Contents

Committee for the 6th International Bridge Engineering Conference ........................................... 2
Sponsors, Cosponsors, Financial Contributors, and Supporting Organizations .................................. 3
Conference Welcomes .................................................................................................................. 5
  Mary Lou Ralls, Conference Chair .......................................................................................... 5
  John Horsley, American Association of State Highway and Transportation Officials .................. 5
  J. Richard Capka, Federal Highway Administration .............................................................. 6
General Information ...................................................................................................................... 7
  Conference Venue .................................................................................................................. 8
  Speaker Ready Room ............................................................................................................ 8
  Spouse and Guest Hospitality Room ..................................................................................... 8
  Registration Desk Hours ....................................................................................................... 8
  Transportation Information .................................................................................................... 8
  Dress ................................................................................................................................... 8
  Name Badges and Tickets ..................................................................................................... 8
  Disclaimer ............................................................................................................................. 8
Conference Background and History ............................................................................................. 9
Program ..................................................................................................................................... 11
  Sunday, July 17 ...................................................................................................................... 12
  Monday, July 18 .................................................................................................................... 13
  Tuesday, July 19 .................................................................................................................... 16
  Wednesday, July 20 .............................................................................................................. 19
Professional Development Hours Form ......................................................................................... 21
Abstracts of Papers ...................................................................................................................... 23
About the National Academies ....................................................................................................... 72
Transportation Research Record: Journal of the Transportation Research Board, Inside CD 11-S ................................................................. Inside back cover
Program at a Glance .................................................................................................................. Back cover
Committee for the 6th International Bridge Engineering Conference

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Timothy J. McGrath, Principal, Simpson Gumpertz & Heger, Inc.
Andrzej S. Nowak, Professor, University of Nebraska, Lincoln
Mark L. Reno, Senior Engineer, Quincy Engineering, Inc.
James E. Roberts, Consulting Bridge Engineer
Mohsen A. Shahawy, President and CEO, SDR Engineering Consultants, Inc.
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Sponsors, Cosponsors, Financial Contributors, and Supporting Organizations

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American Council of Engineering Companies of Massachusetts
American Society for Nondestructive Testing
Boston Society of Civil Engineers Section, ASCE
The Engineering Center in Boston
Engineers’ Society of Western Pennsylvania
International Association for Bridge Maintenance and Safety
The International Association of Foundation Drilling
National Steel Bridge Alliance
Nordic Road Association
Portland Cement Association
Post-Tensioning Institute
Precast/Prestressed Concrete Institute
Structural Engineering Institute of the American Society of Civil Engineers
The Latest Advances Are Here

It’s a pleasure to welcome you to the 6th International Bridge Engineering Conference, in the delightful city of Boston this summer!

Held every 5 years, the conference is sponsored by the Transportation Research Board and the Federal Highway Administration to bring you the latest advancements in bridge research and technologies. As you know, the bridge community is facing significant challenges—the average age of our bridges nationally is 42 years, nearing the end of their design life, and one-quarter of the nation’s 590,000 publicly owned bridges are classified as below standard. We must use the latest technologies to address these challenges. As apparent from this year’s conference theme—Reliability, Security, and Sustainability in Bridge Engineering—you will be hearing presentations that address many of the current issues of interest and concern to bridge owners, engineers, academia, consultants, and industry partners.

Poster presentations highlight the icebreaker reception on Sunday evening and continue through Tuesday to give you the latest information on security, innovative equipment to install bridges in hours, and unique bridge projects. You’ll have the opportunity to interact with those who are most knowledgeable about the latest developments in these technologies.

Each morning begins with plenary presentations that highlight the day’s technical session topics. Topics include accelerated construction, load and resistance factor design and load and resistance factor rating, long-term performance, aesthetics, and innovations in materials and methods. Again, you will have the opportunity to interact with those in-the-know about these technologies. Monday will conclude with a harbor tour of significant local bridges.

As you can see, the three days of the conference provide the opportunity to learn about many of the latest advances in bridge research and technologies. Take notes, talk with the experts, and return with the knowledge that you need to implement these advances in your state, province, or country.

—Mary Lou Ralls, Chair, 6th International Bridge Engineering Conference

Project Delivery and Innovation

Transportation officials in today’s climate—and tomorrow’s—face ever greater challenges in project delivery. “Faster! Better! Longer Lasting!” could well be the motto hanging over every bridge engineer’s desk. Faster reflects the unwillingness of the motoring public to be delayed or detoured during lengthy projects, regardless of the complexity. Better includes the need to develop transportation projects that are sensitive to the environment and the values of the community. Longer lasting involves the ongoing search for new materials, designs, and construction techniques that outperform the old, so that we can respond to our customers’ demands to “get in, get out, and stay out.”

Project delivery is a key focus for the American Association of State Highway and Transportation Officials (AASHTO) through the work of the Project Delivery Council of the Standing Committee on Highways, the Subcommittee on Bridges and Structures, and the Technology Implementation Group. Our focus runs the gamut from concept planning through preliminary engineering and environmental review, to innovative contracting and final design. In each area, there are valuable lessons to learn from each other, not just in the United States but from nations around the world, as evidenced from the International Scanning Tours that...
AASHTO cosponsors with the Federal Highway Administration. Recent tours have examined alternative contracting strategies, prefabricated bridges, context-sensitive design, and prevention of bridge scour. The prefabricated bridges tour identified construction equipment in the Netherlands and Belgium that installs bridges in hours rather than the weeks or months typically required for bridge construction in the United States, and the bridge scour tour identified techniques in Germany, New Zealand, and the United Kingdom that could save some $53 million if applied in the United States.

This is a time of great change in bridge design and construction as the industry shifts to the load and resistance factor design methodology. AASHTO is working closely with the Federal Highway Administration to advance this technology through training, design examples, and other support, with the aim of nationwide implementation by 2007. Still more advances await discovery, and we are pleased that the pending legislation reauthorizing federal highway and transit programs would fund a new bridge research program.

The 6th International Bridge Engineering Conference provides an opportunity for peer exchange, to learn from and share with all the technical experts in bridge construction from around the world.

—John Horsley, Executive Director, American Association of State Highway and Transportation Officials

High Levels of Information

With the rapid explosion in the development and deployment of new technologies, and with the increasing demands on our highways, transportation professionals face an increasingly difficult time keeping up with the latest in information, innovation, and approaches for ensuring an efficient and safe highway transportation system. That is why the Federal Highway Administration has been a strong supporter of and continues to cosponsor the Transportation Research Board’s International Bridge Engineering Conference.

This year’s conference promises to deliver an unusually high level of information and to highlight many important case studies in critical areas of bridge engineering, including design, construction, maintenance, repair, rehabilitation, replacement, management, security, and safety of highway and railroad bridges. This program presents a valuable opportunity for all bridge engineering professionals, whether affiliated with a governmental agency, consulting firm, industry, or academia.

—J. Richard Capka, Deputy Administrator, Federal Highway Administration
General Information and Conference Background and History
Transportation Information

A limited amount of underground valet parking is available to hotel guests at a charge. The prevailing overnight parking fee is $32. Self-park commercial parking is available across the street at a lower rate.

A taxi from Logan Airport to the Westin Copley Place Boston costs approximately $30; a taxi from the Westin back to Logan costs approximately $25. The distance is only 3 miles, but the tunnels have toll fees, and the toll is higher leaving Logan.

Back Bay Coach is a hotel shuttle service that charges $11 to $13 each way to all of the Back Bay hotels. The shuttle service leaves Logan every 15 minutes. Call 617-966-7870 or 888-BACK BAY.

Attendees can ride the subway from Logan to the Westin for $1.25. The Blue Line leaves Logan every 5 to 10 minutes; switch to the Orange Line and get off at Back Bay Station. The Westin is across the street from the Back Bay Station.

Dress

Business or business casual is appropriate for the reception, sessions, and lunches. Casual is appropriate for the dinner and cruise.

Name Badges and Tickets

Conference participants are expected to wear name badges during the reception, sessions, and lunches. Reservation tickets for the dinner cruise are provided at check-in, at the registration desk. At ship boarding, an official company ticket will be presented as a boarding pass to all listed on the ship’s roster.

Disclaimer

All information disclosed in the conference final program was correct at the time of printing. The conference committee reserves the right to alter the conference program in unforeseen circumstances. Information submitted after the time of printing could not be included in the final program.
Reliability, Security, and Sustainability in Bridge Engineering is the theme for the 6th International Bridge Engineering Conference (IBEC), Westin Copley Place Boston, July 17–20, 2005. The conference, organized and conducted by the Transportation Research Board (TRB), brings attendees up to date on the latest bridge research results and technical information on planning, design, construction, maintenance, repair, rehabilitation, replacement, management, security, and safety of vehicular and railroad bridges. The conference focuses on problems and solutions of interest to bridge engineers and administrators of highway, railroad, and transit agencies. Research results from the American Association of State Highway and Transportation Officials (AASHTO)–sponsored National Cooperative Highway Research Program (NCHRP) bridge studies, as well as federal, state, and other research agencies’ programs, will be highlighted.

The previous five conferences in this series have attracted bridge engineers from many countries. The earlier conferences were held in St. Louis, Missouri, in September 1978; Minneapolis, Minnesota, in September 1984; Denver, Colorado, in March 1991; San Francisco, California, in August 1995; and Tampa, Florida, in April 2000. All of these conferences were well attended by bridge engineering executives, practicing bridge engineers, researchers, and the bridge construction industry. Much has transpired since the 2000 conference.

The 6th IBEC is cosponsored by the Federal Highway Administration (FHWA) and TRB.

Background
At an average age of 42 years, many of the bridges in the United States are in need of rehabilitation or replacement, and many more are approaching the end of their service life. Before the adoption of the AASHTO load and resistance factor design (LRFD), the design life for bridges was typically 50 years; the LRFD specification requires a 75-year design life. The nation has 590,000 bridges, including 120,000 bridge-class culverts, and one-quarter of these bridges are classified as structurally deficient or functionally obsolete according to FHWA criteria. Compounding the problems related to an aging infrastructure are the increasing construction activities leading to traffic congestion and delays. These unpleasant and unpredictable interruptions are taxing the public’s patience, especially when the interruptions interfere with their ability to plan their travel time reliably. Furthermore, businesses that are relying more on the “just in time” product or service delivery are taking their business elsewhere because they cannot depend on the transportation facilities to accommodate their demands. Bridge systems are needed that reduce onsite construction time, while ensuring longer-lasting facilities. With available funding that covers only a fraction of the current rehabilitation and replacement needs, innovative methods and materials are urgently needed to more effectively address the public’s demand to “get in, get out, and stay out.”

The public is also expressing more interest in the appearance of bridges, requesting early and continuous involvement to build bridges that complement adjacent surroundings. An additional design priority is the implementation of LRFD, with the 2007 date for its full use approaching. Load and resistance factor rating tools are also now available, and these may improve our knowledge of the performance of the nation’s network of bridges.

In addition, infrastructure security is a heightened concern. Bridges and tunnels are the nodes of the highway infrastructure and must maintain function to allow the flow of people, goods, and services. Cost-effective countermeasures, including changes
Conference Background and History (continued)

Conference Papers
Conference proceedings are being published in English on CD-ROM as *Transportation Research Record: Journal of the Transportation Research Board CD 11-S*, and are available at the conference. The papers have been peer reviewed in accordance with TRB standards, which require review by at least three technical experts and approval for publication by the paper review coordinator for the subject area and by TRB staff.
6TH INTERNATIONAL BRIDGE ENGINEERING CONFERENCE

Program
SUNDAY, JULY 17
4:30 P.M.—6:30 P.M.

Projects Showcase Poster Session
(Light reception included)
Stephen F. Maher, Transportation Research Board, presiding

Replacement of the Troup Howell Bridge, Rochester, New York
Edwin Anthony and Stephen Percassi, Jr., Erdman, Anthony, and Associates, Inc.; Howard Ressel, New York State Department of Transportation

Design of the Dagu Bridge, Tianjin, China
Man-Chung Tang, Tom Ho, and Cheng Xu, T.Y. Lin International

Tremie Concrete Placement for Large Cofferdam Seals at Brightman Street Bridge, Fall River–Somerset, Massachusetts
(presentation without paper)
William Konicki, Simpson Gumpertz & Heger, Inc.; Lisa Grebner, Modern Continental; Paul L. Kelley, Simpson Gumpertz & Heger, Inc.

Transportation Security Administration’s Infrastructure Security Assessment Tools
(presentation without paper)
James Orgill, Transportation Security Administration

Collaborating for Improved Transportation Infrastructure Security (presentation without paper)
Leni Oman, Washington State Department of Transportation

TRB Cooperative Research Programs Security Summary (presentation without paper)
Stephan A. Parker, Transportation Research Board

Making Transportation Tunnels Safe and Secure (presentation without paper)
Irfan Oncu, Parsons Brinckerhoff, Inc.

Insights into Risk Management for Intermodal Transportation Infrastructure (presentation without paper)
Michael Smith, Science Applications International Corporation; Stephen C. Lockwood, Parsons Brinckerhoff, Inc.

Bridging the Future Now (presentation without paper)
Bill Halsband and Patrick van Seumeren, Mammoet

Moving of Bridges: Crossing Obstacles over Land and Water (presentation without paper)
Dirk Verwimp and Steven Sarens, Sarens Group

Hydraulic Modular Platform Transporters Used for the I-10 Bridge Restoration, Pensacola, Florida, September 17–October 8, 2004 (presentation without paper)
Will Smith, Barnhart Crane & Rigging

Bridges to Prosperity (presentation without paper)
Chris Rollins, Bridges to Prosperity
**MONDAY, JULY 18**

8:30 A.M.–9:30 A.M.

**Opening General Session**
Mary Lou Ralls, Ralls Newman, LLC, presiding

**Welcome from the Conference Chair**
Mary Lou Ralls, Ralls Newman, LLC

**Conference Welcome from the Massachusetts Executive Office of Transportation**
John Cogliano, Massachusetts Executive Office of Transportation (invited)

**Conference Welcome from the American Association of State Highway and Transportation Officials**
John C. Horsley, AASHTO

**Conference Welcome from the Federal Highway Administration, U.S. Department of Transportation**
J. Richard Capka, FHWA

9:30 A.M.–10:00 A.M.

Coffee and Tea Break

10:00 A.M.–11:30 A.M.

**Plenary Session 1: Security, Reliability, and Sustainability**
Alexander K. Bardow, Massachusetts Highway Department, presiding

**Recommendations for Blast Design and Retrofit of Typical Highway Bridges**

**Past, Present, and Future of Load and Resistance Factor Design: AASHTO LRFD Bridge Design Specifications**
John M. Kulicki, Modjeski and Masters, Inc.

**Self-Propelled Modular Transporters for Bridge Movements in Europe and the United States**

11:45 A.M.–1:15 P.M.

**Monday Lunch with Speaker**
Benjamin J. Biller, HNTB Corporation, presiding

**Design of the Leonard P. Zakim Bunker Hill Bridge, Boston, Massachusetts**
(presentation without paper)
Ray McCabe, HNTB Corporation

1:30 P.M.–3:00 P.M.

**Technical Session 1: Advances in Load and Resistance Factor Design Research**
Catherine French, University of Minnesota, presiding

**Simplified Live Load Distribution Factor Equations for Bridge Design**
Jay A. Puckett, University of Wyoming; X. S. Huo and M. D. Patrick, Tennessee Technological University; M. C. Jablin, BridgeTech, Inc.; D. Mertz, University of Delaware; and M. D. Peavy, BridgeTech, Inc.

**System Reliability Models for Girder Bridges**
Andrzej S. Nowak, University of Nebraska, Lincoln; Artur A. Czarnecki, University of Michigan

**NCHRP Project 12-56, Application of Load and Resistance Factor Design Specifications to High-Strength Structural Concrete: Shear Provisions**
Daniel A. Kuchma, Kang Su Kim, and Neil M. Hawkins, University of Illinois at Urbana–Champaign

**Live Load Distribution Widths for Reinforced Concrete Box Sections**
Timothy J. McGrath, Atis A. Liepins, and Jesse L. Beaver, Simpson Gumpertz & Heger, Inc.
Program (continued)

MONDAY, JULY 18 (continued)

1:30 P.M.–3:00 P.M.

Technical Session 2: Bridge Management Systems
Andrzej Ajdukiewicz, Silesian University of Technology, presiding

Maintenance Planning of Deteriorating Bridges by Using Multiobjective Optimization
Min Liu and Dan M. Frangopol, University of Colorado, Boulder

Sustainable Bridges: Research Project of the European Community
Jan Bien and Małgorzata Gladysz, Wrocław University of Technology

Modeling Bridge Deck Deterioration by Using Decision Tree Algorithms
George Morcous, University of Nebraska, Lincoln

Summary of AASHTO and FHWA International Scanning Tour for Bridge Preservation and Maintenance
Jay A. Puckett, University of Wyoming; George Hearn, University of Colorado, Boulder

3:00 P.M.–3:30 P.M.

Coffee and Tea Break

3:30 P.M.–5:00 P.M.

Technical Session 4: Advances in Load and Resistance Factor Design Practice
Man-Chung Tang, T.Y. Lin International, presiding

The New Hathaway Bridge, Panama City, Florida: Segmental Concrete Bridge Project Designed Under AASHTO Load and Resistance Factor Design Specifications
Lex Collins, HNTB Corporation

System Factors for Highway Bridge Superstructures
Michel Ghosn, City College of the City University of New York

Unified Resistance Equations for Design of Curved and Tangent Steel Bridge I-Girders
Donald W. White, Georgia Institute of Technology; Michael A. Grubb, Bridge Software Development International, Ltd.

NCHRP 12-61, Simplified Shear Design of Structural Concrete Members
Daniel A. Kuchma, Kang Su Kim, Sang Ho Kim, Shaoyun Sun, and Neil M. Hawkins, University of Illinois at Urbana–Champaign

Designing Bridges for Quick Construction in Urban Areas (presentation without paper)
William J. Rohleder, Figg Bridge Engineers, Inc.

Broadway Bridge Case Study: Bridge Deck Application of Fiber-Reinforced Polymer
Matt Sams, Martin Marietta

1:30 P.M.–3:00 P.M.

Technical Session 3: Prefabricated Bridges
Joost Walraven, Delft University of Technology, presiding

Texas's Totally Prefabricated Bridge Superstructures
Gregg A. Freeby, Texas Department of Transportation

Design and Construction of a Bridge with a Full-Width, Full-Depth Precast Concrete Deck Slab on Steel Girders (presentation without paper)
N. David LeBlanc, Totten Sims Hubicki Associates; Alex Harrison, CH2M Hill
3:30 P.M.–5:00 P.M.

**Technical Session 6: Accelerated Construction**
Barney T. Martin, Modjeski and Masters, Inc., presiding

- **Hyperbuild! Rapid Bridge Construction Techniques in New Jersey**
  Harry A. Capers, Jr., New Jersey Department of Transportation

- **Rapid Bridge Construction in Europe Using Self-Propelled Modular Transporters**
  (presentation without paper)
  Bill Halsband and Patrick van Seumeren, Mammoet; Dirk Verwimp and Steven Sarens, Sarens Group

- **Use of Precast Concrete Members for Accelerated Bridge Construction in Washington State**
  Bijan Khaleghi, Washington State Department of Transportation

- **Simplified Continuity Details for Short- and Medium-Span Composite Steel Girder Bridges**
  Edward P. Wasserman, Tennessee Department of Transportation
TUESDAY, JULY 19
8:30 A.M.–10:00 A.M.

Plenary Session 2: Security, Reliability, and Sustainability
Ian M. Friedland, Federal Highway Administration, presiding

New Japanese Technological Contributions in Earthquake Engineering
Eiichi Watanabe and Hiroyasu Iemura, Kyoto University; Hidesada Kanaji and Tsutomu Nishioka, Hanshin Expressway Public Corporation; Takumi Ohyama, Shimizu Corporation

New Materials Development for Bridges in Europe (presentation without paper)
Joost Walraven, Delft University of Technology

Implementation of High-Performance Materials: When Will They Become Standard?
Louis N. Triandafilou, Federal Highway Administration

10:00 A.M.–10:30 A.M.
Coffee and Tea Break

10:30 A.M.–NOON

Technical Session 7: Seismic Design and Evaluation
Andrzej S. Nowak, University of Nebraska, Lincoln, presiding

Life-Cycle Cost Evaluation of Multiple Bridges in Road Network Considering Seismic Risk
Hitoshi Furuta, Kazuhiro Koyama, and Miki Oi, Kansai University; Hiroyuki Sugimoto, Hokkai-Gakuen University

Performance-Based Seismic Design of New Tacoma Narrows Suspension Bridge, Washington
Michael H. Jones and Semyon Treyger, HNTB Corporation

Enhancing Performance-Based Bridge Seismic Design with Seismic Performance Testing
Jia-Dzwan (Jerry) Shen, Lendis Corp. and FHWA Turner-Fairbank Highway Research Center; W. Phillip Yen and John O’Fallon, Federal Highway Administration

Resistance of a Portal Frame Bridge Pier Under Earthquake Waves from Arbitrary Directions
Hiromu Okamoto, Kazutoshi Nagata, and Kunitomo Sugiura, Kyoto University; Toshihiko Naganuma, Hanshin Expressway Public Corporation; Eiichi Watanabe, Kyoto University

10:30 A.M.–NOON

Technical Session 8: Bridge Durability
Benjamin J. Biller, HNTB Corporation, presiding

Overcoming Barriers to Durable Steel Bridge Systems (presentation without paper)
John W. Fisher, Lehigh University

Improving the Durability of Posttensioned Bridges (presentation without paper)
Thomas R. Cooper, Parsons Brinckerhoff Quade & Douglas, Inc.

Time-Dependent Behavior of a Concrete Integral Abutment Bridge
Jimin Huang, Carol K. Shield, and Catherine French, University of Minnesota

Prediction Model for Deterioration of Concrete Bridge Stocks
G. C. M. Gaal, Lloyd’s Register; Joost Walraven, Delft University of Technology
10:30 A.M.–NOON

Technical Session 9: Innovative Materials and Methods
Mohsen A. Shahawy, SDR Engineering Consultants Inc., presiding
Bridge with Composite Concrete Deck and Glued Laminated Girders Strengthened with Fiber-Reinforced Polymer: Design, Construction, and Load Testing
William G. Davids, Habib J. Dagher, and Olivia Sanchez, University of Maine; Craig Weaver, T.Y. Lin International
Use of Adhesives to Retrofit Out-of-Plane Distortion at Connection Plates
Yuying Hu, Carol K. Shield, and Robert J. Dexter, University of Minnesota
Self-Consolidating Concrete for Repair of Bridges
Maria Kaszynska, Technical University of Szczecin
Strengthening Steel Girder Bridges with Carbon Fiber-Reinforced Polymer Plates
Terry J. Wipf, Brent M. Phares, and F. Wayne Klaiber, Iowa State University; A. H. Al Saidy, Sultan Qaboos University; Yoon-Si Lee, Iowa State University

NOON–1:15 P.M.

Tuesday Lunch with Speaker
Alexander K. Bardow, Massachusetts Highway Department, presiding
Form, Function, and Bridge Aesthetics (presentation without paper)
Man-Chung Tang, T.Y. Lin International

1:30 P.M.–3:00 P.M.

Technical Session 10: Seismic Design and Retrofit
Emmanuel A. Maragakis, University of Nevada, Reno, presiding
Design of California’s New San Francisco–Oakland Bay Self-Anchored Suspension Bridge
Marwan Nader, Rafael Manzanarez, and Man-Chung Tang, T.Y. Lin International
Seismic Design of Highway Bridges in the United States: Design Specification Dilemma (presentation without paper)
Glenn R. Smith, Federal Highway Administration
Design of Skyway Structures for California’s San Francisco–Oakland Bay Bridge
Sajid Abbas and Rafael Manzanarez, T.Y. Lin International
Seismic Retrofit Design of Long-Span Bridges of Metropolitan Expressways in Tokyo
Yozo Fujino, University of Tokyo; Hiroshi Kikkawa, Kenji Namikawa, and Takao Mizoguchi, Metropolitan Expressways Public Corporation

1:30 P.M.–3:00 P.M.

Technical Session 11: Bridge Health Monitoring
James E. Roberts, Consultant, presiding
Continuous Monitoring for the Management, Safety, and Reliability of Connecticut’s Bridge Infrastructure
Paramita Mondal and John T. DeWolf; University of Connecticut; Paul D’Artilio and Eric Feldblum, Connecticut Department of Transportation
Virtual Wireless Infrastructure Evaluation System
Daniel N. Farhey, University of Dayton
TUESDAY, JULY 19 (continued)

Technical Session 11, 1:30 P.M.–3:00 P.M. (continued)

Bridge Inspections Using Electronic Handheld Data Collectors
Kevin Hahn-Keith, Parsons Brinckerhoff, Inc.; James L. Stump, Pennsylvania Turnpike Commission; David Charters, Parsons Brinckerhoff, Inc.; Lance Andrews, Michael Baker Corporation

Thermally Induced Superstructure Stresses in Prestressed Girder Integral Abutment Bridges
Michael Paul, Wilbur Smith Associates; Jeffrey A. Laman and Daniel G. Linzell, Pennsylvania State University

1:30 P.M.–3:00 P.M.

Technical Session 12: Innovative Methods I
Mark L. Reno, Quincy Engineering, presiding

In-Field Performance of the Modified Beam-in-Slab Bridge: A Replacement Option for Low-Volume Bridges
T. F. Konda, F. Wayne Klaiber, and Terry J. Wipf, Iowa State University

Reconstruction of North Avenue Bridge over the Chicago River, Chicago, Illinois
Thomas Powers, Chicago Department of Transportation; Kenneth Price, Eddie He, Craig Hetue, and Murat Aydemir, HNTB Corporation

Extending the Span of H-Beam Bridges by Steel Plate Prestressing (presentation without paper)
Masahiro Sakano, Kansai University; Hironori Namiki, Kyobashi Maintech; Tomoki Sakata, Kobe University

Cooper River Bridge Design–Build Project, Charleston, South Carolina: Successes and Lessons Learned (presentation without paper)
Charles Dwyer, South Carolina Department of Transportation; Kenneth Pierce, HDR, Inc.

3:00 P.M.–3:30 P.M.

Coffee and Tea Break

3:30 P.M.–5:00 P.M.

Technical Session 13: Extreme Events
James D. Cooper, Consultant, presiding

Quantifying Barge Collision Loads for Bridge Pier Design and Vulnerability Assessment
Gary Consolazio, David R. Cowan, and Long H. Bui, University of Florida

Load Combination Factors for Extreme Events
Mark McClelland, Texas Department of Transportation

Vessel Impact Risk Assessment by the Texas Department of Transportation
Beatrice E. Hunt, Hardesty & Hanover, LLP

Bridge Collapse Detection System in Texas
James Justin Mercier, Eligio Alvarez, Juan Marfil, Mark J. Bloschock, and Ronald D. Medlock, Texas Department of Transportation

3:30 P.M.–5:00 P.M.

Technical Session 14: Scour and Maintenance
Timothy J. McGrath, Simpson Gumpertz & Heger, Inc., presiding

The SRICOS–Erosion Function Apparatus Method: An Overview of Its Measurement of Scour Depth
Jean-Louis Briaud and Hamn-Ching Chen, Texas A&M University

Scour Monitoring Programs for Bridge Health
Beatrice E. Hunt, Hardesty & Hanover, LLP

Comprehensive Approach for Riprap Design, Installation, and Maintenance
L. W. Zevenbergen, P. F. Lagasse, and P. E. Clopper, Ayres Associates
WEDNESDAY, JULY 20
8:30 A.M.–10:00 A.M.

**Plenary Session 3: Security, Reliability, and Sustainability**
David B. Beal, Transportation Research Board, presiding

**Load and Resistance Factor Rating for More Uniform Safety in Bridge Load Ratings and Postings**
Bala Sivakumar, Lichtenstein Consulting Engineers

**Experience in the United States with Fiber-Reinforced Polymer Composite Bridge Decks and Superstructures**
Jerome S. O’Connor, State University of New York, Buffalo; John M. Hooks

**The ABCDs of Bridge Building: Affordable, Beautiful, Constructable, and Durable**
John E. Breen, University of Texas, Austin

10:00 A.M.–10:30 A.M.

Coffee and Tea Break

10:30 A.M.–NOON

**Technical Session 16: Bridge Evaluation and Load Rating**

**Load and Resistance Factor Rating Using Site-Specific Data**
Baidurya Bhattacharya, University of Delaware; Degang Li, Lawrie & Associates LLC; and Michael Chajes, University of Delaware

**Field Test and Finite Element Analysis of Isotropic Bridge Deck**
David Ferrand, University of Michigan; Andrzej S. Nowak, University of Nebraska, Lincoln; Maria M. Szerszen, University of Michigan

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TUESDAY, JULY 19 (continued)

Technical Session 14, 3:30 P.M.–5:00 P.M. (continued)

**Monitoring and Mitigation of Stay-Cable Vibrations on the Fred Hartman and Veterans Memorial Bridges, Texas**
Keith L. Ramsey, Texas Department of Transportation

3:30 P.M.–5:00 P.M.

**Technical Session 15: Innovative Methods II**
Conn Abnee, National Steel Bridge Alliance, presiding

**Performance Evaluation of Fiber-Reinforced Polymer Composite Deck Bridges**
Vimala Shekar, Srinivas Aluri, and Hota V. S. GangaRao, West Virginia University

**Shear Buckling Strength of Trapezoidally Corrugated Steel Webs for Bridges**
Heungbae Gil, Korea Highway Corporation; Seungrok Lee, POSCO E&C; Jongwon Lee and Hakeun Lee, Korea University

**Comparison of Cable-Stayed Versus Extradosed Bridges** (presentation without paper)
Sena Kumarasena, HNTB Corporation

**Underwater Sound Pressure Levels Associated with Marine Pile Driving: Assessment of Impacts and Evaluation of Control Measures**
James A. Reyff, Illingworth & Rodkin, Inc.
Program (continued)

WEDNESDAY, JULY 20 (continued)

Technical Session 16, 10:30 A.M.–NOON (continued)
Implementation of Physical Testing for Typical Bridge Load and Superload Rating
Brent M. Phares, Terry J. Wipf, and F. Wayne Klaiber, Iowa State University; Ahmad Abu-Hawash and Scott Neubauer, Iowa Department of Transportation

Load Tests to Rate Concrete Bridges Without Plans (presentation without paper)
Harry Shenton and Jun Huang, University of Delaware

10:30 A.M.–NOON

Technical Session 17: Innovative Design and Research
Eiichi Watanabe, Kyoto University, presiding

Effective Flange Width of Composite Girders in Negative Moment Region
Methee Chiewanichakorn, Amjad J. Aref, Stuart S. Chen, Il-Sang Ahn, and Jeffrey A. Carpenter, State University of New York, Buffalo

Validation of Specification Modification by NCHRP 12-50 Process
Brian L. Goodrich, BridgeTech, Inc.; Jay A. Puckett, University of Wyoming; Mark C. Jablin, BridgeTech, Inc.

Three-Dimensional Finite Element Analysis for Traffic-Induced Vibration of a Two-Girder Steel Bridge with Elastomeric Bearings
Mitsuo Kawatani and Chul-Woo Kim, Kobe University; Naoki Kawada, Asia Civil Engineering Co., Ltd.

New Contribution to Concrete Arch Bridge Construction
Jure Radić, Zlatko Šavor, and Igor Gukov, University of Zagreb

10:30 A.M.–NOON

Technical Session 18: Bridge Aesthetics
Shrinivas Balkrishna Bhide, Portland Cement Association, presiding

Helix Pedestrian Bridge
David K. McMullen, KPFF Consulting Engineers

Main Street Replacement Bridge, Columbus, Ohio
David Rogowski, Genesis Structures, Inc.; Daniel K. O’Rorke, DLZ Ohio, Inc.; Greg DeMond, HNTB Corporation

Structural and Aesthetic Considerations in the Design of Curved-Supported Pedestrian Bridges
Miguel Rosales, Rosales Gottemoeller & Associates, Inc.; Andrea Kratz, Andreas Keil, and Jorg Schlaich, Schlaich Bergermann und Partner

Design of the Main Spans for Chongqing, China, Caiyuanba Bridge
Man-Chung Tang, John Sun, and Marwan Nader, T.Y. Lin International
Many licensure and certification agencies require the demonstration of continuing professional competency. Your attendance at this meeting entitles you to earn Professional Development Hour (PDH) units. This form is for your use in maintaining a record of the PDH units you have earned at this meeting. Complete this form and retain it. **Please do not return it to TRB.**

We recommend that you save this entire Final Program for your records should the licensure or certification agency request information from you. Reporting is done on an honor basis, and members are responsible for maintaining their own records.

The table shows the PDH units that can be earned for the continuing education activities included in the Transportation Research Board **6th International Bridge Engineering Conference held in Boston, Massachusetts, July 17–20, 2005.**

Mark R. Norman  
Director, Technical Activities

<table>
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<td>SUNDAY</td>
<td>4:30 – 6:30 P.M.</td>
<td>Projects Showcase Poster Session</td>
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<td>10:00 – 11:30 A.M.</td>
<td>Plenary Session 1</td>
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<td>1:30 – 3:00 P.M.</td>
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**Subtotal PDH Units:**

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Name __________________________    Date ________________
Sunday, July 17, 4:30 p.m.–6:30 p.m., Projects Showcase Poster Session

Replacement of the Troup Howell Bridge, Rochester, New York
Edwin S. Anthony and Stephen J. Percassi, Jr., Erdman Anthony and Associates, Inc.; and Howard Ressel, New York State Department of Transportation

The Troup Howell Bridge carries I-490 over the Genesee River and several streets in downtown Rochester, New York. When deterioration necessitated a new bridge, engineers sought a context-sensitive replacement. The bridge’s location affords opportunities for aesthetic enrichment: it is set in the foreground of the city skyline, which includes architecturally noteworthy buildings that house mainstays to international businesses such as Eastman Kodak, Xerox, and Bausch & Lomb. The project design team included the New York State Department of Transportation, Erdman Anthony and Associates, Inc., and H2L2 Architects. An aesthetics committee consisting of local government officials, adjoining neighborhood representatives, American Institute of Architects members, and artists provided feedback throughout the design process, which ensured that the solution fit the environment. Many of the committee preferences were implemented in the final design. The centerpiece of the new eight-span bridge will be a 132-m (433-ft) long through arch span crossing the river. The arch will have three steel box ribs, Vierendeel-style braces, and a fanned hanger arrangement supporting the deck system. Aesthetic enhancements were achieved in many areas of the main span design. Arch anchorages were set back from the riverbanks to allow shoreline promenades beneath the bridge. Accent lighting and sculpted floor beam shapes were provided to enhance visual interest from the promenades. Because of the through arch design and the high volume of daily traffic over the bridge, significant challenges were addressed during construction. Structural design details were developed to allow for staged construction, which permitted the bridge to remain open throughout construction.

Design of the Dagu Bridge, Tianjin, China
Man-Chung Tang, Tom Ho, and Cheng Xu, T. Y. Lin International

The city of Tianjin, China, is currently implementing a Haihe River area redevelopment plan to revitalize its downtown area. The Dagu Bridge is located in the center of the redevelopment area and is one of the first projects in this redevelopment plan. The city of Tianjin asked for a bridge that could be a new symbol of the city. The final design is a double arch that complements the surroundings. One of the arches is larger than the other; therefore, the bridge is called the Sun and Moon Bridges. The site poses several severe geometric restrictions with respect to construction depth, maximum allowable vertical slope, and navigation requirements. The final bridge scheme satisfies all those restrictions.
Tremie Concrete Placement for Large Cofferdam Seals at Brightman Street Bridge, Fall River–Somerset, Massachusetts
(presentation without paper)
William P. Konicki, Simpson Gumpertz and Heger, Inc.; Lisa Grebner, Modern Continental; and Paul L. Kelley, Simpson Gumpertz and Heger, Inc.

The development and use of an innovative tremie concrete mixture are described. The concrete was designed to provide extended slump retention and workability, which enabled efficient placement and underwater flow during two massive, continuous placements for cofferdam seals at the bascule piers of the Brightman Street Bridge between Fall River and Somerset, Massachusetts. The 16-ft-thick, 7,200-yd³ concrete tremie seals were each placed in a single, continuous placement under 50 to 55 ft of water. The concrete was produced by a local ready-mix plant, delivered in trucks, and placed by pumping from the riverbank to a series of fixed tremie pipes in the cofferdam. Concrete haul distances and the placement duration and sequencing required concrete with satisfactory workability and flow characteristics for up to 7 h after initial batching. The development of the mix is traced, including a brief review of the literature on the topic and a summary of trial mixes that led to the final product design. The results of laboratory testing of the concrete properties are summarized, including slump, slump flow, slump loss, initial and final set, underwater flow, washout characteristics, and compressive strength. The results of a mock-up placement within a sheet pile cell are presented. The methods and sequence of the actual placements, as well as the field monitoring results, are detailed and discussed. Finally, the results of quality control testing of the production concrete during the placement are compared with the laboratory and mock-up test results, and lessons learned are summarized.

Transportation Security Administration’s Infrastructure Security Assessment Tools (presentation without paper)
James Orgill, Transportation Security Administration

The Transportation Security Administration (TSA), U.S. Department of Homeland Security, is best known for its progress in improving air transportation security. TSA is also responsible for protecting U.S. highway systems from threat exploitation to promote the free flow of commerce. High-profile, symbolic, or nationally critical transportation assets are perceived to be the priority for government programs, but programs also are available to assist the security posture of less-prominent transportation assets. TSA, with cooperation from FHWA, AASHTO, and other industry experts, has created self-assessment modules for highway bridges, tunnels, and operations centers. These web-based tools were designed to be easy to use at no external cost to the user while providing a uniform approach to the assessment process. The tools are designed to evaluate corporate security and asset-specific practices and protocols and provide stakeholders with a threat-based assessment method to analyze organizational security processes to improve their security posture. TSA will leverage the data to analyze the common baseline mitigation approaches and best practices being used by various assets. Additionally, on the basis of input from experts in the field, TSA has incorporated a vulnerability rating section that helps users understand whether they are within accepted practices and a countermeasure listing to help them understand potential mitigation strategies. This self-assessment tool, in conjunction with other TSA tools, will improve the nation’s posture against terrorist threats. Additional information is available at www.tsa.gov/risk.
Collaborating for Improved Transportation Infrastructure Security

Leni Oman, Washington State Department of Transportation

The Defense Threat Reduction Agency (DTRA) and the U.S. Army Corps of Engineers’ Engineer Research and Development Center (ERDC) have substantial experience with designing and analyzing tests to document the impact of explosives on infrastructure. In addition, DTRA has initiated development of a website that will facilitate communication between transportation organizations and those within the military and homeland defense agencies responsible for national security. Through this site, information such as the bridge vulnerability assessment and tools such as the Consequence Assessment Tool Set–Joint Assessment of Catastrophic Events (CATS-JACE) model can be shared, as can information on specific projects and events. This site is intended to provide a more uniform foundation of information to work from and to improve coordination for events and ongoing activities. The Washington State Department of Transportation (DOT) is leading a Transportation Pooled Fund project titled Blast Testing of Full-Scale, Precast, Prestressed Concrete Girder Bridges. This project includes construction of full-scale models that will test the impact of explosive devices set on and below the bridge deck. Information gathered from the tests will be used to develop improved designs and retrofit and response strategies. DTRA and the U.S. Army Corps of Engineers ERDC have agreed to collaborate on this project. The website is described, and the blast testing project led by Washington State DOT is used as an example for sharing information.

TRB Cooperative Research Programs Security Summary

Stephan A. Parker, Transportation Research Board

Homeland Security Presidential Directive 5 spawned the National Incident Management System, “a consistent nationwide approach for federal, state, tribal, and local governments to work effectively and efficiently together to prepare for, prevent, respond to, and recover from domestic incidents, regardless of cause, size, or complexity.” Managers are seeking to reduce the chances that transportation vehicles and facilities are targets or instruments of terrorist attacks and to be prepared to respond to and recover from such possibilities. Since September 11, 2001, $9.5 million has been authorized for 63 security-related projects under TRB’s Cooperative Research Programs. The AASHTO Special Committee on Transportation Security and the APTA Executive Committee Security Affairs Steering Committee steer the coordinated Cooperative Research Programs Security Research. NCHRP Project Panel 20-59, Surface Transportation Security Research, provides technical oversight and project selection guidance. Thirty-four of these projects have been completed; 23 projects are in progress; and six projects have contracts pending or are in development. A summary document is at gulliver.trb.org/publications/dva/CRP-Security Research.pdf. A slide show relating these projects to the broader security activities of TRB and the National Academies is at www.trb.org/publications/dva/SecurityActivities.pdf. TRB and the National Academies have generated extensive information on these issues in recent years. The TRB Transportation System Security website (www4.trb.org/trb/homepage.nsf/web/security) brings together much of this information, including links to websites with discussions of issues, actions that can be taken, guidance, and training opportunities. The TRB Transportation System Security website is sponsored by the TRB Committee on Critical Transportation Infrastructure Protection (san-antonio.tamu.edu/trbabe40/).
Making Transportation Tunnels Safe and Secure
(presentation without paper)
Irfan Oncu, Parsons Brinckerhoff, Inc.

The approximately 550 highways and transit tunnels in the United States move thousands of people and tons of cargo daily. Many of these facilities are located at key choke points in the nation’s transportation network. Yet, as with other components of the transportation infrastructure, tunnels are susceptible to a range of hazards. Transportation tunnels face disruption from natural events such as fire, flooding, and earthquakes. While many tunnels have allowances for these natural disasters incorporated into their design and construction, older tunnels may lack some features that are commonplace today. Tunnels are also susceptible to intentional disruption from terrorist attacks. Tunnels make tempting targets because (a) they are important to the economic viability of surrounding communities, especially when they are used to transport goods; (b) there are large numbers of people present at predictable times; and (c) the enclosed environment further compounds the potential for casualties from the effects of confined blast events, collapse, and flooding. Transit tunnels, in particular, are easily reached from open, accessible environments (i.e., stations) and as a result are high-risk, high-consequence targets. In recognition of tunnels’ vital roles and their precarious exposure to harmful disruption, transportation tunnel security and safety issues have become more important in the national security dialogue. This research project aims to provide tunnel owners and operators with guidelines for (a) protecting their tunnels to minimize the damage from extreme events and (b) returning damaged tunnels to full functionality in a relatively short time.

Insights into Risk Management for Intermodal Transportation Infrastructure (presentation without paper)
Michael Smith, Science Applications International Corporation; and Stephen C. Lockwood, Parsons Brinckerhoff, Inc.

A February 2003 White House report, A National Strategy for the Physical Protection of Critical Infrastructures and Key Assets, acknowledges the many interdependencies between the nation’s intermodal transportation system and other sectors of the national and global economy. During the past 3 years, a consultant team working with TRB, AASHTO, FHWA, and several state department of transportation (DOT) sponsors developed a guide for risk assessment for critical highway infrastructure, provided transportation risk assessment workshops, and assisted several states in conducting transportation risk assessments. The consultant team, through an NCHRP panel in cooperation with AASHTO, FHWA, and the Transportation Security Administration, is currently updating and expanding the initial guide to extend it to intermodal transportation infrastructure. The objective of the current effort is to develop a guide to risk management of multimodal transportation infrastructure that will provide state DOTs and other transportation entities with a risk management methodology that can be used to conduct threat, vulnerability, and criticality assessments of their facilities and to determine cost-effective countermeasures to prevent, detect, and reduce threats to assets on a multimodal basis. An update on the status of the current effort was provided, including many lessons learned from work to date. Many unique challenges associated with risk assessment from an all-hazards perspective were summarized, including risks related to acts of terrorism against critical transportation infrastructure. Threat assessment, critical asset identification, structural and operational vulnerability assessment, cost-effective countermeasures, and rational resource allocation decisions were addressed.
Bridging the Future Now

(presentation without paper)
Bill Halsband and Patrick van Seumeren, Mammoet

Rapid bridge replacement techniques traditionally have been limited to prefabricated bridge components assembled in the field. With self-propelled modular transporters (SPMTs), contractors now have the possibility of erecting entire bridge superstructures. Using SPMTs allows for bridges to be replaced quickly and efficiently, without cranes, temporary or extensive detours, or traffic delays. Bridges can be constructed in controlled environments, which will maximize the quality of the finished bridge. Some of the unique features of SPMTs are one-person steering, regardless of bridge size; self-propelled propulsion; complete freedom of movement in any direction; flexible positioning to support strong points of a bridge; quick assembly; maximum payload of 30 tonnes per axle line; and fast mobilization on standard trailers. Considering the use of this technology early in the planning process allows for full exploitation of project cost-saving solutions.

Moving of Bridges: Crossing Obstacles over Land and Water

(presentation without paper)
Dirk Verwimp and Steven Sarens, Sarens Group

Self-propelled modular transporters (SPMTs) have been used in placing and moving all kinds of steel and concrete bridges, such as bowstrings and highway and railway bridges, throughout the world. Together with their engineers, SPMT owners manage to position a bridge in one weekend, one day, or even less time to minimize traffic disruption. By means of the hydraulic, self-propelled platform trailers, supporting structures, jacking systems, barges, and project-built solutions, bridges with a weight of up to 6,000 metric tons (6,000 tonnes) have been moved transversely and longitudinally into the right place within a millimeter of precision. Lengthy experience with extremely demanding assignments and the advanced SPMT technology ensure that time and thus money are reduced to a strict minimum for owners’ projects. A few of the projects described are (a) the Demka Bridge, replacement of an old bridge by a new one over the Amsterdam–Rhine Canal in Utrecht, the Netherlands, weight of 5,000 tonnes, use of 192 axle lines SPMT; (b) two highway bridges in Deurne, Belgium, weighing 3,000 tonnes each, and at the same time two highway bridges in Wommelgem, Belgium, weighing 1,800 tonnes each, all moved with 88- and 56-axle-line SPMTs, respectively, in only 82 h; and (c) two railway bridges, each with a weight of 900 tonnes, in Ghent, Belgium, moved with a 40-axle-line SPMT.
Hydraulic Modular Platform Transporters Used for the I-10 Bridge Restoration, Pensacola, Florida, September 17–October 8, 2004 (presentation without paper)

Will Smith, Barnhart Crane and Rigging

The I-10 Bridge in Pensacola, Florida, serves as a vital corridor for commerce, with nearly 8,000 trucks traveling the roadway daily. The bridge is composed of bridge segments, or spans, 33 × 64 ft and weighing approximately 300 tons. As a result of Hurricane Ivan’s storm surge in September 2004, 66 spans were displaced a few inches to 12 ft. Another 58 spans were completely knocked off their piers, with the eastbound span receiving the majority of the damage. In many cases the spans were also “racked” relative to the bridge. The project goal was to realign and reposition the spans that were dislocated and relocate spans from the eastbound bridge to the westbound bridge where spans were completely knocked off their piers—and to do this within 24 days. The method used to restore bridge traffic was a floating lift using two nine-line hydraulic modular platform transporters with a lift capacity of 450 tons. They were placed on a single heavy deck barge with a tending tugboat. The barge was ballasted down slightly to allow the hydraulic modular platform transporters to be placed under a bridge span transverse to the bridge. Once in position, the hydraulics of the modular platform transporters lifted the segment from the piers. The spans were lifted high enough to allow them freedom of movement and sufficient room for the existing bolts to be safely cut and sole plates replaced. The spans were then either repositioned and lowered or completely removed and relocated from the eastbound bridge to new piers on the westbound bridge. As a result of this innovative use of hydraulic modular platform transporters, the multimillion-dollar emergency project was completed in only 17 days, 7 days early. There were huge savings to commerce and the local population, and the inconvenience of a 150-mi detour was alleviated.

Bridges to Prosperity (presentation without paper)

Chris Rollins, Bridges to Prosperity

Poor regions that lack the means for sophisticated infrastructure are desperately in need of assistance in building footbridges. Training local staff and workers, facilitating the import of technology and hardware, and forging relationships with domestic government and development groups bring reliable, inexpensive access to areas that are otherwise isolated from schools, markets, and hospitals. Bridges to Prosperity (B2P) is an organization dedicated to accomplishing these tasks. Rehabilitation of a 350-year-old stone masonry arch on the Blue Nile in Ethiopia in 2001 was B2P’s first project. Building on the success of that project and several others in Nepal and Indonesia, in 2003 the group trained with Helvetas in Nepal. That program has built 1,200 hanging cable bridges derived from indigenous technology. In 2004 B2P completed five new pedestrian bridges in Ethiopia by using this Nepali technology and training method. Three are currently under construction, and local staff is nearing completion of training that will allow more independent operation. Relations are being cemented with the roads authority, and soon this system will be incorporated into the Ethiopian Roads Ministry. A new operation in Peru that will capitalize on the lessons learned in Nepal and Ethiopia is now being planned by B2P. New staff will be hired initially to foster quicker integration of the technology into Peruvian culture and building standards, and within 2 years this operation also should achieve independence. Ultimately, the goal of B2P is to facilitate the spread of affordable, reliable footbridge technology to any region of the world that needs it and thereby bring millions of people closer to services and prosperity.
Recommendations for Blast Design and Retrofit of Typical Highway Bridges


Bridge design for security has received national attention following the terrorist attacks on September 11, 2001. Intelligence gathered since then has revealed threats to bridges in California and New York. In addition, suspected terrorists have been arrested with materials such as video footage of critical structural elements and information on cutting devices needed to destroy bridge cables in their possession. As a result, various state departments of transportation (DOTs) and the federal government are looking into ways that highway infrastructure can be designed to withstand extreme loads better. A pool-funded research project supported by seven state DOTs was conducted by the University of Texas and consultants with expertise in structural response to blast loads. The purpose of this research was to develop economical and effective measures to improve bridge security. Because engineers traditionally have not needed to consider security in the design of bridges and few data exist for the response of bridges to explosive tactics used by terrorists, the primary goal of the research was to provide performance-based design guidelines that can be used by designers with little background in the design of structures for security. To accomplish this goal, parametric studies were conducted on five categories of bridges, including prestressed girder, plate girder, segmental box girder, truss, and cable-stayed configurations. This paper provides a summary of design alternatives that engineers can consider before structural hardening, and if these cost-effective techniques are insufficient in reducing the threat to an acceptable level, structural design and retrofit guidelines are proposed.

Past, Present, and Future of Load and Resistance Factor Design: AASHTO LRFD Bridge Design Specifications

John M. Kulicki, Modjeski and Masters, Inc.

A summary is provided of the 7-year process that led to the decision to develop the AASHTO LRFD Bridge Design Specifications, the objectives, and the draft review process culminating in adoption. The implementation and further development during the decade since are described, and an evolving plan to continue development of the limit states specifications for design and rating of bridges is presented. Training materials—past, current, and planned—are also reviewed.
Self-Propelled Modular Transporters for Bridge Movements in Europe and the United States

Mary Lou Ralls, Ralls Newman, LLC; Benjamin M. Tang, Federal Highway Administration; and Henry G. Russell, Henry G. Russell, Inc.

More than 150,000 publicly owned vehicular bridges in the United States are currently structurally deficient or functionally obsolete. The rate at which additional bridges become deficient or obsolete is anticipated to increase as traffic volumes and weights continue to increase and as more bridges across the country reach the end of their service life. New methods are needed to replace these substandard bridges quickly with long-lasting bridges while traffic flow is maintained. Bridge prefabrication is one method that can address this need. An international scan was conducted in April 2004 to learn how other countries are using prefabricated bridge components to minimize traffic disruption, improve work-zone safety, minimize environmental impact, improve constructability, improve quality, and lower life-cycle costs. Countries visited were Japan, the Netherlands, Belgium, Germany, and France. The top implementation recommendation from the scan team is the use of self-propelled modular transporters to move bridges into position in hours rather than the typical months required for conventional bridge construction.

Design of the Leonard P. Zakim Bunker Hill Bridge, Boston, Massachusetts

(presentation without paper)

Ray McCabe, HNTB Corporation

The $100 million Leonard P. Zakim Bunker Hill Bridge is a 1,407-ft-long, 183-ft-wide complex cable-stayed structure serving as a critical link of the Central Artery/Tunnel project in Boston, Massachusetts. It is the city’s newest landmark and was recently named for the late Lenny Zakim, a nationally recognized civil rights advocate, and the Battle of Bunker Hill, a key battle of the Revolutionary War fought in nearby Charlestown in 1775. It is most notable for its graceful structural form and state-of-the-art engineering achievements. The numerous constraints of the project site and the functional requirements governed the key aspects of the bridge. Its structural form is practically born out of the limitations of the heavily built-up project site. The main eight lanes of the I-93 roadway are cradled within two inverted Y-towers, while a secondary two-lane roadway is cantilevered to one side of the main roadway, so that the bridge is asymmetric in cross section. The main span superstructure is of steel composite design. With concrete box girder back spans, the overall layout becomes hybrid. Its cable arrangement, slender inverted Y-towers, and two-lane roadway cantilevered outside the eastern cable plane are among the bridge’s most notable features. One-of-a-kind design solutions and a wide variety of materials, including different types of steel, and normal, lightweight, and heavyweight concrete, were used to optimize the overall structure.
Simplified Live Load Distribution Factor Equations for Bridge Design

Jay A. Puckett, University of Wyoming; X. S. Huo and M. D. Patrick, Tennessee Technological University; M. C. Jablin, BridgeTech, Inc.; D. Mertz, University of Delaware; and M. D. Peavy, BridgeTech, Inc.

Live load distribution factors have been used in bridge design for decades as a simple method with which to estimate live load effects. Live load distribution is important for the design of new bridges as well as for the evaluation of existing bridges. AASHTO’s Standard Specifications for Highway Bridges and the AASHTO LRFD Bridge Design Specifications contain the most common methods in use for computing live load distribution factors. The load and resistance factor design (LRFD) equations were developed under NCHRP Project 12-26 and reflect the wide variation in modern bridge design. The limited ranges of applicability and complexity have been viewed as weaknesses of these equations since their adoption into the LRFD specifications. When bridges fall outside these ranges, the specifications mandate that a refined analysis be used. The design community would welcome a simple and reliable procedure for live load distribution. Research was done to develop simplified live load distribution factor equations for moment and shear to replace those in the current LRFD specifications. In the study, an automated process was used to compare live load distribution factors calculated by using several simplified methods to a grillage analysis. On the basis of the comparison, two methods were chosen for further investigation: Henry’s method (an adjusted uniform distribution method) and the lever rule. The lever rule was simplified to an equation form, and calibration factors were added. Both methods are based on fundamental concepts and were shown to be simple and accurate. A combination of Henry’s method and the calibrated lever rule is recommended. This method predicts both moment and shear distribution factors more accurately than the current LRFD equations, without the restrictions on ranges of applicability of the current LRFD equations. The methods outlined are limited to straight bridges.

System Reliability Models for Girder Bridges

Andrzej S. Nowak, University of Nebraska, Lincoln; and Artur A. Czarnecki, University of Michigan

System reliability can be used as an important and efficient tool in evaluation of existing structures. The traditional approach is based on the consideration of individual components rather than structures. Consequently, the acceptance criteria are formulated for the allowable stress, or ultimate moment, in a component. However, it has been observed that the load-carrying capacity of the whole structure (system) often is much larger than what is determined by the design of components. The difference can be attributed to system behavior. Quantification of this difference is the subject of system reliability. There is a need to take advantage of the available system reliability methods and advanced structural analysis methods and apply them in the design of bridges and evaluation of existing structures. The current advanced analytical procedures allow for a numerically accurate but deterministic analysis of strain and stress in a bridge. Mathematical procedures exist for the calculation of reliability for various idealized systems: parallel, series, and combinations. New developments in materials, technology, and field testing can be used to improve bridge design and evaluation. Calculation of the reliability of the whole bridge structure takes into account realistic boundary conditions and site-specific load and resistance parameters.
NCHRP Project 12-56, Application of Load and Resistance Factor Design Specifications to High-Strength Structural Concrete: Shear Provisions

Daniel A. Kuchma, Kang Su Kim, and Neil M. Hawkins, University of Illinois at Urbana–Champaign

The load and resistance factor design (LRFD) specifications in the current *AASHTO LRFD Bridge Design Specifications* limit the compressive cylinder strength to 10 ksi in relationships for calculating shear design strength, whereas concrete compressive strengths close to twice this level are commercially available in some parts of the United States. To overcome this limitation, allowing the same-size structural sections to span longer distances or carry higher loads, NCHRP has funded Project 12-56, Application of the LRFD Bridge Design Specifications to High-Strength Structural Concrete: Shear Provisions. In the experimental component of this project, 12 prestressed concrete bridge girders 52 ft long and 6 ft deep are being subjected to a uniformly distributed load until failure in shear. The primary variables in this study are concrete strength (ranging from 10 to 18 ksi), the maximum shear design stress (700 to 2,500 psi), strand anchorage details (straight, unbonded, and draped), and end reinforcement detailing (bar size, spacing, level of confinement). Key observations from experiments on the first six girders are presented.

Live Load Distribution Widths for Reinforced Concrete Box Sections

Timothy J. McGrath, Atis A. Liepins, and Jesse L. Beaver, Simpson Gumpertz & Heger, Inc.

AASHTO introduced the *AASHTO LRFD Bridge Design Specifications* in 1994. These load and resistance factor design (LRFD) specifications included new provisions for distributing live loads to reinforced concrete bridge decks that also apply to the design of reinforced concrete box sections with depths of fill less than 2 ft. Designs according to the LRFD specifications can be much more conservative than designs according to the *AASHTO Standard Specifications for Highway Bridges* and are inconsistent at a span of 15 ft. A finite element study sponsored by the Pennsylvania Department of Transportation investigated these issues and determined appropriate live load distributions for box sections subjected to live loads; the results are presented. The computer models were three-dimensional for analysis of the distribution of live load effects along the length (flow direction). Box section models had spans of 8 ft, 16 ft, and 24 ft, and all had an 8-ft rise. The models had different slab and wall thicknesses, different haunch sizes, 0-ft and 2-ft depth of fill, different support reactions, live loading at the section midlength and free edge, and variation of longitudinal stiffness. The results indicate different distribution widths for positive bending moment, negative bending moment, and shear. Distribution widths for shear forces are the narrowest, followed by those for positive bending moment. The analysis results support the following proposed distribution of axle loads to the top slabs of box sections with less than 2 ft of fill: $E (ft) = 8 (ft) + 0.12$ span (ft). Provisions are suggested to address multiple-lane loadings and distribution widths for the bottom slab.
**Maintenance Planning of Deteriorating Bridges by Using Multiobjective Optimization**

Min Liu and Dan M. Frangopol, *University of Colorado, Boulder*

Cost-effective bridge maintenance planning requires balanced consideration of long-term bridge performance and life-cycle maintenance cost. Many of the existing methodologies determine an optimal maintenance planning solution based solely on life-cycle cost minimization while enforcing constraints on bridge performance. The resulting single planning solution, however, may not always satisfy bridge managers’ specific requirements for bridge performance over an intended time horizon. In response, the life-cycle maintenance planning of deteriorating bridges is formulated as a multiobjective optimization problem and is solved by a genetic algorithm. The visual inspection–based condition state, structural assessment–based safety state, and cumulative life-cycle maintenance cost are all treated as competing criteria. A group of different maintenance strategies is considered. A multilinear computational model is adopted to predict time-varying deterioration processes under no-maintenance and maintenance interventions. Relevant parameters in this computational model are described as random variables to account for sources of uncertainty associated with the complex deterioration process. Monte Carlo simulation is performed to estimate sample mean values of performance indicators and maintenance cost on the basis of data collected in the United Kingdom. Application examples are presented for maintaining a group of reinforced concrete crossheads that have been undergoing deterioration in both condition and safety. It is demonstrated that an overall desirable maintenance planning solution can be obtained only by balancing all necessary merit measures (e.g., condition, safety, and cost) through an explicit trade-off analysis.

**Sustainable Bridges: Research Project of the European Community**

Jan Bien and Malgorzata Gladysz, *Wroclaw University of Technology*

The integrated research project Sustainable Bridges—Assessment for Future Traffic Demands and Longer Lives was approved by the European Commission in December 2003 for funding over the next 4 years. The main goal of this research is development of scientific, technological, and technical bases for the adaptation of existing railway bridges to increased loads and higher speeds, with enhanced reliability and durability. The bridge infrastructure needs new effective tools for testing, condition assessment, monitoring, and analysis of damaged structures, as well as for rational rehabilitation. The project is carried out by a consortium of 32 partners from 12 countries, consisting of bridge owners, contractors, consultants, research centers, and universities. Also described is the cooperation of the sustainable bridges project with other international ongoing projects in the area of railway bridges: Assessment, Reliability, and Maintenance of Masonry Arch Bridges, of the International Union of Railways and International Bridge Engineering School, developed by several European universities.
Modeling Bridge Deck Deterioration by Using Decision Tree Algorithms

George Morcous, University of Nebraska, Lincoln

Existing bridge management systems have adopted Markov chain models to predict the condition of different bridge components for network-level analysis. These models assume that the future condition depends only on the present condition and not on the past condition (i.e., state independence). Moreover, these models do not explicitly account for the effect of governing deterioration parameters, such as average daily traffic, percentage of trucks, and environmental impacts, on the predicted condition. Machine learning approaches have been proposed by many researchers as successful tools for modeling infrastructure deterioration. A work in progress evaluates the prediction accuracy of decision tree algorithms—one of the most common techniques of machine learning—against the prediction accuracy of Markov chain models. Field data of concrete bridge decks were obtained from the Ministère des Transports du Québec database to develop and evaluate the performance of decision tree algorithms in modeling bridge deck deterioration. Evaluation results have indicated a slight increase in the performance of decision trees over existing Markov chain models when the past condition is considered or governing deterioration parameters are incorporated.

Summary of AASHTO and FHWA International Scanning Tour for Bridge Preservation and Maintenance

Jay A. Puckett, University of Wyoming; and George Hearn, University of Colorado, Boulder

The AASHTO and FHWA Panel on Bridge System Preservation and Maintenance, which was composed of 10 members representing AASHTO, FHWA, state departments of transportation, the National Association of County Engineers, and academia, traveled to the African and European continents and met with highway agency representatives as well as bridge management and inspection technology practitioners and researchers. The U.S. panel reviewed and documented methods of bridge preservation and management.
Monday, July 18, 1:30 p.m.–3:00 p.m.,
Technical Session 3: Prefabricated Bridges

Texas’s Totally Prefabricated Bridge Superstructures
Gregg A. Freeby, Texas Department of Transportation

The Texas Department of Transportation (Texas DOT) has developed two new bridge superstructure systems that have maximum span lengths of 115 ft and a total superstructure depth of only 38 in. and are totally prefabricated: a steel tub girder and a prestressed concrete pretopped U-beam. The steel tub-girder system uses a conventional prefabricated trapezoidal steel girder, which is topped by a concrete slab before transport to the bridge site. To achieve the shallow superstructure depth of 38 in., shoring the beams during slab placement makes them composite for all loads. After slab placement, the beam is hauled to the bridge site and erected on the bridge piers. A simple cast-in-place closure pour joins the deck girder sections after they are in place. The prestressed concrete pretopped U-beams use a portion of the existing Texas U-beam form system. Each beam is fabricated as a closed U-beam and hauled to the contractor’s yard, where a 4-in. topping is placed before beam erection. A cast-in-place closure pour joins the deck girder sections after erection. Texas DOT anticipates that these two systems will be used over the next 10 years for the rapid construction of nearly 150 bridges that cross I-35 in central Texas. Construction of the first four such structures begins in spring 2005. It is expected that girder erection and closure-pour placement will take less than 24 h and that bridges will open to traffic after as few as 4 days.

Design and Construction of a Bridge with a Full-Width, Full-Depth Precast Concrete Deck Slab on Steel Girders

(presentation without paper)
N. David LeBlanc, Totten Sims Hubicki Associates; and Alex Harrison, CH2M Hill

The West Sandusky Street bridge over I-75 in Findlay, Ohio, consists of a single 170-ft-span hybrid steel plate girder bridge with a concrete deck. To minimize closure times on West Sandusky Street and reduce traffic delays on I-75 during the bridge’s replacement, full-width, full-depth precast concrete deck panels were proposed for the bridge deck construction. The precast deck panels are posttensioned both longitudinally and transversely to minimize cracking and improve durability and are constructed with shear stud pockets to allow for the installation of shear studs after erection and posttensioning. During detail design, a finite element analysis of the bridge deck was carried out to determine the required level of prestress in the deck. A time-dependent analysis was subsequently completed to determine the long-term creep effects and posttensioning losses, including the effects of restraint from the steel girders. A sensitivity analysis determined the optimum curing time required before stressing the longitudinal posttensioning tendons and grouting the shear pockets. The steel plate girders were designed for the long-term creep effects due to the posttensioning of the deck, which imposed additional axial loads and moments on the steel girders. The replacement deck panels were fabricated before bridge demolition and road closure. Bridge construction was completed in fall 2004.
Designing Bridges for Quick Construction in Urban Areas

William J. Rohleder, Figg Bridge Engineers, Inc.

Providing new transportation facilities and increased capacity on existing roadways and bridges is a significant challenge in urban environments. Demanding factors for today’s engineers include limited affordable right-of-way, the maintenance of traffic for the traveling public, and the creation of structures that enhance the urban landscape. Through the use of precast segmental concrete construction, aesthetically pleasing structures can be erected in difficult construction sites. Existing medians can be used for elevated structures without expensive right-of-way acquisition costs being incurred. By the nature of the selected construction methodology, segments can be erected rapidly with minimal effect on traffic. Equally, the final structures can be designed to be aesthetically pleasing and provide for low maintenance and long service lives. Examples are given of successful urban projects in which quick construction, durable designs, and pleasing aesthetics have been achieved to meet the nation’s future transportation challenges.

Broadway Bridge Case Study: Bridge Deck Application of Fiber-Reinforced Polymer

Matt Sams, Martin Marietta

Research into using fiber-reinforced polymer (FRP) for bridge deck applications began in the early 1990s as aerospace companies looked for alternative uses for their advanced products. By the mid-1990s, FRP was gaining acceptance from the bridge community as it was applied to small, low-volume deck demonstration projects. Since that time, FRP decks have been used on increasingly significant projects throughout the United States. Designers have become more familiar with the characteristics that FRP offers and have begun to apply FRP to projects that would most benefit—cases where low weight, corrosion resistance, or rapid installation is critical. FRP decks are often suitable for historic, movable, or high-traffic bridges. One excellent example of an FRP deck application is the Broadway Bridge in downtown Portland, Oregon. This project demanded a new deck that matched the weight of the bridge’s existing steel grating, offered improved skid resistance, and could be installed rapidly.
Monday, July 18, 3:30 p.m.–5:00 p.m., Technical Session 4: Advances in Load and Resistance Factor Design Practice

The New Hathaway Bridge, Panama City, Florida: Segmental Concrete Bridge Project Designed Under AASHTO Load and Resistance Factor Design Specifications
Lex Collins, HNTB Corporation

The new Hathaway Bridge in Panama City, Florida, is a design–build bridge replacement project that consists of replacing an existing structure with two side-by-side precast segmental box girder bridges. The project was designed by the Orlando office of HNTB Corporation and constructed by Granite Construction Company. Each new bridge has seven 330-ft (100.6-m) spans, 265-ft (80.8-m) transition spans, and 200-ft (61-m) end spans. The load and resistance factor design (LRFD) specification used for the design was the AASHTO LRFD specification (1998 with interims through 2000). The LRFD design is compared with the AASHTO specification requirements (16th edition) as well as the requirements of the Guide Specifications for Design and Construction of Segmental Concrete Bridges (2nd edition). Studies during design showed that, for this bridge, the transverse and longitudinal bending requirements under the LRFD specification were similar to what would have been expected under previous specifications using HS20 loading. However, the shear requirements of the LRFD specification for these box girders were less conservative than the requirements of previous specifications.

System Factors for Highway Bridge Superstructures
Michel Ghosn, City College of the City University of New York

Although traditional methods of bridge structural design proportion each member separately, the members do not behave independently but interact to form a single structural system. To account for overall system safety during the design process, the current AASHTO load and resistance factor design (LRFD) specifications (AASHTO LRFD Bridge Design Specifications, 2002) provide a load modifier factor, $\eta$, which explicitly accounts for the effects of ductility, redundancy, and operational importance. In the absence of precise information, the values used for the load modifiers are assigned subjectively. The results of a research project funded by NCHRP that led to the development of objective measures of redundancy and a method that uses system factors, $\phi$, during the design and load capacity evaluation process to account for the system’s reserve strength are summarized. A set of proposed system factors was calibrated to provide bridges with adequate levels of overall safety and system reliability. Nonredundant bridges would be penalized by requiring their members to provide higher safety levels than those of similar bridges with redundant configurations. The system factors are tabulated for typical superstructure configurations. Differences in member ductility and redundancy levels are accounted for by assigning different system factors depending on member detailing and topologic configurations. The approach proposed to account for operational importance is consistent with current trends to develop performance-based design while the uncertainties in estimating member and system capacities as well as future loads are considered.
Unified Resistance Equations for Design of Curved and Tangent Steel Bridge I-Girders
Donald W. White, Georgia Institute of Technology; and Michael A. Grubb, Bridge Software Development International, Ltd.

The provisions of the 2004 AASHTO load and resistance factor design specifications for steel I- and box-girder bridge design have been updated relative to previous specifications to simplify their logic, organization, and application and to improve their accuracy and generality. These provisions provide a unified approach for the flexural design of both tangent and curved I- and box-girder bridges. Updated resistance equations are a key component of this unified approach. An overview is provided of the updated resistance equations for I-section members. The primary focus is on handling coupled major-axis bending, minor-axis bending, and torsion from any source in both straight and horizontally curved I-section members.

NCHRP Project 12-61, Simplified Shear Design of Structural Concrete Members
Daniel A. Kuchma, Kang Su Kim, Sang Ho Kim, Shaoyun Sun, and Neil M. Hawkins, University of Illinois at Urbana–Champaign

A new method of shear design was introduced into the U.S. community with the AASHTO LRFD Bridge Design Specifications. This method, which is based on the modified compression field theory, provides a unified approach for the shear design of both prestressed and nonprestressed members, overcomes a number of safety concerns, and enables members to be designed for higher shear stress levels. Unfortunately, this design methodology is perceived by many as being more complex than AASHTO’s standard specifications. To address this concern, NCHRP funded Project 12-61, Simplified Shear Design of Structural Concrete Members. The objective of this project was to supplement the full LRFD method for shear design with a simplified procedure that provides a direct solution for transverse and longitudinal reinforcement of concrete structures of common proportions. The research approach was to establish the simplified provisions after a rigorous assessment of the merits and limitations of existing shear design methodologies. This assessment was made by using a large experimental database of shear test results and a shear reinforcement calculator tool, which is used to compare the reinforcement required ($\rho v/H_{11547}$) by shear design methods for about 500 design cases that represent the breadth and frequency of structures built in the field.
Time-Domain Reflectometry to Detect Voids in Posttensioning Ducts

Jian Li, Laura Akl, Robert Hunsperger, Wei Liu, and Michael Chajes, University of Delaware; Eric Kunz, Vetek Systems Corp.

Because incompletely grouted posttensioned ducts result in voids, the steel strands are vulnerable to premature corrosion. This paper describes a nondestructive evaluation (NDE) procedure that allows bridge owners to ensure that posttensioned ducts are properly grouted (i.e., have no voids). The NDE procedure uses time-domain reflectometry (TDR), a technique developed by electrical engineers for locating discontinuities in transmission lines. TDR involves sending a signal created by a step-pulse generator through a transmission line, determining whether the signal is reflected back, and, if it is reflected back, using the elapsed time to determine the location of the discontinuity. Prior research funded by the Delaware Department of Transportation and the National Science Foundation has shown that TDR can be used to detect corrosion on strands and can be implemented in the field. To detect and evaluate voids, the transmission line is placed either in or adjacent to the region where a void is suspected. The presence of a void affects the electric field surrounding the transmission line and causes a distinct reflection. Data are presented to show the measurement of both the relative size and the position of voids. The effects of environmental conditions, such as moisture content, temperature, and material contained in the void (e.g., corrosion products), also are reported.

Fast Location of Prestressing Steel Fractures in Bridge Decks and Parking Lots

Horst Scheel and Bernd Hillmeier, Technische Universität, Berlin

The remanent magnetism (RM) method allows identification of potentially unsafe conditions in pretensioned and posttensioned concrete structures by locating fractures of single wires, even if they are bundled with intact wires. Once the tendons have been premagnetized with an electromagnet, the magnetic field of tendons is measured at the concrete surface. Fractures produce characteristic leakage fields that can be measured with appropriate sensors at the concrete surface. The measuring speed of the RM method can be significantly enhanced by replacement of the time-consuming multistep magnetization with a single-step magnetization. Large yoke-shaped magnets have been constructed to magnetize transverse tendons in bridge decks over lengths of up to 3.5 m (=3.8 yd) in a single process. Measuring the magnetic flux density of an entire bridge deck simplifies the comparison of data from measurements at different times; this simplification would be helpful for monitoring the longtime behavior of the structure.
Critical Evaluation and Condition Assessment of Posttensioned Bridges in Texas

Mohsen Shahawy, SDR Engineering Consultants, Inc.
and William R. Cox, Texas Department of Transportation

The recent findings of corrosion in longitudinally posttensioned (PT) tendons in several bridges in Florida and other states raised an alarm about conditions of PT bridges in Texas. The Texas Department of Transportation Bridge Division in Austin initiated an investigation to assess the actual conditions of three major PT bridges within its area of operation: the US-183 segmental bridge in Austin, the San Antonio Y segmental bridge, and the Veterans Memorial Bridge (cable-stay) in Port Arthur. This investigation consisted of two phases. Phase I included the preliminary evaluation of construction and design details and conducting a detailed walkthrough inspection to evaluate existing conditions visually. The walkthrough inspection was designed to identify any existing potential problems and their locations. The information collected in Phase I was used in developing the testing plan for the in-depth evaluation carried out in Phase II. This paper covers the work performed under Phase II for all three bridges. The objectives of this investigation were to examine these bridges closely to identify any PT-related deficiencies. Observed deficiencies are analyzed to determine their effects on the structural performance and long-term durability of the bridges. The findings from Phase II and recommendations for future actions are presented.

Nondestructive Evaluation of Bridges

(presentation without paper)

Mark Moore and Travis P. Green, Wiss, Janney, Elstner Associates, Inc.
and Hamid Ghasemi, Federal Highway Administration

The aging highway and bridge infrastructure presents a significant challenge to effectively maintaining the operational status and safety of the highway system. Effective and reliable condition assessment tools are an important part of the ongoing efforts to evaluate and maintain the nation’s bridge structures. Nondestructive evaluation (NDE) technologies have played an increasingly important role in the inspection and assessment process. Recent advances in NDE techniques have improved the functional characteristics of many NDE methods and have led to systems that are more reliable. Increased use of NDE methods will depend on several factors, including the ability of the systems to detect deteriorated conditions accurately, the ease of use and field portability of the systems, and the total cost of completing the NDE-based inspections. A review of NDE systems for bridges has been completed. The capabilities of selected NDE techniques and systems have been evaluated.
Monday, July 18, 3:30 p.m.–5:00 p.m.,
Technical Session 6: Accelerated Construction

Hyperbuild! Rapid Bridge Construction Techniques in New Jersey
Harry A. Capers, Jr., New Jersey Department of Transportation

All owners are looking for ways to build more durable structures faster and more safely while maintaining safe traffic flow through the work zone. In reaction, many designers are providing unique solutions for demolishing and reconstructing structures that reduce the time to construct a bridge while providing maximum quality to ensure a long service life. Prefabricated structures, more rapidly constructible details, unique construction methods, and traffic maintenance developed during the design of structures have successfully reduced exposure time for the contractor and the public. The New Jersey Department of Transportation has applied prefabricated bridge details in its bridge projects to accelerate construction.

Rapid Bridge Construction in Europe Using Self-Propelled Modular Transporters
(presentation without paper)
Bill Halsband and Patrick van Seumeren, Mammoet; and Dirk Verwimp and Steven Sarens, Sarens Group

Europe is leading the way in accelerated bridge construction, with hundreds of entire bridge superstructures installed in hours or days instead of the weeks or months required for conventional bridge construction. To accomplish this significant reduction in on-site construction time requires the use of specialized equipment that can lift and transport thousands of tons of bridge in confined locations, at times with allowable tolerances within fractions of an inch. Self-propelled modular transporters (SPMTs), with their computer-controlled multiple axles, meet the exacting requirements at congested bridge sites. Various European bridge installations over land using SPMTs were studied. Also studied were various European bridge installations over water using SPMTs in combination with barges, where SPMTs were used because crane and barge–crane combinations were not possible or practical. The studies included what was done on these bridge installations and why SPMTs were the best choice for the job.
Use of Precast Concrete Members for Accelerated Bridge Construction in Washington State

Bijan Khaleghi, Washington State Department of Transportation

Innovative methods are presented for using precast concrete members in bridge construction; summaries include the essentials of design, detailing, and construction of precast, pretensioned girders; posttensioned spliced girders; and precast deck panels used for bridge structures. The key aspects of using precast members in seismic regions are discussed, with an emphasis on suitable connections that meet ductility requirements. Precast bridges consisting of pretensioned girders, posttensioned spliced girders, trapezoidal open-box girders, and other types of superstructure members have been gaining popularity in recent years. These types of bridges have the advantages of minimizing traffic disruption, accelerating construction, and solving constructability issues in traffic-congested areas and in other specific cases. Handling and shipping limitations often control the span capability of pretensioned girders. Spliced girder design has provided a solution where a one-piece pretensioned girder could not otherwise have been used. Precast deck systems consisting of precast, prestressed concrete deck panels have advantages in accelerated bridge construction and rapid deck replacement. A parametric study has been performed to demonstrate the effectiveness of using precast members in bridge structures. Design examples for each application that use load and resistance factor design specifications are provided. Criteria used in optimizing and developing standard drawings for precast bridge members are discussed. Recommendations for effective use of precast members in seismic regions are provided, and areas for further research are identified.

Simplified Continuity Details for Short- and Medium-Span Composite Steel Girder Bridges

Edward P. Wasserman, Tennessee Department of Transportation

State departments of transportation are being requested to produce bridge designs that are cost-effective, require less maintenance over a projected 75- to 100-year lifetime, and are adaptable to rapid construction operations. Most continuous bridges in the United States constructed of prefabricated girders and high-quality materials meet these requirements. Some geographic areas, however, have steel beam girder bridges that are at a competitive disadvantage to precast, prestressed concrete in spans up to 150 ft. Tennessee is developing bridge systems for steel bridges that can be erected similarly to precast, prestressed beams made continuous, with cranes of the same or lower lifting capacity, and can be fabricated at a reduced cost to be competitively priced. This development, it is hoped, will lower prices for both concrete and steel bridges.
New Japanese Technological Contributions in Earthquake Engineering

Eiichi Watanabe and Hirokazu Iemura, Kyoto University; Hidesada Kanaji and Tsutomu Nishioka, Hanshin Expressway Public Corporation; and Takumi Ohyama, Shimizu Corporation

Recently in Japan bridge specifications have been revised toward performance-based design, and various innovative earthquake-resistant countermeasures have been proposed after the tragedy of the Great Hanshin–Awaji Earthquake. A report on the state of the art of recent Japanese contributions in earthquake engineering is given, including buckling-restrained bracings, unbonded bracings, online network pseudodynamic testing, base isolation, aseismic controls, and international earthquake mitigation projects in the Asia–Pacific region, in addition to the recent revision of the Japanese specifications on roadway bridges.

New Materials Development for Bridges in Europe

(presentation without paper)

Joost Walraven, Delft University of Technology

In 1997 the first prestressed bridges of high-strength concrete in Europe were made in the Netherlands. The mean concrete compressive strength in those bridges was 100 N/mm². The successful application of high-strength concrete in these projects caused a general rise in the strength of concrete in standard bridges, from about 30 to about 60 N/mm². The high-strength concrete of those days turned out to be only an intermediate step in the development of new high-performance types of concrete, such as self-consolidating concrete and high-performance fiber concrete. The last type especially offers challenging possibilities. In France a 45-m-long bridge was built in concrete with a compressive strength of about 200 MPa (28,500 psi). In the Netherlands self-consolidating concrete and ultrahigh-performance fiber concrete meanwhile have been applied several times in bridge deck repair. Not only the development of new materials has received increasing attention, however. The quality of “old” materials in bridges has become a subject of intensified consideration. In Germany, for reasons of service life, it was decided to build all new prestressed bridges with external prestressing tendons. In the Netherlands evaluations of the residual capacity of existing bridges are now being carried out. Tests were conducted on large strips sawn out of bridges attacked by the alkali–silica reaction. A new point of concern is that cylinders taken from existing bridges that at first sight are healthy show an unexpectedly low axial tensile strength. In recent years, some extraordinary large and advanced bridges were finished. The bridges Rion Anterion in Greece and Millau in France are examples of superb bridge engineering.
Tuesday, July 19, 8:30 a.m.–10:00 a.m.,
Plenary Session 2: Security, Reliability, and Sustainability

**Implementation of High-Performance Materials: When Will They Become Standard?**
Louis N. Triandafilou, Federal Highway Administration

The use of high-performance materials (HPMs) for the infrastructure has increased dramatically in the past 10 years. HPMs offer substantial hope for better systems that last much longer than conventional materials. These engineered products have enhanced mechanical and durability property advantages over traditional bridge materials. Although likely to have higher initial costs, HPMs are being touted for their long-term life-cycle cost-effectiveness. The properties of three HPMs currently being implemented in the U.S. market are described (high-performance concrete, high-performance steel, and fiber-reinforced polymer composites). A historic perspective from the 1990s to the present is provided, including many accomplishments in each material area. The impact of the FHWA’s Innovative Bridge Research and Construction Program is explored, and future trends are discussed.

Tuesday, July 19, 10:30 a.m.–noon,
Technical Session 7: Seismic Design and Evaluation

**Life-Cycle Cost Evaluation of Multiple Bridges in Road Network Considering Seismic Risk**
Hitoshi Furuta, Kazuhiro Koyama, and Miki Oi, Kansai University; and Hiroyuki Sugimoto, Hokkai-Gakuen University

Earthquakes are one of the major natural disasters that cause great losses in Japan. An attempt is made to introduce the effects of earthquake damage into life-cycle cost (LCC) analysis. LCC analysis is formulated to consider the social and economic effects resulting from the collapse of structures by earthquakes as well as the minimization of maintenance costs. A stochastic model of structural response is proposed that accounts for the variation caused by the uncertain characteristics of earthquakes. The probability of failure due to earthquake excitation is then calculated on the basis of reliability theory. LCC evaluations are performed not only for a single bridge but also for many bridges forming a road network.
Tuesday, July 19, 10:30 a.m.–noon,
Technical Session 7: Seismic Design and Evaluation

Performance-Based Seismic Design of New Tacoma Narrows Suspension Bridge, Washington
Michael H. Jones and Semyon Treyger, HNTB Corporation

Performance-based design criteria developed for the new Tacoma Narrows Suspension Bridge as well as aspects of the seismic analysis of the bridge required to verify compliance with the design criteria are presented. The Tacoma Narrows Bridge is located in the Seattle–Tacoma area of the state of Washington, a region of high seismicity capable of producing earthquakes of Richter moment magnitude 8 or larger. Project-specific performance-based design criteria were developed to ensure that prescribed levels of seismic resistance were provided at a reasonable cost. The performance-based design criteria stipulated that nonlinear time–history analysis should be used to verify that the performance goals were achieved. Analysis subjects discussed include soil–structure interaction, caisson rocking, and finite element modeling of various bridge components. It is demonstrated that seismic goals specified by performance-based design criteria are achievable for bridges in high seismic regions through the use of proper analysis techniques.

Enhancing Performance-Based Bridge Seismic Design with Seismic Performance Testing
Jia-Dzwan (Jerry) Shen, Lendis Corp. and FHWA Turner-Fairbank Highway Research Center; W. Phillip Yen and John O’Fallon, Federal Highway Administration

Introducing performance-based criteria to bridge seismic design increases the demand for seismic performance testing results that can be compared with each other to provide critical information used in the design. The current practice of seismic performance testing of bridge piers employs diverse testing conditions. Some variations result from a lack of consensus-based testing guidance. Such unnecessary variation impedes the data comparison with other research and the reliable engineering application of testing results. Current problems and resolutions found in an FHWA study on seismic performance testing methodologies of bridge piers are reported. A brief preview of the guidance document for seismic performance testing of bridge piers that is produced in this study is given. Information on specimen preparation, loading, and the documentation of bridge pier seismic performance testing is provided. This document is intended for use with both scientific experiment and engineering validations. Elaborate description of an assembly of practiced testing procedures is provided, and alternatives are offered for special test needs. Procedures are provided for testing piers made of conventional or advanced material. Requirements on test records, which are consistent with the needs in establishing or expanding seismic performance databases, are given to enable user access and verification of test results. Technical terms used in seismic testing and seismic design are defined and their relationships clarified. An expert panel including members from academia, state highway agencies, and federal government was assembled to advise on the development and to review the product.
Resistance of a Portal Frame Bridge Pier Under Earthquake Waves from Arbitrary Directions

Hiromu Okamoto, Kazutoshi Nagata, and Kunitomo Sugiura, Kyoto University; Toshihiko Naganuma, Hanshin Expressway Public Corporation; and Eiichi Watanabe, Kyoto University

Steel portal frames are used in Japan as basic structural frames for viaducts in metropolitan areas. These structures may be subject to both near-field and far-field earthquake motions from all directions. Although for isolated single piers the earthquake-resistant design appears to be well established, the earthquake response and the resistance are not fully clarified for portal frames. A study on elastoplastic finite displacement analysis by a finite element model for earthquake resistance of steel portal frame piers of an elevated highway is presented. The incidental earthquake waves are assumed to come from arbitrary directions; for simplicity, the analysis considers five different directions covering the in-plane of the frame (0° from the transverse direction of the bridge axis) and the out-of-plane directions (30°, 60°, 75°, and 90°). Some results were compared with those from experiments on portal rigid-frame bridge piers under in-plane loading conducted at Kyoto University. It was found that it is important to take the correlation of in-plane and out-of-plane responses into consideration for the rational earthquake-resistant design of a portal frame bridge pier.

Overcoming Barriers to Durable Steel Bridge Systems

(presentation without paper)

John W. Fisher, Lehigh University

Experience with steel bridges has demonstrated that one of the primary barriers to durability of steel bridge systems was inadequacies in the fatigue design criteria and practice before 1980. The development of a rational fatigue-resistance knowledge base and the introduction of stress range as the appropriate fatigue design condition have minimized this limitation. Small web gaps and arbitrary rules to avoid welding to tension flanges resulted in extensive web gap fatigue cracking from out-of-plane distortion. A second major factor has been excessive corrosion of steel members because of failure to keep bridges clean and lack of control of water. Corrosion notches, severe section loss, or both, often developed in steel members with or without protective coatings when dirt and debris accumulated and created active corrosion cells from wetting, salts, and other contributors to electrochemical cell activity. Excessive deterioration of concrete decks also contributed. For the future, high-performance steels are providing enhanced weathering resistance for uncoated members along with more reliable fracture resistance and weldability. Control of water and debris by minimizing joints in bridge decks, including the use of integral abutments, offers enhanced protection for both coated and uncoated bridge members. The orthotropic steel deck is shown to be one system likely to provide modularity for prefabrication and easy erection and capable of providing a 100-year life when thicker deck plates are used with thin epoxy concrete wearing surfaces. These have been shown to permit immediate use and are not pothole sensitive, even if local surface deterioration develops.
Improving the Durability of Posttensioned Bridges

*(presentation without paper)*


Intrusive investigations have shown that, in many posttensioned segmental bridges, the posttensioning systems are in good condition, but some contain significant faults—singly or in combination—such as large voids, moisture, salts, and corrosion of stressing tendons. Measures aimed at improving the design, detailing, specifications, materials, construction methods, and testing for grouted, posttensioned concrete bridges are outlined. Adoption of these measures will significantly improve the durability of these bridges.

Time-Dependent Behavior of a Concrete Integral Abutment Bridge

Jimin Huang, Carol K. Shield, and Catherine French, *University of Minnesota*

Time-dependent behavior of an integral abutment bridge near Rochester, Minnesota, was investigated from the beginning of construction through 7 years of service by using field data collected from more than 150 instruments installed in the bridge during construction. Long-term bridge shortening was observed from the readings of horizontal extensometers installed behind the abutments. Measured pile curvatures steadily increased with time. To understand this unexpected bridge behavior better, a time-dependent numerical study using the creep and shrinkage models from American Concrete Institute Committee 209 was conducted. The results obtained in this research indicate that concrete creep and shrinkage had a significant effect on the behavior of the concrete integral abutment bridge over the course of the 7-year study.
Prediction Model for Deterioration of Concrete Bridge Stocks

G. C. M. Gaal, Lloyd’s Register; and Joost Walraven, Delft University of Technology

The first reinforced concrete structures were built at the end of the 19th century. In the early 20th century, when the first concrete bridges were built, the general idea was that concrete made with sufficient cement would prevent the reinforcement from corroding. In those days, it was assumed that an everlasting protective layer would prevent such corrosion. During the 1980s and 1990s, a strong increase in the need for maintenance of concrete bridges was observed in the United States and Great Britain. It is therefore not surprising that in the United States approximately 150 to 200 bridges, of a total of 600,000, suffer partial or full collapse in any year. However, long before a bridge collapses, sections of concrete may come off because of spalling. These loose sections of concrete might already endanger passing traffic. In this paper, “failure” is therefore defined as the undesirable event of an intolerable amount of spalling. The scope of the paper is thus limited to deterioration that results in damage to concrete bridges due to cracks and concrete spalling that is the result of corrosion of the steel reinforcement. This paper introduces a new solution to Fick’s second law of diffusion; this solution takes into account both the ongoing hydration of the concrete and the start of application of salt as a deicer in the late 1960s. A new model is used to predict the extent of spalling of Dutch concrete bridges. The outcome of the model is used to validate the results of 92 inspections of Dutch concrete highway bridges.

Bridge with Composite Concrete Deck and Glued Laminated Girders Strengthened with Fiber-Reinforced Polymer: Design, Construction, and Load Testing

William G. Davids, Habib J. Dagher, and Olivia Sanchez, University of Maine; and Craig Weaver, T.Y. Lin International

The design, construction, and monitoring of a bridge with fiber-reinforced polymer (FRP) and glued laminated (glulam) girders with FRP tension reinforcing and a composite concrete deck, constructed during fall 2003 in Fairfield, Maine, are addressed. The use of a composite concrete deck was motivated by the fact that deflection often governs the design of glulam girder bridges, and composite behavior increases the stiffness of the bridge by over 200% and significantly increases strength. The structure relies on a dowel-type shear connector to ensure composite action between the girders and the concrete deck. The design and construction of this bridge required the laboratory testing of both the shear connectors and girder specimens to determine their fatigue durability and strength as well as the development of new analysis tools. An overview of the laboratory testing program is given, including the fatigue testing of both the dowel-type shear connectors and two 9.15-m-span FRP–glulam–concrete beams. Strains and displacements measured during the testing program agree well with the analysis results. Design details of the 21.3-m-long bridge in Fairfield are discussed, followed by a summary and assessment of the construction of the bridge. Strains and displacements measured during live load testing of the bridge are reported, which indicate that the as-built bridge achieves a high degree of composite action.
Use of Adhesives to Retrofit Out-of-Plane Distortion at Connection Plates
Yuying Hu, Carol K. Shield, and Robert J. Dexter, University of Minnesota

Before 1985, it was common practice to avoid welding floor beam and diaphragm connection plates to the tension flange of steel bridge girders. This practice often resulted in web-gap cracking due to out-of-plane distortion of the girder web. The most widely applicable and accepted retrofit method is to attach the connection plate rigidly to the flange. There was an investigation of a retrofit option that used a two-part epoxy cured at room temperature to join a small length of 3⁄4-in.-thick steel angle shape to the tension flange and the connection plate. Field tests conducted on two multiple-girder bridges indicated that significant out-of-plane stress ranges were typically reduced by at least 40% after retrofit. For details that have the potential for web-gap cracking but have not yet exhibited detectable cracks, the 40% reduction in stress range is likely enough to eliminate the possibility of future web-gap cracking effectively.

Self-Consolidating Concrete for Repair of Bridges
Maria Kaszynska, Technical University of Szczecin

There is a growing need for a more efficient approach to evaluation and repair of existing structures. Damaged bridge deck slabs and girders are repaired by removing debris, placing additional reinforcement, splicing broken prestressing tendons, and filling the gaps with concrete or epoxy resin. Test results are presented for verification of the performance of self-consolidating concrete (SCC) used to repair existing structures. SCC offers an excellent solution. It can be used to fill large potholes and also in high-to-reach repair projects with restricted access for pumping concrete. The tests confirmed that SCC can be considered an attractive repair technology. However, the optimum mixtures are sensitive to small variations in the characteristics of components such as cement type, type and amount of superplasticizer, and type of sand and fillers. The tests and analyses showed that determination of the optimum properties of SCC is most efficient when the paste and mortar are tested first.
Strengthening Steel Girder Bridges with Carbon Fiber–Reinforced Polymer Plates

Terry J. Wipf, Brent M. Phares, and F. Wayne Klaiber, Iowa State University; A. H. Al Saidy, Sultan Qaboos University; Yoon-Si Lee, Iowa State University

A large percentage of short- and medium-span steel bridges are deteriorating because of age and environmental effects. Although these bridges are still in service, many need strengthening because of increases in legal live load, loss of section, or both. The results of two investigations are presented—a laboratory study and a field study—in which carbon fiber–reinforced polymer (CFRP) plates were used to strengthen composite steel stringers. In the laboratory investigation, small-scale steel–concrete composite beams were tested; there were control beams (no damage or CFRP applied), damaged beams (a percentage of the bottom flange removed), and damaged beams with CFRP applied to the bottom flanges, webs, or both. In all cases the strength of all damaged and repaired beams was fully restored to the original undamaged state. Details on both the strengthening system and the behavior of undamaged, damaged, and repaired scale-model specimens are presented. On the basis of the laboratory results, a second project was undertaken in which an existing steel girder bridge was strengthened with CFRP plates. This bridge is a 150- × 30-ft three-span continuous rolled I-beam bridge in southwestern Iowa. The original noncomposite four-beam bridge was widened in 1965 by adding two composite beams. A recent rating of this bridge determined that several of the original beams were understrength in the positive moment regions; thus CFRP was bonded to the positive moment regions of the bottom flanges of the two original interior beams and the “new” exterior beams. At some locations on the exterior beams, the plates were installed on the top surface of the bottom flange to investigate the performance and in-service durability under detrimental environmental conditions. This bridge has been load tested three times—before and after installation of the CFRP plates and approximately 1 year later—to determine the effectiveness of the strengthening system. Results are presented to illustrate this effectiveness.

Form, Function, and Bridge Aesthetics

Man-Chung Tang, T.Y. Lin International

About 2,000 years ago, in De Architectura, probably the first book on architecture, Marcus Vitruvius Pollio wrote, “Structures shall be safe, functional, and beautiful.” This is obvious with a look at the structures built during the Roman Empire. The form of structures depends on the construction materials available. The Romans primarily had stone, so they made good use of the compressive strength of stone to build many spectacular structures with arches and domes. The structures were functional and at the same time beautiful. Today’s new and much more versatile construction materials allow development of many new forms of structures to satisfy the demand of functionality. Long and wide bridges can be built. There are more choices and possibilities now. Should bridges be at least as beautiful as those 2,000-year-old Roman structures? Form follows function, but this concept is not sufficient. The most beautiful form must be selected for the bridges that are designed: this is aesthetics.
Design of California’s New San Francisco–Oakland Bay Self-Anchored Suspension Bridge

Marwan Nader, Rafael Manzanarez, and Man-Chung Tang, T.Y. Lin International

The seismically vulnerable east span of California’s San Francisco–Oakland Bay Bridge will be replaced with a dual eastbound and westbound parallel structure 3.6 km long. The Bay Bridge lies between the Hayward and the San Andreas Faults, which can generate magnitude 7.5 and 8.1 M earthquakes, respectively. Performance criteria require that the bridge be operational immediately after a 1,500-year-return-period earthquake from either of these two faults. Four distinct structures will make up the bridge crossing: a low-rise posttensioned concrete box girder near the Oakland shore, a segmental concrete box girder 2.4 km long, a self-anchored suspension signature span, and a posttensioned concrete box girder that connects to the east portal of the Yerba Buena Island tunnel. The single-tower asymmetric self-anchored suspension bridge was selected from a total of four design alternatives that were developed for the signature main span; these included two cable-stayed bridges and two self-anchored suspension bridges (each bridge type included single-tower and dual portal tower alternatives). Each design alternative was evaluated on the basis of its seismic response, construction cost, and aesthetic properties.

Seismic Design of Highway Bridges in the United States: Design Specification Dilemma

Glenn R. Smith, Federal Highway Administration

AASHTO’s specifications for standard and load and resistance factor design (LRFD) guide the seismic design of highway bridges in the United States. Except for provisions amplifying capacity-controlled design, seismic design requirements have not been significantly updated in a decade. There have been damaging earthquakes and much research to learn from. The AASHTO standard specifications will no longer be updated. The LRFD seismic provisions will not have a major revision in the foreseeable future. A consensus guide specification will not be approved before mid-2006. Guidance is provided on options available to bridge engineers to implement the state of the art in seismic design. Several complete seismic design specifications have been developed or are in current use. These provide guidance for performance-based seismic design that is not available from AASHTO. They are of value in developing project-specific seismic design criteria. These alternatives were reviewed to identify provisions in them to be used for more reliable, more easily implemented, and more economical seismic design than is provided by AASHTO alone. Difficulties with these alternative design criteria include lack of experience with the concepts, limited availability of supporting references, lack of worked examples, and limited availability of training and computer software. The technical support available was surveyed. In mid-America, confusion about seismic risk and the severe economic impact of designing for the extreme event inhibit adoption of rational seismic design criteria. It is recommended that the issues be resolved.
Design of Skyway Structures for California’s San Francisco–Oakland Bay Bridge
Sajid Abbas and Rafael Manzanarez, T.Y. Lin International

The seismically vulnerable eastern spans of California’s San Francisco–Oakland Bay Bridge are being replaced with a dual, 3.6-km-long parallel structure. The skyway section, which consists of 2.1-km-long twin viaducts, is under construction by a joint venture of Kiewit, FCI, and Manson. The viaducts are precast segmental bridges erected in balanced cantilever, with a typical span of 160 m. The foundation consists of six 2.5-m-diameter pipe piles 100 m in length with a steel pile cap that is in-filled with concrete. The precast segments for the superstructure, which are as heavy as 7 MN, are lifted into position with self-launching winch lifters and are posttensioned. The bridge is situated between the Hayward and the San Andreas Faults, which can generate large earthquakes. Performance criteria require the bridge to be operational after a 1,500-year-return-period earthquake from either of these two faults.

Seismic Retrofit Design of Long-Span Bridges on Metropolitan Expressways in Tokyo
Yozo Fujino, University of Tokyo; Hiroshi Kikkawa, Kenji Namikawa, and Takao Mizoguchi, Metropolitan Expressways Public Corporation

The seismic retrofit design of large cable-supported bridges in Tokyo, namely, Rainbow Bridge, Yokohama Bay Bridge, and Tsurumi Fairway Bridge, is described. The site-dependent far-field ground motion due to a possible maximum credible earthquake was calculated by using a fault rupture model together with the wave propagation technique. The nonlinear seismic responses of the bridges, including the soil-structure interaction, were computed, and it was found that all three bridges may suffer considerable damage. A careful retrofit design was prepared for the structural elements that would receive severe damage. Because large bridges are complex structural systems, an increase in the structural redundancy and the use of the fail-safe concept in the retrofit design are emphasized.
Continuous Monitoring for the Management, Safety, and Reliability of Connecticut’s Bridge Infrastructure

Paramita Mondal and John T. DeWolf, University of Connecticut; Paul D’Attilio and Eric Feldblum, Connecticut Department of Transportation

Researchers at the University of Connecticut have been working with researchers at the Connecticut Department of Transportation to develop and implement continuous bridge monitoring systems on a series of bridges in Connecticut. The monitoring systems are designed to evaluate the long-term behavior of the bridges and to evaluate safety and reliability to ensure that no major structural changes could lead to significant problems. The approach used to organize the large amount of data that are collected from the first three bridges in the project is described. The goal of this work is to facilitate the continuous evaluation of the bridge network and thus assist those responsible for the management and safety of Connecticut’s bridge infrastructure.

Virtual Wireless Infrastructure Evaluation System

Daniel N. Farhey, University of Dayton

System identification through nondestructive experimental testing and analysis is essential for reliable structural evaluation. Experimental testing and monitoring of full-scale structures in the field are complicated, time-consuming, and labor-intensive. The lack of practical field experimental technology impedes further research and development of bridges. This issue critically conflicts with public needs to preserve existing bridges and upgrade substandard bridges. Thus, it is imperative to develop a particularly efficient field-testing and monitoring system for identification, condition assessment, and performance evaluation. A study considering system intelligence characterizations conceptualized an effective upgrade. A virtual wireless infrastructure evaluation system was designed and developed. The system is devised for structural field experimentation through static or moving loads, by use of various types of electronic sensors. The system integrates a computer-controlled site network of multiple-channel wireless transmission. A software-based virtual instrumentation program was developed to control the system, collect data, and monitor the results through a user-friendly graphical user interface. Results of successfully testing two bridges in the field under real-world conditions are presented.
Bridge Inspections Using Electronic Handheld Data Collectors
Kevin Hahn-Keith, Parsons Brinckerhoff, Inc.; James L. Stump, Pennsylvania Turnpike Commission; David Charters, Parsons Brinckerhoff, Inc.; and Lance Andrews, Michael Baker Corporation

For assessment of the condition of an owner’s assets, accurate, efficient data collection is required to monitor reliability, ensure security, and maintain sustainability. Replacing cumbersome clipboards, pencils, and paper with an electronic data collection system is a way to streamline the data collection process, improve the accuracy of data collection, and enhance management of all asset data. At the request of the Pennsylvania Turnpike Commission (PTC), a consultant developed and used a handheld data collection system for the National Bridge Inspection Standards (NBIS) inspections for more than 800 bridges on the Pennsylvania Turnpike. In addition to developing the data collection system, the same consultant was chosen to perform a second 2-year cycle of routine inspections, this time using the electronic data collection system, instead of handwritten reports. Many of the same personnel worked on both inspection cycles; this situation provided a unique opportunity to compare the two ways of collecting inspection data and preparing bridge inspection reports. The hardware and software used for the PTC inspection program and the report preparation processes for both cycles (handwritten and electronic) are described in detail. Feedback from inspectors and PTC is used to show the resulting benefits of an electronic reporting system: reduced costs, better quality assurance and quality control, and easier access to inspection information. Finally, lessons learned and possible future developments are discussed. The conclusion is that handheld data collection units will continue to replace the handwritten reporting system and improve the reports prepared for NBIS bridge inspections.

Thermally Induced Superstructure Stresses in Prestressed Girder Integral Abutment Bridges
Michael Paul, Wilbur Smith Associates; Jeffrey A. Laman and Daniel G. Linzell, Pennsylvania State University

Forces and stresses that develop in the superstructure of prestressed concrete integral abutment bridges as a result of thermal load are investigated. Applied loading consists of uniform temperature changes in the superstructure. The influence of bridge length, number of spans, abutment height, and pile orientation on thermally induced superstructure forces is investigated. The largest thermally induced superstructure forces and stresses occurred near the abutment. It was determined that bridge length and abutment height most strongly influence thermally induced superstructure forces. The number of spans has the greatest influence on thermally induced superstructure stresses. Pile orientation influences thermally induced superstructure forces and stresses to a smaller degree. Results also indicate that thermally induced superstructure stresses and shear forces are comparable in magnitude to those caused by live load.
In-Field Performance of the Modified Beam-in-Slab Bridge: A Replacement Option for Low-Volume Bridges

T. F. Konda, F. Wayne Klaiber, and Terry J. Wipf, Iowa State University

Managers of most low-volume roads (LVR) face a deteriorating bridge population, and replacement is frequently the most cost-effective solution. With more structures needing replacement than available funds to do so, low-cost alternatives that are constructible in-house are a desirable option. The modified beam-in-slab bridge (MBISB) is one such alternative that has been developed specifically for LVRs. The MBISB system consists of longitudinal steel stringers that support a transverse concrete arched deck. Composite action is obtained by using an alternative shear connector (ASC) rather than shear studs. Other than nominal transverse reinforcement, which is part of ASC, MBISB requires minimal additional reinforcement—approximately 70% of that required in conventional decks. Two demonstration bridges—MBISB 1, 50 ft (15.24 m) long and 31 ft (9.45 m) wide, and MBISB 2, 70 ft (21.34 m) long and 32 ft (9.75 m) wide—saved the bridge owner slightly more than 20% of the cost of conventional bridge systems. Field testing of both demonstration bridges determined the behavior of the bridges under service loading. Strains and deflections were measured at critical locations; the resulting data were used to confirm composite action and to determine the load distribution characteristics for use in the design methodology that was developed. On the basis of analyses and the field data, the demonstration MBISBs exceed AASHTO design requirements. Supporting documentation describes the construction and structural behavior of the MBISBs.

Reconstruction of North Avenue Bridge over the Chicago River, Chicago, Illinois

Thomas Powers, Chicago Department of Transportation; Kenneth Price, Eddie He, Craig Hetue, and Murat Aydemir, HNTB Corporation

This project involves the removal of an inoperable bascule bridge carrying North Avenue over the Chicago River and the construction of a wider, fixed-span structure at the same location in Chicago, Illinois. A hybrid structural system was selected for the new structure to meet various geometric and clearance constraints, provide for future utilization of the riverbanks adjacent to the structure, and provide for an aesthetic structure. The hybrid structural system consists of a combination of a self-anchored suspension bridge and a cable-stayed bridge. The bridge consists of a 252-ft main span and two 84-ft back spans. The middle portion of the main span is supported by suspension cables and hangers, and the remainder of the main span and both back spans are supported by cable stays arranged in a fan or semiharp configuration. Galvanized structural strands are used for the suspension cable and hangers, and prestressing steel strands are used for the cable stays. Steel pylons support the cable stays and suspension cable. The bridge deck will be posttensioned and constructed from high-performance concrete to provide greater durability and strength characteristics. This project is a pioneer effort in applying the innovative cable-stayed–suspension hybrid system. The design will serve as a good opportunity to study the behavior of such a unique structural system and provide valuable knowledge for its future applications.
Extending the Span of H-Beam Bridges by Steel Plate Prestressing
(presentation without paper)
Masahiro Sakano, Kansai University; Hironori Namiki, Kyobashi Maintech; and Tomoki Sakata, Kobe University

Information is provided on extending the span of rolled H-beam bridges by applying the steel plate prestressing method.

Cooper River Bridge Design–Build Project, Charleston, South Carolina: Successes and Lessons Learned
(presentation without paper)
Charles Dwyer, South Carolina Department of Transportation, and Kenneth Pierce, HDR, Inc.

The South Carolina Department of Transportation (DOT) is in the final stages of its largest single contract in the state’s history, the $531 million Cooper River Bridge Replacement Project in Charleston. This complex project consists of a 2-mi river crossing that includes North America’s longest cable-stayed bridge, two large interchanges with 15 ramps, and a total of 28 lane miles of bridge structure. The design of the bridge was complex because of many challenges, including the potential for hurricanes, earthquakes, and ship collisions. In addition to these factors, South Carolina DOT classified the bridge as critical and used the highest level of criteria for the project. For example, the criteria called for a service life of 100 years, even though the new bridge is in the middle of a saltwater marine environment. With a sufficiency rating of 4 on a scale of 1 to 100, one of the existing bridges was in immediate need of replacement. Because of the complexity of the project and the immediate need for a replacement, South Carolina DOT decided to use the design–build procurement method. With only two claims to date on the project and cost growth less than 2%, the project is on schedule for completion in June 2005, more than 1 year ahead of the required contract completion date. Successes and lessons learned from the project and design–build process are described.
Quantifying Barge Collision Loads for Bridge Pier Design and Vulnerability Assessment
Gary R. Consolazio, David R. Cowan, and Long H. Bui, University of Florida

Designing new bridge structures that cross barge-navigable waterways requires that consideration be given to the lateral loads that are imparted to bridge piers during barge collision events. Similarly, assessing the vulnerability of existing structures to barge impact loading, especially bridges that form critical components of high-volume transportation networks, requires that engineers have access to tools for both determining impact loading and assessing structural response. Results are presented from a comprehensive study being conducted to develop improved procedures for quantifying barge impact loads. To understand and characterize such loads better, high-resolution contact–impact finite-element analysis techniques were employed to simulate barge impact conditions with varying pier configurations, barge types, and soil characteristics. Although such models permit detailed analysis of impact phenomena, they are generally not appropriate for use in routine design. For this reason, an intermediate-resolution design-oriented dynamic finite-element analysis technique is discussed; it uses predetermined barge crush data to link a design-oriented dynamic finite-element pier analysis program to a low-order, nonlinear barge model. Comparisons between the two methods are presented. Finally, preliminary impact-load results from recently completed full-scale experimental barge impact tests are presented.

Load Combination Factors for Extreme Events
Michel Ghosn, City College of the City University of New York

The AASHTO load and resistance factor design (LRFD) specifications were developed with the use of a reliability-based calibration that covered the basic combination of dead load plus live load. The other load combinations were obtained from previous generations of specifications and the experience of bridge engineers and thus may not be consistent with the reliability methodology of the LRFD specifications. Work done as part of a recent NCHRP project to study in a systematic way the reliability of bridges under the combined effects of extreme load events and to develop a rational set of load combination factors consistent with the LRFD philosophy is described. The load events considered include live loads, seismic loads, wind loads, ship collision loads, and short-term scour. The analysis considered structural safety as well as foundation safety, and member safety was compared with system safety. The study recommended revisions to the AASHTO LRFD load combination factors and also calibrated new factors for combinations of events that include the presence of short-term scour. The calibration took into account previous experience with so-called safe bridge structures to provide acceptable and consistent levels of reliability.
Vessel Impact Risk Assessment
by the Texas Department of Transportation

Mark McClelland, Texas Department of Transportation

On September 15, 2001, a four-barge tow struck and collapsed Bent 32 of the Queen Isabella Causeway Bridge (Park Road 100 bridge crossing the Gulf Intracoastal Waterway) in Texas. In the aftermath of the collapse, the Bridge Division of the Texas Department of Transportation conducted a vessel impact risk analysis for all bridges crossing waterways with documented barge or cargo vessel traffic. To identify all bridge crossings over navigable waterways, Bridge Division engineers queried the Bridge Inspection Database and confirmed the resulting list with district personnel. Investigating engineers screened the bridges in steps on the basis of exposure of structural elements to vessel traffic, bridge type, and level of protective system already in place. They then evaluated bridges requiring analysis in accordance with the load and resistance factor design (LRFD) vessel collision provisions of the AASHTO LRFD Bridge Design Specifications. The engineers then scored bridges on the basis of vulnerability to vessel impact and criticality of bridge structure and normalized the scores to assign a value of 100 to the bridge representing the worst combination of these criteria. Investigators identified five bridges that require modification or installation of protective systems. From their findings, a program was initiated to design and install protective measures at each of the five bridge locations. In June 2003 a contract was assigned for the first project, to install protective measures on the south vessel approach of the Queen Isabella Causeway Bridge. In February 2004, a second project was begun, to install similar protective measures on the north vessel approach of the same bridge. Design is proceeding on protective measures for the other four bridges.

Bridge Collapse Detection System in Texas

James Justin Mercier, Eligio Alvarez, Juan Marfil, Mark J. Bloschock, and Ronald D. Medlock, Texas Department of Transportation

The Texas Department of Transportation (DOT) installed a collapse detection system on the Queen Isabella Memorial Bridge that will detect a span collapse and warn motorists to stop. The system consists of a fiber-optic cable that carries a current under the bridge deck for the 2½-mi length of the bridge. A span collapse will break the current, initiating flashing red lights to tell motorists on the bridge to stop, closing gates at each end of the bridge to keep additional cars off, and sending alarms to Texas DOT and local law enforcement to notify them of the event.
The SRICOS–Erosion Function Apparatus Method: An Overview of Its Measurement of Scour Depth

Jean-Louis Briaud and Hamn-Ching Chen, Texas A&M University

In the United States, the scour depth around a bridge pier is calculated by using the HEC-18 equation described by Richardson and Davis in 2001. This equation was developed for piers founded in sand, and there is a sense that in clay the depth of scour is not as large. A study was made to develop a method for clays, silts, and dirty sands. The SRICOS–erosion function apparatus (EFA) method was developed on the basis of flume tests, numerical testing, and erosion testing of the soil. The EFA was built for engineers for testing the soil for erodibility in the laboratory. The output of the simple SRICOS-EFA method is a scour depth after a given time. If a hydrograph is used as input, the extended SRICOS-EFA method can be used and results in a scour depth versus time curve. All the details for this method and the software that automates the calculations are available from ceprofs.tamu.edu/briaud/sricos-efa.htm.

Scour Monitoring Programs for Bridge Health

Beatrice E. Hunt, Hardesty & Hanover, LLP

One of the most common causes of catastrophic bridge failures worldwide has been bridge scour, and in the United States this phenomenon accounts for more than 60% of bridge collapses. Scour monitoring programs that use sonar devices were developed for four bridges in the Northeast—three bridges on Long Island’s South Shore in New York and the Woodrow Wilson Memorial Bridge over the Potomac River in Washington, D.C. These projects incorporated the sonar devices first recommended under NCHRP Project 21-3 and featured site-specific, detailed monitoring systems and programs for each bridge. This work included a series of firsts: a fixed sonar system installation for a tidal–cold weather environment, a multiple-station sonar system design with numerous innovative features, and a scour monitoring program manual. The scour monitoring program comprised investigation of the scour problem, consideration of countermeasure alternatives, analyses of pier stability, determination of scour critical depths, design of sonar instrument systems, and development of a plan of action with normal and emergency procedures. Water stage and velocity meters included in the installed systems provide additional data for bridge scour research as well as for replacement bridges that are under design. These state-of-the-art systems may be designed and installed in a relatively short time span, and they provide efficient, cost-effective alternatives for scour critical bridges. By providing continuous data on streambed elevations, the systems help ensure the safety of the traveling public. The design and installation of the systems are described, along with the ongoing, round-the-clock monitoring, after installation. A general discussion highlights lessons learned and trends in scour monitoring technology.
Comprehensive Approach for Riprap Design, Installation, and Maintenance

L. W. Zevenbergen, P. F. Lagasse, and P. E. Clopper, Ayres Associates

Many methods and criteria are available for designing riprap for erosion protection of riverbanks, bridge piers and abutments, guidebanks, and other highway structures in riverine environments. Different design criteria for riprap can give different results for protecting the same installation. A design procedure may be confusing to apply and can result in unsuitable gradations and ambiguous specifications. Many state highway departments have developed their own specifications based on trial, error, and field experience. To provide adequate protection, riprap must be properly designed and specified. Equally important, the rock material must be produced and installed to satisfy the specifications requirements and the design intent. The objectives for NCHRP Project 24-23 were to develop a comprehensive approach to riprap design, installation, and maintenance at bridges. As a preview to the project, preliminary results of a sensitivity analysis of selected revetment riprap design equations are presented. When completed, NCHRP 24-23 will provide design guidelines, material specifications and test methods, construction specifications, and construction inspection and quality control guidelines for riprap for bankline revetment, bridge pier and abutment protection, and river training countermeasures, such as guidebanks and spurs.

Monitoring and Mitigation of Stay-Cable Vibrations on the Fred Hartman and Veterans Memorial Bridges, Texas

Keith L. Ramsey, Texas Department of Transportation

Large-amplitude stay-cable vibrations are a major concern to bridge owners; if left unchecked, the serviceability of these bridges can be seriously affected. The Texas Department of Transportation addressed stay-cable vibrations on two bridges in its inventory. A study was made of the vibration mechanisms and their causes through the use of a vibration-monitoring system. Data from this system were used to design a mitigation strategy to eliminate or minimize the effects of vibrations. Efforts are also under way to quantify possible damage to the stay-cable systems of both bridges through full-scale fatigue testing. To aid with damage detection, an acoustic monitoring system for detecting possible wire breaks was tested in the laboratory and installed on one of the bridges. These steps are part of ongoing monitoring of the health of cable-stay bridges in Texas.
Performance Evaluation of Fiber-Reinforced Polymer Composite Deck Bridges

Vimala Shekar, Srinivas Aluri, and Hota V. S. GangaRao, West Virginia University

FHWA is committed to the strategic goals of rehabilitating the nation’s bridges that are structurally deficient. Fiber-reinforced polymer (FRP) composites are one of the advanced materials that appear to have great potential in bridge deck repair and replacements. In West Virginia alone, more than 30 bridges have been built or rehabilitated with FRP composite materials. Katy Truss and Market Street are two such bridges constructed with FRP bridge decks, and they are being monitored. The West Virginia University Constructed Facilities Center along with the West Virginia Department of Transportation initiated field monitoring of these bridges by performing static and dynamic load tests. The response measurements from controlled truck load tests on the two bridges included (a) deck and stringer strains and (b) deflections and deck accelerations. The following static response parameters were computed from measured data: (a) degree of composite action between deck and stringer, (b) transverse load distribution factor, and (c) stringer and deck stresses and deflections. The following dynamic response parameters were evaluated: (a) dynamic load allowance factors, (b) natural frequencies, and (c) damping ratios. The static and dynamic performance evaluations of Katy Truss and Market Street Bridges are highlighted here. This study found that, under static load, the stresses and deflections for deck and stringers of both bridges were well within the design limits. It was found that, on the basis of dynamic tests, deck accelerations due to trucks traveling were perceptible to bridge users. The high accelerations are attributed to the low inherent damping of these two bridges.

Shear Buckling Strength of Trapezoidally Corrugated Steel Webs for Bridges

Heungbae Gil, Korea Highway Corporation; Seungrok Lee, POSCO E&C; Jongwon Lee and Hakeun Lee, Korea University

Trapezoidally corrugated steel webs are composed of a series of flat and inclined subpanels and have been used as the webs of prestressed concrete box girder bridges to reduce superstructure weight and increase the effectiveness of prestressing. Because of accordion effects, the corrugated web resists only the shear stress, and the flanges resist most of the bending stress. The shear stress in the web can cause three different modes of shear buckling: local, global, and interactive (zonal) buckling. Several studies have been performed to determine buckling formulas for each mode. However, there are differences regarding the buckling strength, and some of the formulas are found to overestimate it. The results of a study are presented; a series of experiments was done with large corrugated plates. The specimens were designed to fail by the local, global, or interactive buckling mode in elastic and inelastic states. The effect of geometric parameters on the shear buckling strength was also studied. Nonlinear buckling analysis, which considered both geometric and material nonlinearity, was also performed to verify the test results. The results from this and previous studies are used to propose a shear buckling formula, which can be applied to all three buckling modes.
Comparison of Cable-Stayed Versus Extradosed Bridges
(presentation without paper)
Sena Kumarasena, HNTB Corporation

A cable-stayed bridge is generally characterized as a bridge having a flexible superstructure supported by inclined cables with a minimum angle with respect to the superstructure of 20°. An extradosed bridge is characterized by a stiff superstructure supported by flat cables with cable angles considerably less than 20°. A parametric study compares the behavior of the two bridge types. The study provides valuable information to designers and owners who are considering such bridge types.

Underwater Sound Pressure Levels Associated with Marine Pile Driving: Assessment of Impacts and Evaluation of Control Measures
James A. Reyff, Illingworth & Rodkin, Inc.

Bridge engineers should be aware that marine pile driving has resulted in high underwater sound pressures that have been lethal to fish and have resulted in harassment of pinnipeds under the Marine Mammal Protection Act. Most waterways in the nation include fish and marine mammals that are protected by state or federal agencies. Impacts from pile driving have contributed to costly construction delays for some major bridge projects. Recent construction activities in the marine environments of northern California have provided the opportunity to characterize these sound pressures and evaluate control measures to protect fish and marine mammals. Sound attenuation measures evaluated include different pile-driving methods, cofferdams (with and without water), confined air bubble curtain systems, and unconfined bubble curtain systems. Some attenuation measures have achieved more than 30 dB of noise reduction. However, each situation can present difficulties in achieving targeted reduction goals. Use of appropriate attenuation systems has greatly reduced the impacts to the species of concern for those projects. In this study, recent experiences are summarized from many projects in measuring both attenuated and unattenuated underwater sound pulses from pile-driving activities.
Load and Resistance Factor Rating for More Uniform Safety in Bridge Load Ratings and Postings
Bala Sivakumar, Lichtenstein Consulting Engineers

The new AASHTO Guide Manual for Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges (LRFR manual) (1) was developed under NCHRP Project 12-46 to be consistent with the AASHTO LRFD Bridge Design Specifications in the use of a reliability-based limit-states philosophy. The new manual provides procedures and calibrated load and resistance factors for load rating, posting, overweight permit review, and fatigue life assessment. The LRFR manual has implemented a systematic approach to bridge rating and posting that yields uniform reliability indexes where possible while providing a more realistic assessment of the safe load capacity of existing bridges. LRFR proposes a system for bridge load rating and permit evaluation that uses site-specific information to narrow the uncertainty in some of the evaluation variables. This paper provides an overview of the major changes introduced in the new LRFR manual, with emphasis on LRFR load rating, posting, and permit evaluation procedures that are intended to provide consistent reliability in bridge safety evaluations.

Experience in the United States with Fiber-Reinforced Polymer Composite Bridge Decks and Superstructures
Jerome S. O’Connor, State University of New York at Buffalo; and John M. Hooks, Sterling, Virginia

Research on the use of fiber-reinforced polymer (FRP) composite materials for bridge decks and superstructures has been ongoing since the 1980s. Vehicular bridges have been in service since 1996, and pedestrian bridges, longer than that. This paper focuses on vehicular bridges, of which many were funded by FHWA’s Innovative Bridge Research and Construction Program or other funding initiatives. The objective is to summarize where the projects are, who supplied them, how they were constructed, what the benefits of using FRP were, what lessons can be learned, and what the projects cost. A review of this information should be useful to civil engineers or bridge owners who want to assess the state of the practice and make a judgment about using FRP for bridge decks or superstructures.
Wednesday, July 20, 8:30 a.m.–10:00 a.m.,
Plenary Session 3: Security, Reliability, and Sustainability

The ABCDs of Bridge Building:
Affordable, Beautiful, Constructable, and Durable
(presentation without paper)
John E. Breen, University of Texas at Austin

The interrelation of aesthetics with overall bridge design, construction, and maintenance was studied. Beauty is highly desirable, but aesthetics must always be balanced with consideration of efficiency, constructability, and attention to durability. Examples show that great beauty is completely compatible with efficient, fast construction techniques and that beauty is greatly degraded if proper detailing is not provided for durability and control of staining. Rapid construction techniques are important and valuable, and they can be completely compatible with enhanced aesthetics and environmental sensitivity. A case study examined two attractive but different structural systems that were designed with different intents for blending with their surroundings. They differed in initial cost by a factor of 10, and the higher-cost structure also will require more intensive maintenance to preserve its appearance. The enigma of deciding “What price beauty?” was clearly illustrated in this comparison but was not answered.

Wednesday, July 20, 10:30 a.m.–noon,
Technical Session 16: Bridge Evaluation and Load Rating

Load and Resistance Factor Rating Using Site-Specific Data
Baidurya Bhattacharya, University of Delaware; Degang Li, Lawrie & Associates, LLC; and Michael Chajes, University of Delaware

Traditional techniques for bridge evaluation are founded on design-based deterministic equations that use limited site-specific data; they do not necessarily conform to a quantifiable standard of safety and often are quite conservative. The newly emerging method of load and resistance factor rating (LRFR) addresses some of these shortcomings and allows bridge rating in a manner consistent with load and resistance factor design but is not based on site-specific information. A probability-based method for load rating of bridges using site-specific in-service structural response data in an LRFR format is presented. The use of site-specific structural response data eliminates a substantial portion of modeling uncertainty in live load characterization (involving dynamic impact and girder distribution) and yields more accurate bridge ratings. Rating at two limit states—yield and plastic collapse—is proposed for specified service lives and target reliabilities. This method considers a conditional Poisson occurrence of independent and identically distributed loads as well as uncertainties in field measurement and modeling and Bayesian updating of the empirical distribution function to obtain an extreme value distribution of the time-dependent maximum live load. An illustrative example uses in-service peak strain data from ambient traffic collected on a high-volume bridge and develops in-service LRFR equations to rate the instrumented bridge. Results from the proposed method are compared with ratings derived from more traditional methods.
Field Test and Finite Element Analysis of Isotropic Bridge Deck

David Ferrand, University of Michigan; Andrzej S. Nowak, University of Nebraska; and Maria M. Szerszen, University of Michigan

The new AASHTO code for the load and resistance factor design of bridges introduced a so-called empirical method for designing deck slabs of reinforced concrete. The reinforcement ratio is constant, and it does not depend on the girder spacing. The objective is to verify whether the empirical method is adequate for wider girder spacing (~3 m (~10 ft)). Bridge behavior is analyzed by an advanced finite element method. The developed procedures are applied to two structures: a steel girder bridge and a prestressed concrete girder bridge. Strains and corresponding stresses due to dead load, live load, and shrinkage effect are determined. The analytical model is calibrated with the use of field test data. Stress distribution is then investigated. Field test results indicate a considerable difference in live load distribution factors between steel and prestressed concrete girders, primarily because of stiffness differences between the girders and the slab. Prestressed concrete girders are considerably more rigid than steel girders and therefore have very limited load sharing. For bridges designed by the empirical method, expected extreme values of the stress caused by live load (heavy trucks) were observed to be lower than the critical (cracking) values. However, dead and live loads combined with shrinkage (particularly restrained shrinkage) can lead to cracking and eventually even failure of the deck and the bridge.

Implementation of Physical Testing for Typical Bridge Load and Superload Rating

Brent M. Phares, Terry J. Wipf, and F. Wayne Klaiber, Iowa State University; and Ahmad Abu-Hawash and Scott Neubauer, Iowa Department of Transportation

Accurately and effectively assessing the safe load-carrying capacity of bridges is a common problem that bridge owners face. Diagnostic testing can be especially beneficial for bridges that are part of an aging, rapidly decaying infrastructure. In addition, diagnostic testing can assess whether superloads can safely cross a bridge. When tested, bridges typically exhibit strength and stiffness characteristics greater than traditional codified parameters and beyond conventional rating values. Commercial equipment and analytical tools have simplified the process of testing, modeling, and rating bridges. Two case studies are presented that use diagnostic load testing by the Iowa Department of Transportation (DOT) and provide information about the Iowa DOT implementation perspective. Results from testing the first bridge illustrate the diagnostic testing process. In addition, pertinent results from a bridge tested before passage of a superload (~2,848 kN (~640,000 lb)) are presented. Before the superload, the bridge was instrumented with strain transducers and tested with known, more typical loads. Several finite element models of the bridge were developed and calibrated on the basis of observed behavior and field-measured strains. Results from the calibrated model were used to calculate load ratings for the bridge through the superload geometry and axle loadings. On the basis of predicted results, the bridge owner allowed passage of the superload. During subsequent superload passages, the bridge was instrumented and monitored similarly, and data were correlated with the initial predictions to determine the validity of the system’s predictive superload capability.
Load Tests to Rate Concrete Bridges Without Plans
(presentation without paper)
Harry Shenton and Jun Huang, University of Delaware

Rating a reinforced concrete slab bridge for which plans do not exist can be a challenge for any bridge engineer. Without complete drawings, the engineer can only estimate the layout and quantities of reinforcing steel in the bridge. It is not surprising that these estimates tend to be conservative, and as a result, load ratings for these types of bridges also tend to be extremely conservative. Research has been conducted to develop a methodology for load rating of concrete bridges for which plans do not exist by using the results of a diagnostic load test. The procedure involves instrumenting the slab to measure concrete strains and displacements caused by a loaded truck of known weight. The data are then used to develop an equivalent or estimated area of reinforcing steel in the slab. Once the estimated area of steel has been determined, the slab can be rated with the use of standard analysis and rating programs. The theoretical development of the equations used to estimate the area of steel on the basis of the measured strains and displacements is presented. The procedure was tested on a typical simple slab bridge for which plans exist. The estimated areas of steel, based on the measured strains, were two to three times higher than the actual area of steel.

Effective Flange Width of Composite Girders in Negative Moment Region
Methee Chiewanichakorn, Amjad J. Aref, Stuart S. Chen, Il-Sang Ahn, and Jeffrey A. Carpenter, State University of New York, Buffalo

In the analysis and design of steel–concrete composite bridges, stresses and displacements are typically computed on the basis of elementary beam theory by using the effective flange width concept. Currently, the AASHTO load and resistance factor design (LRFD) code specifies the same effective flange width design criteria for both positive moment sections and negative moment sections. The effective flange width concept for the positive moment has been well established by many researchers. However, the classical effective flange width definition does not take into account the strain variation through the slab thickness or the stress transfer mechanism from concrete to steel reinforcements after cracking. A more appropriate effective flange width definition for the negative moment section is introduced to account for these factors. This definition was developed on the basis of the effective flange width definition for positive moment sections proposed previously. The proposed definition for the negative moment section is explored by using finite element analyses. The finite element modeling is briefly discussed, and the model is successfully verified by comparison of the results obtained through the model with the experimental results. A parametric study was performed to evaluate the effective flange width for the negative-moment section. The force transfer mechanism between concrete and reinforcements is addressed quantitatively. The finite element model–extracted effective flange widths demonstrate that full width can be used as the effective flange width in the design and analyses of the negative moment region in most cases. Numerical results also show that the effective flange width criterion in the current AASHTO LRFD specification is typically conservative, especially for bridges with wide girder spacings. The recommended revised criterion is the use of the full width.
Validation of Specification Modification by NCHRP 12-50 Process

Brian L. Goodrich, BridgeTech, Inc.; Jay A. Puckett, University of Wyoming; and Mark C. Jablin, BridgeTech, Inc.

A replacement to Article 6.10 of the AASHTO LRFD Design Bridge Design Specifications was proposed to the Subcommittee on Bridges and Structures (SCOBS) (June 2003). With data obtained from AASHTO’s Virtis Load Rating System, approximately 200 steel bridges were analyzed and reviewed by using the proposed load and resistance factor design (LRFD), the current LRFD, and the current load factor design methods. The engineering process, a comparison of the results obtained by the different methods, and the observed trends are outlined. The goal was to determine the effects that the proposed AASHTO LRFD Article 6.10 modifications had on bridges before the adoption of the specification revisions by the AASHTO SCOBS. Oral presentations at the AASHTO Annual Meeting helped bridge engineers to understand the effects of the new version of Article 6.10 on practice. This process, which uses NCHRP 12-50, is outlined, and the results are systematically reported. This is the first truly systematic validation of a significant specification modification before its adoption. The experience is noteworthy and should be documented. This process could become a trend in specification development.

Three-Dimensional Finite Element Analysis for Traffic-Induced Vibration of a Two-Girder Steel Bridge with Elastomeric Bearings

Mitsuo Kawatani and Chul-Woo Kim, Kobe University; and Naoki Kawada, Asia Civil Engineering Co., Ltd.

A three-dimensional traffic-induced dynamic response analysis of a two-span continuous two-girder steel highway bridge seated on elastomeric bearings was used to investigate the dynamic responses of local bridge members such as decks and web plates. The validity of the numerical procedure was verified by comparison of the data obtained by the procedure with data obtained in a field test. A bump that develops between the rigid surface of the approaching part of the bridge and the elastic deformation of the elastomeric supports at the instant that a vehicle enters the bridge induces an impulsive energy on the vehicle. Consequently, it affects the dynamic response of the bridge. This investigation shows that the lower torsional rigidity of two-girder bridges compared with that of conventional multigirder bridges renders the bridge susceptible to vibration because vehicles run on the cantilever part of the bridge deck. In addition, this analysis demonstrates that the out-of-plane dynamic response of the web plate is easily affected by the deck deformation caused by vehicles running between two girders. The dynamic property of the web plate connected with crossbeams is strongly affected by the dynamic characteristics of the entire motion of the bridge as well as the pitching and bouncing motions of heavy vehicles. The response of the web plate apart from that of the crossbeams, however, is dominated by dynamic sources with higher-frequency features, such as the axle-hop motion of vehicles.
New Contribution to Concrete Arch Bridge Construction
Jure Radić, Zlatko Šavor, and Igor Gukov, University of Zagreb

True reinforced concrete arches are discussed from the aspects of the structural materials, the structural system, the shape of the arch, and construction methods. Four large concrete arch bridges were built on the Adriatic Sea coast in Croatia from 1965 to 1980. The degradation of those bridges and their maintenance problems are discussed. The designs for two new large arch bridges are presented. The shapes of the arches were designed so that the bending moments under permanent actions would be minimized. This was done by the use of a computer program developed for the purpose.

Helix Pedestrian Bridge
David K. McMullen, KPFF Consulting Engineers

Amgen Incorporated, one of the world’s largest biotechnology firms, recently developed a new research center on the Elliot Bay waterfront of Seattle, Washington. As part of the research center, a pedestrian bridge was built to connect the campus with a major transportation corridor. The owner’s goal for the new pedestrian bridge was to create a signature gateway to Amgen’s campus. The pedestrian bridge is a three-arch structure that depicts a three-dimensional helix. The overall shape of the bridge both reflects the helical DNA that connects all life and references the vital research under way at Amgen. The arches create the outline of the basic DNA helix, and the deck support and roof trusses complete the remaining components of the helix. The abstract double helix provided many design and construction challenges. The slim profile, large enclosed areas, and suspended deck meant wind and pedestrian vibration would be critical design considerations. The unique shape made it difficult to apply the standard building or bridge design codes. The contractor was faced with erecting this twisting structure over active railroad tracks while meeting tight geometric specifications. The bridge stands today as a testimony to the owner’s vision, teamwork, innovation in bridge design, and creative construction techniques. The bridge combines both form and function to show how an ordinary pedestrian bridge can become an extraordinary statement while serving its intended function. The project has won broad community support in the few months that it has been open.
Main Street Replacement Bridge, Columbus, Ohio
David M. Rogowski, Genesis Structures, Inc.; Daniel K. O’Rorke, DLZ Ohio, Inc.; and Greg DeMond, HNTB Corporation

Faced with the challenge of replacing an existing Art Deco arch bridge, the city of Columbus, Ohio, decided against replication in favor of constructing a new aesthetic symbol for the city. The proposed Main Street Replacement Bridge, a bridge consisting of a single-ribbed arch inclined at a 10-degree angle, will gracefully span the Scioto River and will provide the city with its new aesthetic symbol, as well as provide the final link between new parkway developments on both banks of the river. The original design concept was abandoned because of increasing construction complexities compounded by a decreasing budget allowance. With a client committed to aesthetic design, a requirement for a less complicated erection process, and a shortened construction timeline, the engineers were challenged to redesign the bridge within the revised budget while maintaining the intriguing geometry of the previous bridge design. How the design team overcame the new design challenges and, specifically, the redesign of the arch geometry, the reshaping and redesign of the pedestrian and vehicular decks, the redesign of the lateral bracing of the inclined arch, and the complete overhaul of the bridge piers is described.

Structural and Aesthetic Considerations in the Design of Curved Cable-Supported Pedestrian Bridges
Miguel Rosales, Rosales Gottemoeller & Associates, Inc.; Andrea Kratz, Andreas Keil, and Jorg Schlaich, Schlaich Bergermann und Partner

Pedestrian bridges should create interest in their configuration and demonstrate the possibilities of bridge engineering. A curved plan may allow a bridge to be oriented toward a particular view or to fit into a larger urban design plan. The design of curved cable-supported pedestrian bridges requires certain aesthetic and structural considerations. Two case studies are presented: a recently completed 380-ft curved pedestrian bridge supported by a single suspension cable over the Reedy River in Greenville, South Carolina, and a proposed curved cable-stayed bridge over the Charles River next to the Museum of Science in Boston, Massachusetts. The curved configuration of these bridges takes advantage of opposing cable forces to provide dynamic stability with a minimum of materials and without the use of dampers. Both bridges are expected to become instant icons because of their unique configurations and spectacular sites.
Design of the Main Spans of the Chongqing, China, Caiyuanba Bridge
Man-Chung Tang and John Sun, T. Y. Lin International

The new Caiyuanba Bridge over the Yangtze River in Chongqing, China, will carry six lanes of highway and two pedestrian walkways on its upper deck as well as two tracks of monorails on its lower deck. As one of the transportation backbones for this ever-expanding city, it will connect the two busiest business districts: Yuzhong and Nanan. Because the bridge is located at the center of the city and is visible from most parts of the city, aesthetic issues are an important concern. After careful study of the location, a slender tied arch was selected to carry the double-level bridge girder over the Yangtze River. On completion, its 420-m span will be the world’s longest tied arch span for combined rail and highway traffic. The side spans are 102 m long.
The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy’s purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. William A. Wulf are chair and vice chair, respectively, of the National Research Council.

The Transportation Research Board is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board’s mission is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. The Board’s varied activities annually engage more than 5,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.
## Program at a Glance

### Sunday, July 17, 2005
- **4:30 P.M.–6:30 P.M.** Projects Showcase Poster Session (light reception included)

### Monday, July 18, 2005
- **8:30 A.M.–9:30 A.M.** Opening General Session
- **9:30 A.M.–10:00 A.M.** Coffee and tea break
- **10:00 A.M.–11:30 A.M.** Plenary Session 1: Security, Reliability, and Sustainability
- **11:45 A.M.–1:15 P.M.** Monday Lunch with Speaker
- **1:30 P.M.–3:00 P.M.** Technical Session 1: Advances in Load and Resistance Factor Design Research
- **3:00 P.M.–3:30 P.M.** Coffee and tea break
- **3:30 P.M.–5:00 P.M.** Technical Session 2: Bridge Management Systems
- **5:00 P.M.–5:30 P.M.** Technical Session 3: Prefabricated Bridges
- **5:30 P.M.–6:30 P.M.** Technical Session 4: Advances in Load and Resistance Factor Design Practice
- **6:30 P.M.–7:30 P.M.** Technical Session 5: Nondestructive Evaluation of Bridges
- **7:30 P.M.–8:30 P.M.** Technical Session 6: Accelerated Construction

### Tuesday, July 19, 2005
- **8:30 A.M.–10:00 A.M.** Plenary Session 2: Security, Reliability, and Sustainability
- **10:00 A.M.–10:30 A.M.** Coffee and tea break
- **10:30 A.M.–NOON** Technical Session 7: Seismic Design and Evaluation
- **NOON–1:15 P.M.** Tuesday Lunch with Speaker
- **1:30 P.M.–3:00 P.M.** Technical Session 8: Bridge Durability
- **3:00 P.M.–3:30 P.M.** Coffee and tea break
- **3:30 P.M.–5:00 P.M.** Technical Session 9: Innovative Materials and Methods
- **5:00 P.M.–5:30 P.M.** Technical Session 10: Seismic Design and Retrofit
- **5:30 P.M.–6:30 P.M.** Technical Session 11: Bridge Health Monitoring
- **6:30 P.M.–7:30 P.M.** Technical Session 12: Innovative Methods I
- **7:30 P.M.–8:30 P.M.** Technical Session 13: Extreme Events
- **8:30 P.M.–9:00 P.M.** Technical Session 14: Scour and Maintenance
- **9:00 P.M.–10:00 P.M.** Technical Session 15: Innovative Methods II

### Wednesday, July 20, 2005
- **8:30 A.M.–10:00 A.M.** Plenary Session 3: Security, Reliability, and Sustainability
- **10:00 A.M.–10:30 A.M.** Coffee and tea break
- **10:30 A.M.–NOON** Technical Session 16: Bridge Evaluation and Load Rating
- **NOON–1:15 P.M.** Technical Session 17: Innovative Design and Research
- **1:15 P.M.–2:15 P.M.** Technical Session 18: Bridge Aesthetics