involved collecting and compiling information. The second part involved a review of the American Association State Highway and Transportation Officials (AASHTO) Standard Specifications for Transportation Materials and Methods of Sampling and Testing, and the Standard Specifications for Highway Bridges, and the Load and Resistance Factor Design Bridge Design Specifications and the Bridge Construction Specifications. The third part of the project involved the development of proposed revisions to the AASHTO specifications. The fourth part of the project involved the development of specific recommendations for needed research.

FHWA Research Library and http://www.tfhrc.gov/structur/pubs/05060/index.htm

Compilation and Evaluation of Results from High-Performance Concrete Bridge Projects, Volume II: Appendixes
FHWA-HRT-05-057

In 1993, the Federal Highway Administration 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. 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. This project is composed of four parts. The first part involved collecting and compiling information. The second part involved a review of the American Association State Highway and Transportation Officials (AASHTO) Standard Specifications for Transportation Materials and Methods of Sampling and Testing, and the Standard Specifications for Highway Bridges, and the Load and Resistance Factor Design Bridge Design Specifications and the Bridge Construction Specifications. The third part of the project involved the development of proposed revisions to the AASHTO specifications. The fourth part of the project involved the development of specific recommendations for needed research.
FHWA Research Library

Optimized Sections for High-Strength Concrete Bridge Girders--Effect of Deck Concrete Strength
FHWA-HRT-05-058

This report contains an evaluation of the effect of high-performance concrete on the cost and structural performance of bridges constructed with high-performance concrete bridge decks and high-strength concrete girders. Bridge designers and owners are the main audience.
FHWA Research Library and http://www.tfhrc.gov/structur/pubs/05058/index.htm

Users Manual for LS-DYNA Concrete Material Model 159
FHWA-HRT-05-062

An elasto-plastic damage model with rate effects was developed for concrete and implemented into LS-DYNA, a commercially available finite element code. This manual documents the theory of the concrete material model, describes the required input format, and includes example problems for use as a learning tool. A default material property input option is provided for normal strength concrete. The model was developed for roadside safety applications, such as concrete bridge rails and portable barriers impacted by vehicles, but it should also be applicable to other dynamic applications.

The companion report to this manual is entitled *Evaluation of LS-DYNA Concrete Material Model 159, FHWA-HRT-05-063*
http://www.tfhrc.gov/safety/pubs/05062/index.htm

Evaluation of LS-DYNA Concrete Material Model 159

FHWA-HRT-05-063

An elastoplastic damage model with rate effects was developed for concrete and implemented into LS-DYNA, a commercially available finite element code. This manual documents the evaluation of the concrete material model, including the selection of the concrete model input parameters. The model is evaluated through correlations with test data: drop tower impact of ⅓-scale beams (plain and reinforced), bogie vehicle impact of full-scale reinforced beams, pendulum impact of bridge rails, and quasi-static loading of a safety-shaped barrier. Although the model was developed and evaluated for roadside safety applications, it should also be applicable to many dynamic problems.

The companion manual to this report is *Users Manual for ls-dyna Concrete Material Model 159*, FHWA-HRT-05-062.
http://www.tfhrc.gov/safety/pubs/05063/index.htm

Seismic Retrofitting Manual for Highway Structures: Part 1 – Bridges
FHWA-HRT-06-032

This report is the first of a two-part publication entitled: Seismic Retrofitting Manual for Highway Structures: Part 1: Bridges, Part 2: Retaining Structures, Slopes, Tunnels, Culverts and Roadways. Part 1 of this manual is based on previous Federal Highway Administration publications on this subject including Seismic Retrofitting Manual for Highway Bridges, published in 1995. Revisions have been made to include current advances in earthquake engineering, field experience with retrofitting highways bridges, and the performance of bridges in recent earthquakes. It is the result of several years of research with contributions from a multidisciplinary team of researchers and practitioners.
FHWA Research Library

Material Property Characterization of Ultra-High Performance Concrete
FHWA-HRT-06-103

This report presents the results from a large suite of material characterization tests that were completed in order to quantify the behaviors of a commercially available UHPC. The characteristics of this UHPC under four different curing regimes were captured. This study focused on strength-based behaviors, long-term stability behaviors, and durability behaviors.
FHWA Research Library and http://www.tfhrc.gov/structur/pubs/06103/index.htm

Structural Behavior of Ultra-High Performance Concrete Prestressed I-Girders
FHWA-HRT-06-115

In the past decade significant advances have been made in the field of high performance concretes (HPC). The next generation of concrete, ultra-high performance concrete (UHPC), exhibits exceptional tensile and compressive strength characteristics that make it well suited for use in highway bridge structures. Prestressed highway bridge girders were cast from this material and tested under flexure and shear loadings. These tests demonstrated that UHPC can carry all shear forces normally demanded of a prestressed I-girder and can also significantly enhance the flexural capacity of the

girder. Based on this research, a basic structural design philosophy for bridge I-girder design is proposed.
FHWA Research Library and http://www.tfhrc.gov/structur/pubs/06115/index.htm

Freeze-Thaw Resistance of Concrete With Marginal Air Content
FHWA-HRT-06-117

Freeze-thaw resistance is a key durability factor for concrete pavements. Recommendations for the air void system parameters are normally: 6±1 percent total air and spacing factor less than 0.20 millimeters. However, it was observed that some concretes that did not possess these commonly accepted thresholds presented good freeze-thaw resistance in laboratory studies. This study evaluated the freeze-thaw resistance of several "marginal" air void mixes, with two different types of air-entraining admixtures—a Vinsol resin and a synthetic admixture. This study used rapid cycles of freezing and thawing in plain water, in the absence of deicing salts. For the specific materials and concrete mixture proportions used in this project, the marginal air mixes presented an adequate freeze-thaw performance when Vinsol resin based air-entraining admixture was used. The synthetic admixture used in this study did not show the same good performance as the Vinsol resin admixture.
FHWA Research Library and http://www.fhwa.dot.gov/pavement/pccp/pubs/06117/

Effects of Inlet Geometry on Hydraulic Performance of Box Culverts
FHWA-HRT-06-138

Each year, the South Dakota Department of Transportation (SDDOT) designs and builds many cast-in-place (CIP), or field cast, and precast box culvert structures that allow drainage to pass under roadways. The CIP boxes typically have 30-degree-flared wingwalls, and the precast have straight wingwalls with 10.16-centimeter (cm) (4-inch) bevels on the inside edges of the wingwalls and top slab. Previous research conducted on a limited number of single barrel box culverts indicated that further research was necessary to determine (1) the effects of multiple barrel structures, (2) loss coefficients of unsubmerged outlets, and (3) the effects of 30.48-cm (12-inch) corner fillets versus 15.24-cm (6-inch) corner fillets. In order to optimize the design of both types of box culverts, it was also necessary to determine the effects of span-to-rise ratios, skewed end conditions, and optimum edge conditions on typical box culvert installations.
http://www.fhwa.dot.gov/engineering/hydraulics/pubs/06138/index.cfm

Durability of Segmental Retaining Wall Blocks: Final Report
FHWA-HRT-07-021

Segmental retaining wall (SRW) systems are commonly and successfully used in a range of applications, including highway projects. Their popularity can be attributed to a combination of reduced construction costs, versatility, aesthetic appearance, ease of installation, and an increasing number of proprietary designs available in the market. Despite these inherent advantages, there have been some reported problems with durability of SRW blocks in cold climates. The deterioration of some SRW installations in State highway agency (SHA) applications has resulted in concern over the long-term performance of SRW systems and has led to stricter specifications and, in some cases, restrictions on future use of SRW systems. In response to these concerns, a Federal

Highway Administration (FHWA)-funded research project was initiated to determine the cause and extent of SRW block distress, to identify and recommend test methods for improving durability of SRW systems, and to recommend specifications for SHAs to ensure long-term durability and performance of SRW systems in highway applications. This report summarizes the key findings of this project and provides guidance on producing durable SRW blocks to ensure long-term performance of SRW systems in highway applications.
FHWA Research Library http://www.tfhrc.gov/structur/pubs/07021/index.htm

Flexural Capacity of Fire-Damaged Prestressed Concrete Box Beams
FHWA-HRT-07-024

A gasoline tanker truck fire caused significant damage to an adjacent member box-beam bridge in southwestern Connecticut. It was unclear whether the type of damage that these box beams experienced was sufficient to critically impair the structure's ability to serve its intended purpose. Four of the beams were removed from the bridge and were loaded in flexure to failure. These tests indicated that each of the beams retained sufficient flexural capacity to resist a 1,572 kilonewton-meter (kN-m) (1,160 kip-feet (kip-ft)) moment prior to ultimate flexural failure. This value is greater than the rated ultimate flexural capacity of each beam. As such, it seems that these beams had sufficient remaining flexural capacity to serve their intended purpose in the immediate aftermath of the fire. The long-term viability of these beams is more questionable. The visual and petrographic examinations indicated that the damage to the bottom flange concrete was sufficient to allow pathways through the concrete to the depth of the bottom strands. Therefore, it is possible that fire may have acted to allow for the accelerated deterioration of the superstructure and thus decreased the long-term flexural capacity of the bridge.
http://www.tfhrc.gov/structur/pubs/07024/index.htm

Bottomless Culvert Scour Study: Phase II Laboratory Report
FHWA-HRT-07-026

Bottomless culverts are three-sided structures that use the natural channel for the bottom. These structures could be used to convey flows from one side of a highway to the other. As such, they are an environmentally attractive alternative to box, pipe, and pipe arch culvert designs. Bottomless culverts range in size from less than a meter (1.5 feet) to more than 10 meters (35 feet) in width. The failure of such a structure could have severe consequences similar to the failure of a bridge. On the other hand, since the cost of the foundation and scour countermeasures represents a significant portion of the cost of this type of structure, overdesign of these elements can add significantly to the cost of the project.

Several dozen physical modeling configurations of bottomless culverts were tested, and the resulting scour at the entrance along the foundation and outlet was measured. Predictive equations for estimating scour depth were developed and compared to MDSHA methodology. These equations will provide guidance for the design of footing depths for bottomless culverts.

The study was conducted in two phases. The first phase focused on measuring maximum scour depths at the culvert entrance and developing an analysis procedure

using methods found in the literature to approximate prescour hydraulic parameters that drive the analysis. No fixed-bed experiments were conducted in the first phase to measure actual prescour hydraulic parameters. No submerged entrance experiments were conducted in the first phase. The second phase expanded the investigation to include scour measurements at the outlet, submerged entrance scour measurements, and detailed velocity and depth measurements with a prescour fixed bed at locations where maximum scour occurred. Additional tests were conducted to evaluate the use of various measures to reduce scour including wingwalls, pile dissipators, riprap, and cross vanes.
http://www.fhwa.dot.gov/engineering/hydraulics/pubs/07026/

Junction Loss Experiments: Laboratory Report
FHWA-HRT-07-036

The current study has two objectives. The first is to evaluate Roger Kilgore's proposed procedure, which requires conducting some of the same types of tests that were run in the previous study. The new tests conducted include a wider range of parameters, such as greater plunge-height ratios and steeper pipe slopes. Previous research was limited in that it was applicable to storm drain systems located only in relatively flat areas; the research would not hold up for systems in hilly and mountainous regions of the country where steep pipe slopes are the norm.

The second and more challenging objective is to characterize the energy level in an access hole. If that can be accomplished, then the familiar culvert hydraulics analyses can be applied to the access hole that serves as the tailbox where inflow pipes enter and to the headbox for outflow pipes where the water exits. Researchers have attempted numerous analyses of particle image velocimetry (PIV) data and three-dimensional (3–D) numerical model data, with uneven results. Characterizing energy in the access hole is highly problematic because the flow is so chaotic, and arbitrary assumptions had to be made to obtain results that fall between intuitive limits.

Researchers at the FHWA lab now have investigated the more organized flow in the contracted area of the outflow pipe, using the contraction ratio as an indirect measure of the contraction loss in the flow from the access hole to the outflow pipe to backcalculate the energy loss in the access hole.
http://www.fhwa.dot.gov/engineering/hydraulics/pubs/07036/index.cfm

Corrosion Resistant Alloys for Reinforced Concrete
FHWA-HRT-07-039

The present research study is being performed jointly by Florida Atlantic University and the Florida Department of Transportation to evaluate alloys that have been identified as candidate corrosion resistant reinforcements. These include MMFX-XX™, solid stainless steels 3Cr12, 2201DX, 2205, and two 316L alloys; and two 316 stainless steel clad black bar products. Black bar reinforcement was included for comparison purposes. Testing methods included three types of short-term exposures: (1) a previously developed method that involves cyclic exposure to synthetic pore solution (SPS) with incrementally increasing chlorides and then to moist air, (2) anodic potentiostatic exposure in SPS with incrementally increasing chlorides, and (3)

potentiodynamic polarization scans in saturated $Ca(OH)_2$ at different chloride concentrations. This report details findings for the initial 3 years of this 5 year project.
FHWA Research Library and http://www.fhwa.dot.gov/bridge/pubs/07039/

Multiple Corrosion Protection Systems for Reinforced Concrete Bridge Components
FHWA-HRT-07-043

Eleven systems combining epoxy-coated reinforcement with another corrosion protection system are evaluated using the rapid macrocell, Southern Exposure, cracked beam, and linear polarization resistance tests. The systems include bars that are pretreated with zinc chromate to improve the adhesion between the epoxy and the reinforcing steel; two epoxies with improved adhesion to the reinforcing steel; one inorganic corrosion inhibitor, calcium nitrite; two organic corrosion inhibitors; an epoxy-coated bar with a primer containing microencapsulated calcium nitrite; the three epoxy-coated bars with improved adhesion combined with the corrosion inhibitor calcium nitrite; and multiple coated bars with an initial 2-mil coating of 98 percent zinc and 2 percent aluminum followed by a conventional epoxy-coating. The systems are compared with conventional uncoated reinforcement and conventional epoxy-coated reinforcement. The results presented in this report represent the findings obtained during the first half of a 5-year study that includes longer-term ASTM G 109 and field tests. In the short-term tests used to date, the epoxy-coatings evaluated provide superior corrosion protection to the reinforcing steel. The results also indicate that the bars will continue to perform well in the longer term, although the tests do not evaluate the effects of long-term reductions in the bond between the epoxy and the reinforcing steel.
FHWA Research Library and http://www.fhwa.dot.gov/bridge/pubs/07043/