

# Bridge Evaluation Quality Assurance in Europe

## **SPONSORED BY:**



U.S. Department of Transportation  
Federal Highway Administration

## **IN COOPERATION WITH:**

American Association of State Highway and  
Transportation Officials

National Cooperative Highway Research Program

**MARCH 2008**

## **NOTICE**

The Federal Highway Administration provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

1. Report No. FHWA-PL-08-016	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Bridge Evaluation Quality Assurance in Europe		5. Report Date March 2008	
7. Author(s) Thomas D. Everett, Peter Weykamp, Harry A. Capers, William R. Cox, Thomas S. Drda, Lawrence Hummel, Paul Jensen, David A. Juntunen, Tod Kimball, Glenn A. Washer		6. Performing Organization Code	
9. Performing Organization Name and Address American Trade Initiatives P.O. Box 8228 Alexandria, VA 22306-8228		8. Performing Organization Report No.	
12. Sponsoring Agency Name and Address Office of International Programs Office of Policy Federal Highway Administration, U.S. Department of Transportation American Association of State Highway and Transportation Officials National Cooperative Highway Research Program		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. DTFH61-99-C-005	
15. Supplementary Notes FHWA COTR: Hana Maier, Office of International Programs		13. Type of Report and Period Covered	
16. Abstract The National Bridge Inspection Standards require transportation agencies to use quality control and quality assurance procedures to maintain accuracy and consistency in their bridge inspection programs. The Federal Highway Administration, American Association of State Highway and Transportation Officials, and National Cooperative Highway Research Program sponsored a scanning study to look at European bridge inspection practices related to quality assurance.  The scan team found that European agencies use their bridge inspection programs to insure highway user safety, meet durability and serviceability expectations, and enhance capital investment decisions. They emphasize quality assurance through well-defined inspector qualifications, periodic calibration of inspectors, data collection, and the use of appropriate equipment to evaluate structures.  Team recommendations for U.S. implementation include developing a rational basis for bridge inspection frequency, guidelines for developing quality assurance/quality control procedures, illustrations and reference photos for manuals, and integrated inspection repair approaches.		14. Sponsoring Agency Code	
		17. Key Words bridge inspection, inspector training, nondestructive testing, quality assurance, quality control	
19. Security Classify. (of this report) Unclassified	20. Security Classify. (of this page) Unclassified	21. No. of Pages 56	22. Price Free



# Acknowledgments

THE SCAN TEAM MEMBERS wish to acknowledge all of the international host transportation agencies and private firms for their significant contributions to the success of this scan. We also thank them for their gracious hospitality, their excellent presentations, and their sharing of their knowledge and experiences with the team. We truly learned much from our interaction with them all.

The team also thanks the Federal Highway Administration Office of International Programs and the American Association of State Highway and Transportation Officials for their leadership, vision, and support of this effort and American Trade Initiatives, Inc. for making this effort happen.





# Bridge Evaluation Quality Assurance in Europe

## PREPARED BY THE INTERNATIONAL SCANNING STUDY TEAM:

**Thomas D. Everett** (cochair)  
*FHWA*

**Peter Weykamp** (cochair)  
*New York State DOT*

**Harry A. Capers** (report facilitator)  
*Arora and Associates*

**William R. Cox**  
*Texas DOT*

**Thomas S. Drda**  
*FHWA*

**Lawrence Hummel**  
*Van Buren County, MI,  
Road Commission*

**Paul Jensen**  
*Montana DOT*

**David A. Juntunen**  
*Michigan DOT*

**Tod Kimball**  
*FHWA*

**Glenn A. Washer**  
*University of Missouri–Columbia*

for

**Federal Highway Administration  
U.S. Department of Transportation**

**American Association of State Highway  
and Transportation Officials**

**National Cooperative Highway  
Research Program**

**March 2008**

# International Technology Scanning Program

## THE INTERNATIONAL TECHNOLOGY

Scanning Program, sponsored by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP), evaluates innovative foreign technologies and practices that could significantly benefit U.S. highway transportation systems. This approach allows for advanced technology to be adapted and put into practice much more efficiently without spending scarce research funds to re-create advances already developed by other countries.

FHWA and AASHTO, with recommendations from NCHRP, jointly determine priority topics for teams of U.S. experts to study. Teams in the specific areas being investigated are formed and sent to countries where significant advances and innovations have been made in technology, management practices, organizational structure, program delivery, and financing. Scan teams usually include representatives from FHWA, State departments of transportation, local governments, transportation trade and research groups, the private sector, and academia.

After a scan is completed, team members evaluate findings and develop comprehensive reports, including recommendations for further research and pilot projects to verify the value of adapting innovations for U.S. use. Scan reports, as well as the results of pilot programs and research, are circulated throughout the country to State and local transportation officials and the private sector. Since 1990, about 70 international scans have been organized on topics such as pavements, bridge construction and maintenance, contracting, intermodal transport, organizational management, winter road maintenance, safety, intelligent transportation systems, planning, and policy.

The International Technology Scanning Program has resulted in significant improvements and savings in road program technologies and practices throughout the United States. In some cases, scan studies have facilitated joint research and technology-sharing projects with international counterparts, further conserving resources and advancing the state of the art. Scan studies have also exposed transportation professionals to remarkable advancements and inspired

implementation of hundreds of innovations. The result: large savings of research dollars and time, as well as significant improvements in the Nation's transportation system.

Scan reports can be obtained through FHWA free of charge by e-mailing [international@dot.gov](mailto:international@dot.gov). Scan reports are also available electronically and can be accessed on the FHWA's Office of International Programs Web site at [www.international.fhwa.dot.gov](http://www.international.fhwa.dot.gov).

# International Technology Scanning Reports

## International Technology Scanning Program: Bringing Global Innovations to U.S. Highways

### Safety

- Safety Applications of Intelligent Transportation Systems in Europe and Japan* (2006)
- Traffic Incident Response Practices in Europe* (2006)
- Underground Transportation Systems in Europe: Safety, Operations, and Emergency Response* (2006)
- Roadway Human Factors and Behavioral Safety in Europe* (2005)
- Traffic Safety Information Systems in Europe and Australia* (2004)
- Signalized Intersection Safety in Europe* (2003)
- Managing and Organizing Comprehensive Highway Safety in Europe* (2003)
- European Road Lighting Technologies* (2001)
- Commercial Vehicle Safety, Technology, and Practice in Europe* (2000)
- Methods and Procedures to Reduce Motorist Delays in European Work Zones* (2000)
- Innovative Traffic Control Technology and Practice in Europe* (1999)
- Road Safety Audits—Final Report and Case Studies* (1997)
- Speed Management and Enforcement Technology: Europe and Australia* (1996)
- Safety Management Practices in Japan, Australia, and New Zealand* (1995)
- Pedestrian and Bicycle Safety in England, Germany, and the Netherlands* (1994)

### Planning and Environment

- Active Travel Management: The Next Step in Congestion Management* (2007)
- Managing Travel Demand: Applying European Perspectives to U.S. Practice* (2006)

- Transportation Asset Management in Australia, Canada, England, and New Zealand* (2005)
- Transportation Performance Measures in Australia, Canada, Japan, and New Zealand* (2004)
- European Right-of-Way and Utilities Best Practices* (2002)
- Geometric Design Practices for European Roads* (2002)
- Wildlife Habitat Connectivity Across European Highways* (2002)
- Sustainable Transportation Practices in Europe* (2001)
- Recycled Materials in European Highway Environments* (1999)
- European Intermodal Programs: Planning, Policy, and Technology* (1999)
- National Travel Surveys* (1994)

### Policy and Information

- European Practices in Transportation Workforce Development* (2003)
- Intelligent Transportation Systems and Winter Operations in Japan* (2003)
- Emerging Models for Delivering Transportation Programs and Services* (1999)
- National Travel Surveys* (1994)
- Acquiring Highway Transportation Information From Abroad* (1994)
- International Guide to Highway Transportation Information* (1994)
- International Contract Administration Techniques for Quality Enhancement* (1994)
- European Intermodal Programs: Planning, Policy, and Technology* (1994)

### Operations

- Commercial Motor Vehicle Size and Weight Enforcement in Europe* (2007)
- Active Travel Management: The Next Step in Congestion Management* (2007)
- Managing Travel Demand: Applying European Perspectives to U.S. Practice* (2006)
- Traffic Incident Response Practices in Europe* (2006)

*Underground Transportation Systems in Europe: Safety, Operations, and Emergency Response* (2006)

*Superior Materials, Advanced Test Methods, and Specifications in Europe* (2004)

*Freight Transportation: The Latin American Market* (2003)

*Meeting 21st Century Challenges of System Performance Through Better Operations* (2003)

*Traveler Information Systems in Europe* (2003)

*Freight Transportation: The European Market* (2002)

*European Road Lighting Technologies* (2001)

*Methods and Procedures to Reduce Motorist Delays in European Work Zones* (2000)

*Innovative Traffic Control Technology and Practice in Europe* (1999)

*European Winter Service Technology* (1998)

*Traffic Management and Traveler Information Systems* (1997)

*European Traffic Monitoring* (1997)

*Highway/Commercial Vehicle Interaction* (1996)

*Winter Maintenance Technology and Practices—Learning from Abroad* (1995)

*Advanced Transportation Technology* (1994)

*Snowbreak Forest Book—Highway Snowstorm Countermeasure Manual* (1990)

## **Infrastructure—General**

*Audit Stewardship and Oversight of Large and Innovatively Funded Projects in Europe* (2006)

*Construction Management Practices in Canada and Europe* (2005)

*European Practices in Transportation Workforce Development* (2003)

*Contract Administration: Technology and Practice in Europe* (2002)

*European Road Lighting Technologies* (2001)

*Geometric Design Practices for European Roads* (2001)

*Geotechnical Engineering Practices in Canada and Europe* (1999)

*Geotechnology—Soil Nailing* (1993)

## **Infrastructure—Pavements**

*Warm-Mix Asphalt: European Practice* (2008)

*Long-Life Concrete Pavements in Europe and Canada* (2007)

*Quiet Pavement Systems in Europe* (2005)

*Pavement Preservation Technology in France, South Africa, and Australia* (2003)

*Recycled Materials in European Highway Environments* (1999)

*South African Pavement and Other Highway Technologies and Practices* (1997)

*Highway/Commercial Vehicle Interaction* (1996)

*European Concrete Highways* (1992)

*European Asphalt Technology* (1990)

## **Infrastructure—Bridges**

*Bridge Evaluation Quality Assurance in Europe* (2008)

*Prefabricated Bridge Elements and Systems in Japan and Europe* (2005)

*Bridge Preservation and Maintenance in Europe and South Africa* (2005)

*Performance of Concrete Segmental and Cable-Stayed Bridges in Europe* (2001)

*Steel Bridge Fabrication Technologies in Europe and Japan* (2001)

*European Practices for Bridge Scour and Stream Instability Countermeasures* (1999)

*Advanced Composites in Bridges in Europe and Japan* (1997)

*Asian Bridge Structures* (1997)

*Bridge Maintenance Coatings* (1997)

*Northumberland Strait Crossing Project* (1996)

*European Bridge Structures* (1995)

***All publications are available on the Internet at  
www.international.fhwa.dot.gov.***

# Table of Contents

<b>Executive Summary</b> .....	1	Nondestructive Testing .....	23
Overview .....	1	Finland .....	23
Summary of Initial Findings .....	2	Norway.....	23
Detailed and Illustrated Inspection References		Germany .....	23
and Tools .....	2	Cause of Damage Determination .....	24
Reports and Data Management .....	2	Other .....	25
Bridge Inspector Training and Certification .....	2	Recommendations.....	25
Inspection Types and Frequencies .....	2	Planned Implementation Activities .....	26
Use of Reference Bridges .....	3		
Nondestructive Testing.....	3	<b>Chapter 3: Recommendations and</b>	
Cause of Damage Determination.....	3	<b>Implementation Activities</b> .....	27
Other.....	3	Introduction.....	27
Recommendations.....	4	Key Items for Implementation.....	27
Implementation Activities.....	4	Develop a Rational Basis for Bridge Inspection	
<b>Chapter 1: Introduction</b> .....	5	Frequency.....	27
Background.....	5	Develop Guidelines for Developing QA/QC	
Objectives .....	5	Procedures for States.....	27
Amplifying Questions.....	5	Develop Illustrations and Reference Photos	
Host Countries .....	5	for Manuals.....	28
Team Members .....	6	Develop Integrated Inspection Repair	
		Approaches .....	28
<b>Chapter 2: Findings on Bridge</b>		Transfer Technology Discoveries From the	
<b>Evaluation Quality Assurance</b> .....	7	Scanning Study .....	29
Detailed and Illustrated Inspection		Initiate a Demonstration Project on the	
References and Tools .....	7	Ultrasonic Shear Wave Transducer.....	29
Finland .....	7		
Norway.....	8	<b>Appendix A: Amplifying Questions</b> .....	31
Germany .....	8	<b>Appendix B: Team Members</b> .....	33
Reports and Data Management .....	10	<b>Appendix C: Host Country Contacts</b> ....	37
Finland .....	10	<b>Appendix D: Glossary of Terms</b> .....	39
Norway.....	11	<b>Appendix E: Abbreviated Index to the</b>	
Germany .....	12	<b>Finnish Road Administration Bridge</b>	
Bridge Inspector Training and Certification.....	14	<b>Repair Directives (SILKO)</b> .....	41
Finland .....	15		
Norway.....	16	<b>Figures</b>	
Sweden.....	17	<b>Figure 1.</b> Sample pages from the Finnra Guidelines for	
France.....	17	Bridge Inspection that include diagrams of how to	
Germany .....	18	perform inspections and typical structural details. ....	7
Inspection Types and Frequencies.....	19		
Finland .....	19		
Denmark .....	20		
Norway.....	20		
Sweden.....	21		
France .....	21		
Germany .....	21		
Use of Reference Bridges.....	22		

## TABLE OF CONTENTS

<b>Figure 2.</b> Sample pages from the Finnra Bridge Inspection Manual providing specific coding guidelines. ....	8
<b>Figure 3.</b> Finnra’s Bridge Repair Manual (SILKO Guidelines). ....	8
<b>Figure 4.</b> German federal guidance on describing cracks in superstructures. ....	10
<b>Figure 5.</b> Interior of German inspection vehicle showing conferencing workspace. ....	11
<b>Figure 6.</b> Finnra guidelines for coding condition, damage type, and cause. ....	11
<b>Figure 7.</b> Standardized report form used by Danish firm Ramboll. ....	12
<b>Figure 8.</b> Calculation of Condition Index. ....	12
<b>Figure 9.</b> Screenshot of SIB-Bauwerke Release 2006 showing cataloged damage to bridge deck joint. ....	14
<b>Figure 10.</b> Screenshot of SIB-Bauwerke Release 2006 showing inspector-generated rating page. ....	16
<b>Figure 11.</b> IQOA grading scheme for bridge condition. ....	21
<b>Figure 12.</b> Ultrasonic shear wave transducer. ....	24
<b>Figure 13.</b> Permanent traveler on Great Link Bridge to provide inspection and maintenance access to underside of superstructure. ....	25
 <b>Tables</b>	
<b>Table 1.</b> Scan itinerary. ....	6
<b>Table 2.</b> Classification of cracks in concrete structures and recommended repair procedures, from the Finnra Bridge Inspection Manual. ....	9
<b>Table 3.</b> Damage assessment—structural stability. ....	13
<b>Table 4.</b> Damage assessment—traffic safety. ....	13
<b>Table 5.</b> Damage assessment—durability. ....	14
<b>Table 6.</b> Condition Index (1). ....	15
<b>Table 7.</b> Condition Index (2). ....	16
<b>Table 8.</b> Number of reference bridges to be inspected versus anticipated inspector assignments. ....	23

# Abbreviations and Acronyms

<b>AASHTO</b>	American Association of State Highway and Transportation Officials
<b>ADT</b>	average daily traffic
<b>BASt</b>	Bundesanstalt für Straßenwesen
<b>BaTMan</b>	Swedish Road Administration's bridge management system
<b>BMS</b>	bridge management system
<b>BRUTUS</b>	Norwegian Public Roads Administration's bridge management system
<b>Danbro</b>	Danish Road Directorate's bridge management system
<b>DOT</b>	department of transportation
<b>DRD</b>	Danish Road Directorate
<b>FHWA</b>	Federal Highway Administration
<b>Finnra</b>	Finnish Road Administration
<b>GIS</b>	geographic information system
<b>IQOA</b>	Image de la Qualité des Ouvrages d'Art
<b>LCPC</b>	Laboratoire Central des Ponts et Chaussées
<b>MR&amp;R</b>	maintenance, repair, and rehabilitation
<b>NBIS</b>	National Bridge Inspection Standards
<b>NCHRP</b>	National Cooperative Highway Research Program
<b>NDE</b>	nondestructive evaluation
<b>NDT</b>	nondestructive testing
<b>QC/QA</b>	quality control/quality assurance
<b>SETRA</b>	Service d'Etudes Techniques des Routes et Autoroutes
<b>SRA</b>	Swedish Road Administration
<b>TRB</b>	Transportation Research Board



# Executive Summary

## Overview

ONE OF THE PRIMARY GOALS OF THE U.S. transportation community is to improve safety on the Nation's roadways. In response to that goal, Federal, State, and local transportation agencies consider the inspection of the country's nearly 600,000 bridges vitally important. These agencies invest significant funds in bridge inspection activities each year. There is high interest in making sure that the quality of the bridge inspection program is maintained at the highest level and that funds are used as effectively as possible.

The National Bridge Inspection Standards (NBIS) were developed to establish standards for a nationwide bridge inspection program. The intent of this program is to monitor and document the condition of bridges and enhance bridge safety. The January 2005 revision of the NBIS specifically requires State and Federal agencies to assure that quality control/quality assurance (QC/QA) procedures are used to maintain a high degree of accuracy and consistency in the bridge inspection program. The Federal government defines quality assurance as the use of sampling and other measures to assure the adequacy of quality control procedures to verify or measure the quality level of the entire bridge inspection and load rating program. It defines quality control as procedures intended to maintain the quality of a bridge inspection and load rating at or above a specified level. In addition, many bridge owners have elected to collect data beyond that required by the NBIS. Better knowledge of QC/QA programs and data types collected abroad should provide meaningful advice to the U.S. transportation community.

The Federal Highway Administration (FHWA) and most bridge owners also have strategic goals on improving the overall condition of bridges and tactical programs aimed at extending service life. These goals are commonly derived from the interpretation of bridge deficiency data identified and documented through the bridge inspection program. In addition, FHWA uses the inspection data as a factor in allocating and distributing Highway Bridge Program funds. Improving the overall quality and determining that the right data are reported through the inspection program will help maintain a high level of safety for the traveling public, ensure effective

use of limited funds with an equitable distribution, and assist bridge owners in achieving their safety and mobility goals.

A 10-member team was formed to study European bridge inspection practices, specifically those related to quality assurance. This team consisted of three representatives from FHWA, four representatives from State departments of transportation, a representative from the National Association of County Engineers, a representative from academia, and a structural engineering design consultant who also served as the report facilitator. The scan was sponsored by FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP).

The team conducted a series of meetings and site visits with representatives of government agencies and private sector organizations abroad between June 1 and 17, 2007. The team visited Denmark, Finland, France, and Germany and also met with representatives from Norway and Sweden. The countries were selected through a desk scan based on their advanced activities in bridge evaluation, bridge management, and quality assurance.

The results of this scanning study are intended to assist bridge owners and FHWA in refining and continuously improving actions taken to address the provisions of the 2005 NBIS regulation. Although many QC/QA programs exist in the United States, there was significant interest in exploring the most effective bridge inspection systems in other countries. FHWA is also obligated to satisfy the guidelines provided through the Data Quality Act passed by the U.S. Congress in 2001. The data collected through the U.S. bridge inspection program not only enhance bridge safety for the traveling public, but also help form the basis for programming bridge maintenance, repair, rehabilitation, and replacement activities.

Scan team topics of interest included the following:

- ❖ Organizational structure and background
- ❖ Inspection data
- ❖ Personnel qualifications
- ❖ Process control
- ❖ Equipment
- ❖ Documentation

## Summary of Initial Findings

Generally speaking, the team found that the European host agencies put a tremendous value on their bridge inspection programs not only to ensure highway user safety, but also to ensure that durability and serviceability expectations are met and to enhance capital investment decisions on the existing bridge inventory. The agencies place major emphasis on providing for quality assurance through well-defined inspector qualifications, periodic calibration of inspectors, data collection processes, and the use of appropriate equipment to evaluate their structures. Most of the agencies had major programs aimed at inspection uniformity, developed a multitiered inspection program, and had procedures for performing damage assessment and programming maintenance and repair through their inspection process.

The scan team identified many bridge inspection practices and technologies related to the topics of interest. The order in which they are presented in this report is for clarity and does not reflect the priority recommended by the team.

### *Detailed and Illustrated Inspection References and Tools*

Many detailed, heavily illustrated manuals and references were available as tools for bridge inspectors. These included inspection manuals, maintenance guides, repair manuals, and coding and recording data guides. The primary approach in the United States and the European countries the team visited is visually based inspection. The Europeans use visual aids to a greater extent in recording and coding of data, damage assessment, and maintenance and repair. Numerous manuals are available for inspection and maintenance. To focus inspectors and provide more uniform ratings, types of damage with performance indices were quantified with accompanying photographs. These manuals contain many photos and drawings showing damage and corresponding rating levels. Several countries have implemented standards to quantify concrete cracking in inspection reports. European inspectors were observed to have photographs from past inspections on site to use in current inspections. Inspection vehicles in Germany were fully equipped with field equipment, office space, and bridge records to support activities at the inspection site.

### *Reports and Data Management*

All countries visited practiced standardization of inspection reports, forms, terms, and ratings. Noteworthy practices included generating customized bridge inspection forms by bridge management systems, standardizing terms and rating criteria for inspectors, embedding digital photographs in inspection reports,

and requiring designers to identify critical areas of a structure to be inspected. In the field, the inspectors include a level of urgency for any required repair in their assessment of damage found. This level of urgency is used to determine annual allocations of funds, program maintenance repairs, and track repair backlogs.

In Germany, inspectors use a computer program in which they select a structural condition from a pull-down menu and allow the program to generate a rating. In Denmark, separate asset management policies, systems, and practices have been established for major structures to allow better decisionmaking for capital investments.

### *Bridge Inspector Training and Certification*

A variety of approaches are taken by European countries to train and certify inspectors. All countries have technical educational requirements for inspectors, and most require those who lead inspectors to have an engineering degree. Many have specialized training requirements for inspectors to ensure the quality of the inspection and the data provided. Specialized training at the program manager level and performance-based testing requirements were believed to be significant.

Maintaining a core of in-house staff with expertise in bridge inspection is a high priority for European owners. Experienced staff provides a cadre of personnel to act as trainers and certifiers of new staff and vendors, provide quality assurance reviews of work performed on behalf of the agency, and develop reference materials in support of agency programs.

### *Inspection Types and Frequencies*

All of the countries visited had clear definitions of inspection types and several well-defined scopes for their inspections.

A typical finding was that European agencies have developed a technical decisionmaking process for determining inspection frequency. Usually included in this process is the competency of the inspection crew. Host nations visited believed that inspector qualifications and experience requirements provided confidence in allowing inspectors to determine the duration between cycles of inspections, which are typically up to 5 or 6 years but up to 9 years in France. Denmark and France use risk acceptance criteria to help determine inspection type and frequency.

In establishing their programs, the host nations chose inspection intervals based on the amount of detail in their inspections, interim maintenance inspections, and qualifications of their inspectors. However, the host

nations allow the inspection frequency of any individual bridge to be shorter (or perhaps longer in the case of France) than the set frequency or maximum frequency to allow for better allocation of human and capital resources. They base the decision on a number of factors typically related to inventory data, such as condition, size, structure type, age, average daily traffic, and complexity.

### ***Use of Reference Bridges***

Finland had a unique approach to insuring quality. The Finnish Road Administration uses 106 bridges and 26 steel culverts as a control sample or set of reference bridges. Baseline data are gathered from these bridges by experienced in-house bridge inspection staff to provide consistency.

Data gathered are used to fulfill a variety of needs, including the following:

- ❖ Provision of data on bridge serviceability and durability over time
- ❖ Trend analysis of data gathered on similar bridges and updating of deterioration models in the bridge management system
- ❖ Quality control of inspection data from nonreference bridges by providing baseline data for comparison
- ❖ Training and refresher training of inspectors and evaluation of inspector condition ratings against condition ratings provided by in-house staff and the mean of all inspectors

### ***Nondestructive Testing***

During inspections, host nation bridge inspectors use nondestructive testing (NDT) to assist in their condition coding. Several agencies had detailed references outlining the appropriate use of NDT devices and methods, including terms and definitions, defects for which they are applicable and, in Germany, independent evaluations of NDT products by users. Also, the team observed several unique applications of NDT technology, such as the German use of a specially configured ultrasonic shear wave transducer to identify defects.

Several agencies also use bridges to be demolished to evaluate the effectiveness of NDT methods when possible.

### ***Cause of Damage Determination***

Most of the agencies visited include a cause-of-damage investigation by the inspector as part of their bridge inspection procedure. Inspectors are trained to assess damage to a structural element based on structural stability, user safety, and effect on the damaged component's durability and to recommend corrective action to address the damage. Using the inspector's knowledge of structures, coupled with a determination of urgency,

an agency can calculate the immediate and short-term programming levels required. All agencies had procedures that would initiate actions based on the severity of the condition found, with or without a higher level of review and approval. In all cases in which critical structural conditions are found, immediate needs are addressed by contact with the individual responsible for the facility, thus ensuring public safety and protection of the facility from additional damage. Several other owners have procedures to initiate maintenance activities at the direction of the inspector.

Maintenance activities were generally tracked by all agencies in their bridge records. This provided better management data on actual bridge conditions and costs associated with a structure.

In Europe, the emphasis is greater on determining the cause of a particular defect in the bridge. This is in contrast to the U.S. approach of characterizing the element or component, which essentially characterizes the effect of the defect. As a result, integration of mitigation strategies is greater (i.e., repair and rehabilitation activities specified by the inspector).

### ***Other***

An additional item of interest identified for consideration in the United States was a DVD developed for use in Germany, "Inspection According to German Industrial Standard (DIN) No. 1076." The DVD is intended for viewing by the general public and outlines the reasons for bridge and structure inspection. The DVD not only provides an informative overview of the inspection process, it also appears to be a useful mechanism for maintaining support from its audience for bridge inspection activities.

The general practice of host agencies was not to use dedicated inspectors on bridges, but to rotate inspectors on subsequent inspections. This practice provides a fresh assessment of the bridge's condition, which in turn should provide for a more reliable assessment or at least confirmation of the bridge's true condition.

During bridge inspection site visits, the team observed bridge details incorporated in the design process to facilitate bridge inspections. At the Great Link Bridge in Denmark, elevators allowed easy access to the towers. Inspectors used a monorail inside the tub girder to move through the structure and transport inspection equipment. A permanent traveler was installed for inspecting the structure's exterior. A measuring system integral with the bearing was used to determine bearing displacement. Also, the pier cap at the expansion end was designed to allow access to inspect the post-tensioning anchor block and modular joint. In Germany,

concrete steps were built along the wing wall to allow for safe traverse of the side slope. These details would also be helpful in performing bridge maintenance activities.

### Recommendations

Based on the above findings, the preliminary recommendations of the team are as follows:

1. Develop a nationally accepted basis for determining bridge inspection frequencies that combines different levels of inspection intensity based on factors such as safety, condition, age of the structure, and engineering judgment with clear standards for inspector education, training, and qualification.
2. Draft national guidelines for developing QC/QA procedures for use by State in-house staff, as well as similar guidelines to be made a part of bridge inspection services contracts.
3. Develop detailed coding guidance, complete with illustrations and reference photos.
4. Develop integrated inspection and repair approaches for use by bridge inspectors.
5. Consider the following discoveries from the scanning study as potential candidates for transfer technology:
  - ❖ Crack mapping keys and 2-D scaled representations
  - ❖ Nondestructive evaluation toolbox data sheets from the European Union's Sustainable Bridge project
  - ❖ Expanded inventory of access equipment for bridge inspection
  - ❖ Available data from the Sustainable Bridge project
6. Initiate a demonstration project on the ultrasonic shear wave transducer for use in identifying defects in concrete.

### Implementation Activities

The scan team has developed a detailed implementation plan for the recommended initiatives and practices. Included in the plan are a number of technical presentations and papers at national meetings and conferences sponsored by FHWA, AASHTO, and other organizations to disseminate information from the scan. The plan also includes coordination with AASHTO and FHWA to advance these initiatives and practices, including assisting with development of new FHWA and AASHTO standards and guidelines governing quality in bridge inspection. These and other planned activities are discussed in Chapter 3.

## CHAPTER 1:

# Introduction

## Background

ONE OF THE PRIMARY GOALS OF THE U.S. transportation community is to improve safety on the Nation's roadways. In response to that goal, Federal, State, and local transportation agencies consider the inspection of the country's nearly 600,000 bridges vitally important. These agencies invest significant funds in bridge inspection activities each year. There is high interest in making sure that the quality of the bridge inspection program is maintained at the highest level and that funds are used as effectively as possible.

The National Bridge Inspection Standards (NBIS) were developed to establish standards for a nationwide bridge inspection program. The intent of this program is to monitor and document the condition of bridges and enhance bridge safety. The January 2005 revision to the NBIS specifically requires State and Federal agencies to assure that quality control/quality assurance (QC/QA) procedures are used to maintain a high degree of accuracy and consistency in the bridge inspection program. The Federal government defines quality assurance as the use of sampling and other measures to assure the adequacy of quality control procedures to verify or measure the quality level of the entire bridge inspection and load-rating program. It defines quality control as procedures intended to maintain the quality of a bridge inspection and load rating at or above a specified level. In addition, many bridge owners have elected to collect data beyond that required by the NBIS. Better knowledge of QC/QA programs and data types collected abroad should provide meaningful advice to the U.S. transportation community.

The Federal Highway Administration (FHWA) and bridge owners also have strategic goals on improving the overall condition of bridges and tactical programs aimed at extending service life. These goals are commonly derived from the interpretation of bridge data identified and documented through the bridge inspection program. FHWA also uses the inspection data as a factor for allocating and distributing Highway Bridge Program funds. Improving the overall quality and determining that the right data are reported through the inspection program will help maintain a high level of safety for the traveling public, ensure effective use of limited funds with an equitable distribution, and assist bridge owners in achieving their safety and mobility goals.

## Objectives

The results of this scan are intended to assist bridge owners and FHWA in refining and continuously improving actions taken to address the provisions of the 2005 NBIS regulation. Although many QC/QA programs exist in the United States, there was significant interest in exploring the most effective bridge inspection systems in other countries. FHWA is also obligated to satisfy the guidelines of the Data Quality Act, passed by the U.S. Congress in 2001. The data collected through the U.S. bridge inspection program must not only enhance bridge safety for the traveling public, but also help form the basis for programming bridge maintenance, repair, rehabilitation, and replacement activities.

The scanning study was cosponsored by the American Association of State Highway and Transportation Officials (AASHTO), FHWA and, the National Cooperative Highway Research Program (NCHRP).

Scan team topics of interest included the following:

- ❖ Organizational structure and background
- ❖ Inspection data
- ❖ Personnel qualifications
- ❖ Process control
- ❖ Equipment
- ❖ Documentation

## Amplifying Questions

Amplifying questions were developed to help the foreign experts more fully understand the topics of interest to the scan team members. These questions, in Appendix A, were provided to the host countries before the scan. The contacts in each country are listed in Appendix C, and the scan itinerary is in table 1.

## Host Countries

The team conducted a series of meetings and site visits with representatives of government agencies and private sector organizations abroad between June 1 and 17, 2007. The panel visited Denmark, Finland, France, and Germany and met with representatives from Norway and Sweden while in Denmark. These six countries were selected through a desk scan based on their advanced activities in bridge evaluation, bridge management, and quality assurance.

## Team Members

A 10-member team was formed to study European bridge inspection practices, specifically targeting quality assurance. This team consisted of three representatives from FHWA, four representatives from

State departments of transportation (DOTs), one representative from the National Association of County Engineers, one representative from academia, and one structural engineering design consultant who also served as the report facilitator.

**Table 1.** *Scan itinerary.*

DATE	LOCATION	ACTIVITIES
Monday, June 4, 2007	Helsinki, Finland	Meeting in offices of Finnish Road Administration (Finnra). Presentations on bridge MR&R in Finland, BMS in Finland (tools: bridge database, inspection data, BMS project and network level), and general information on inspections (organizational structure and background, inspection data).
Tuesday, June 5, 2007	Helsinki, Finland	Meeting in offices of Finnra. Presentations on inspection quality (process control, personnel qualifications), inspection methods and equipment, reference bridges, special inspections, and documentation.
Wednesday, June 6, 2007	Helsinki, Finland	Meeting in offices of Finnra. Presentations on bridge engineering research and development, cooperative programs with northern countries, and the National Structural Monitoring Project.
Thursday, June 7, 2007	Copenhagen, Denmark	Meeting hosted by Danish Road Directorate at Eighthveds Pakhus. Presentations by Norway, Denmark, and Sweden on amplifying questions.
Friday, June 8, 2007	Virum, Denmark	Meeting in offices of Ramboll Consulting Engineers. Presentations on the company, internal quality assurance procedures, principal inspection, special inspection (including nondestructive testing), bridge deterioration, evaluating inspection results, and improving evaluation of bridges, and demonstration of Ramboll's inspection van, equipment, and procedures. Field visit to the Storebaelt Great Belt Fixed Link for presentations on the operation of the Great Belt Bridge and the East Bridge anchor block and tower.
Monday, June 11, 2007	Bagneux, France	Meeting in offices of Center for Technical Studies of Highways and Motorways (SETRA). Presentations on methodology for management of national bridges (IQA, Sustainable Bridge project), steel bridges: use of inspection data for existing bridges, design versus inspection of steel bridges: fatigue assessment philosophy, brittle fracture, detailing, and training and qualification of inspectors.
Tuesday, June 12, 2007	Paris, France	Meeting in offices of Central Laboratory for Bridges and Highways (LCPC). Presentations on prestressed concrete bridges (inspection of external prestressing), cable-stayed and suspension bridges, assessment of cable by acoustical method and by vibrating methods, and LREP practice.
Thursday, June, 14 2007	Bergisch- Gladbach, Germany	Field visit and observation of two ongoing bridge inspections. Meeting in offices of German Federal Highway Research Institute (BAST). Presentations on organizational structure of federal highways, background and personnel qualifications, and training programs.
Friday, June, 15 2007	Bergisch- Gladbach, Germany	Meeting in offices of BAST. Presentations on bridge inspection (rules, regulations, and documentation inspection of engineering structure equipment) and nondestructive training bridge management system (post-processing of the excursion, results of the inspection).

# Findings on Bridge Evaluation Quality Assurance

THE TEAM FOUND THAT THE EUROPEAN HOST agencies visited valued their bridge inspection programs not only to ensure highway user safety, but also to ensure that durability and serviceability expectations were met and to enhance capital investment decisions on the existing bridge inventory. The agencies placed major emphasis on providing quality assurance through well-defined inspector qualifications, periodic calibration of inspectors, data collection processes, verification of data, and use of appropriate equipment to evaluate their structures. Nearly all of the agencies the scan team visited had major programs aimed at inspection uniformity and had developed a multitiered inspection program with procedures for performing damage assessment and programming maintenance and repair through the inspection process.

The scan team identified many bridge inspection practices and technologies related to the previously stated topics of interest. The items that the team believes could enhance bridge inspection practices in the United States are discussed in this chapter. The order in which they are presented is for clarity and does not reflect the priority recommended by the team.

## Detailed and Illustrated Inspection References and Tools

In the countries the scan team visited, many detailed, heavily illustrated manuals and references were available as tools for bridge inspectors, including inspection manuals, maintenance guides, repair manuals, and coding and recording data guides. The primary approach in the United States and the European countries the team visited is visually based inspection. The host nations use visual aids to a greater extent in recording and coding of data, damage assessment, and maintenance and repair. Numerous manuals are available for inspection and maintenance. To focus inspectors and

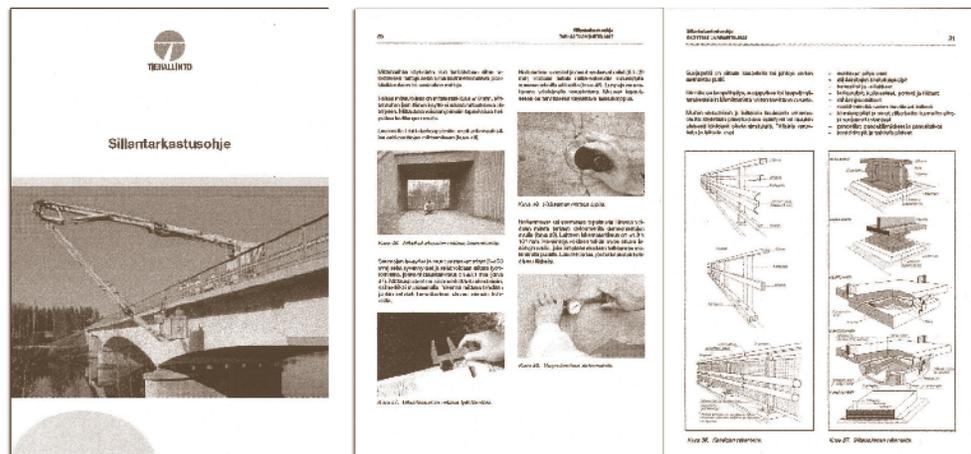
provide more uniform ratings, the types of damage with performance indices were quantified with accompanying photographs. These manuals contain many photos and drawings showing damage and corresponding rating levels.

### Finland

The Finish Road Administration (Finnra) provides guidance in five documents:

- ❖ *Guidelines and Policy for Bridge Maintenance, Repair, & Rehabilitation Operation*
- ❖ *Guidelines for Bridge Inspection* (figure 1)
- ❖ *Bridge Inspection Manual* (figure 2, see next page)
- ❖ *Bridge Repair Manual* (SILKO Guidelines) (figure 3, see next page)
- ❖ *Bridge Register Inventory and User Guidelines*

Two of these, the *Bridge Inspection Manual and Guidelines for Bridge Inspection*, guide field inspection activities for bridge inspections. The guidelines set out the procedures for gathering and checking the structural and damage data at the bridge site, as well as the methods for processing and using the accumulated data. The Finnra bridge inspection system is presented in the *Guidelines for Bridge Inspection*. Figure 1 illustrates the cover and two internal pages from this document. The *Bridge Inspection Manual* provides guidance for classifying and entering data in the bridge register, a database containing structural and condition data on Finnish



**Figure 1.** Sample pages from the Finnra Guidelines for Bridge Inspection that include diagrams of how to perform inspections and typical structural details.

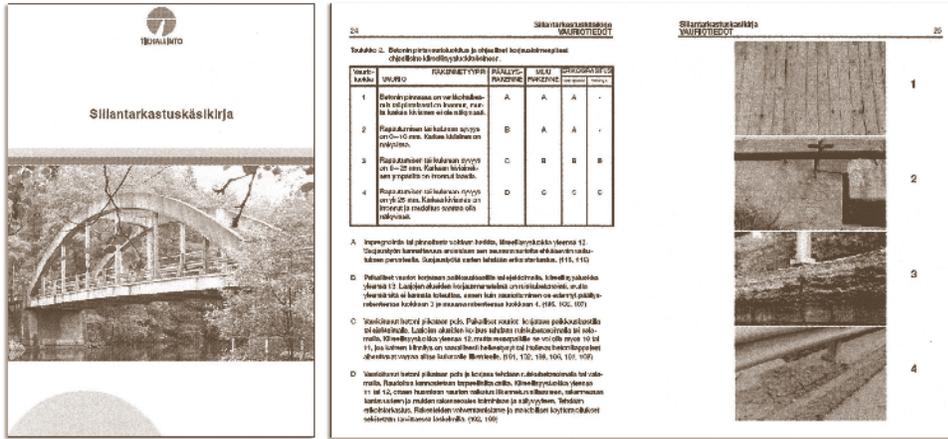


Figure 2. Sample pages from the Finnra Bridge Inspection Manual providing specific coding guidelines.

bridges. Figure 2 shows the cover and two internal pages from this document.

An interesting finding was that several countries had implemented standards to quantify concrete cracking in inspection reports. For instance, table 2 illustrates a scheme for classifying concrete cracking from the Finnra Bridge Inspection Manual.

The Finnish Road Administration has also issued standardized bridge repair directives in its *Bridge Repair Manual (SILKO Guidelines)* to standardize and guide repair work on bridges identified during the inspection process. These manuals and several data sheets are



Figure 3. Finnra's Bridge Repair Manual (SILKO Guidelines).

shown in figure 3. The stated goal of these manuals is to provide standardized repair scenarios for various types of damage to a bridge, to improve durability of a bridge, and to improve bridge construction and maintenance. Directives are issued for a wide range of items. An abbreviated table of contents listing the directives is in Appendix E.

Each directive contains a detailed discussion on the structural element, applications and limitations, warrants for repair, equipment needed to make the repair, approved materials for use in making the repair, and job site needs and safety. The directives, issued as individual brochures for each repair directive, are maintained in a four-volume set. These directives are linked to the Finnish bridge management system (BMS) and, when repairs are made using the directives, a record of the repairs is entered in the bridge register. Finnra monitors the repair work and uses the information it obtains to improve guidance. Training on these manuals is viewed as essential. The training provides guidance to users on recommending repair methods and approving materials.

**Norway**

The Norwegian Public Roads Administration *Handbook for Bridge Inspection* provides a thorough explanation of condition ratings. The manual contains many photos showing damage and corresponding rating with both degree and consequence of damage. The handbook, prepared to cover the requirements of the staff involved in bridge inspections, provides thorough and detailed guidance on damage evaluation. Emphasis has been placed on explaining different types of damage to different types of structures using photos and explanatory damage evaluation guidance. The photos have been used extensively to facilitate a better understanding of the damage type.

**Germany**

The Federal Department of Transportation, Construction, and Housing's Office of Road Construction and Traffic (German Federal Ministry of Traffic, Building, and Urban Affairs) has issued two documents, *DIN 1076: Engineering Structures in Connection With Roads—Inspection and Test and Directive for Uniform Determination Assessment, Recording, and Analysis of the Results of the Inspection of the Structures in*

**Table 2.** Classification of cracks in concrete structures and recommended repair procedures, from the Finnra Bridge Inspection Manual.

DAMAGE CLASS	TYPE OF STRUCTURE DAMAGE	SUPERSTRUCTURE		OTHER STRUCTURE	SPECIAL STRESS	
		Normal reinforcement	Prestressed reinforcement		Edge beam	Water level range
1	Crack width is under 0.2 mm. Cracks are small, mainly surface cracks.	A	A	–	B	–
2	Crack width is 0.2 to 0.4 mm. Cracks are small structural cracks, generally due to shrinkage.	B	C	B	B	–
3	Crack width is 0.3 to 1.0 mm. Structural cracks are generally due to deflection, exceeding of the shear capacity, or creep. Cracks are generally found in the superstructure.	C	D	C	C	C
4	Crack depth is over 1.0 mm. Structural cracks are due to uneven settlement or a large deformation. Cracks are often serrated and generally found in the substructure.	D	D	D	D	D

**A.** Surface treatment may be considered. A special inspection shall be undertaken to determine the degree of reinforcement corrosion as well as the chloride concentration and depth of carbonation. The surface treatment must be able to withstand minor structural deformation. A specification shall be drawn up.

**B.** The cracks in the upper surfaces are soaked using capillary action. Other cracks are injected as needed. A leaking crack must always be injected. A specification shall be drawn up.

**C.** A special inspection shall be undertaken to determine the cause of cracking. The cracks are injected using epoxy

to restore original structural strength. Leaking cracks place special demands on the epoxy and the work method to be used. The effect of cracks on the condition of tendons in prestressed structures must be determined. A specification shall be drawn up.

**D.** The reason for cracking is determined through a special inspection. The cracks are injected using epoxy or cement slurry with filler added as needed. Calculations are used to determine the need for additional strengthening of structures and possible service limitations. A special inspection is carried out and a repair plan is drawn up. In the case of prestressed structures, the effect of the damage on tendons and cables must be determined.

Accordance with DIN 1076. These documents provide detailed guidance on documentation of inspection and testing performed during bridge inspections.

The scan team observed host nation inspectors with photographs from past inspections on site to use in current inspections. This practice allows the inspector to make more accurate observations of changes in bridge conditions since the last inspection. In Germany, digital photographs are imbedded in the

final report, along with report text and associated sketches.

Inspection vehicles in Germany were fully able to support activities at the inspection site. A maintenance repair and rehabilitation specialized truck was modified to incorporate office workspace for the inspector that included a desk, a laptop computer (including inspection program SIB-Bauwerke), a reference library complete with all pertinent inspection

references, and a complete set of bridge records for the bridges being inspected. The interior of one such vehicle is shown in figure 5. One example observed was a manual from a bearing manufacturer that provided specific inspection guidance for the inspector in the field. A locker is provided for tools and diagnostic and NDT devices necessary to perform an inspection to accepted standards. Storage space for personal safety equipment and boots is also provided. These inspection vehicles, along with other necessary access and safety vehicles, enable bridge inspectors to work in a variety of inspection scenarios and in remote areas for a prolonged period without

dependence on other assets, thereby promoting efficient field activities.

## Reports and Data Management

All countries visited practice standardization of inspection reports, forms, terms, and ratings. Noteworthy practices included generating customized bridge inspection forms by bridge management systems, standardizing terms and rating criteria for inspectors, embedding digital photographs in inspection reports, and requiring designers to identify critical areas of a structure to be inspected. The inspector's

recommendations are integrated into maintenance activities and are used to initiate agency actions to correct deficiencies identified based on recommended action, timing, and cost. The inspector, through various agency-established protocols, addresses critical needs.

### Finland

The coding of the type of damage, cause of damage, and condition rating is standardized in Finland's inspection guidelines (figure 6).

Finish bridge inspectors include the following minimum information in their written report:

- ❖ Inspection type, date, inspector, and inspector's organization
- ❖ Overall bridge condition
- ❖ Condition of the main structural parts
- ❖ Next inspection: type and year
- ❖ Free comments
- ❖ Inspection equipment
- ❖ Bridge repair recommendations
- ❖ Photos
- ❖ Data from physical testing

Damage data are recorded by the inspector and include the following information:

- ❖ Longitudinal and transverse location in the bridge
- ❖ Identification of structural component and material
- ❖ Type of damage
- ❖ Cause of damage
- ❖ Class of damage
- ❖ Extent of damage
- ❖ Effect of damage on the bearing capacity of the bridge

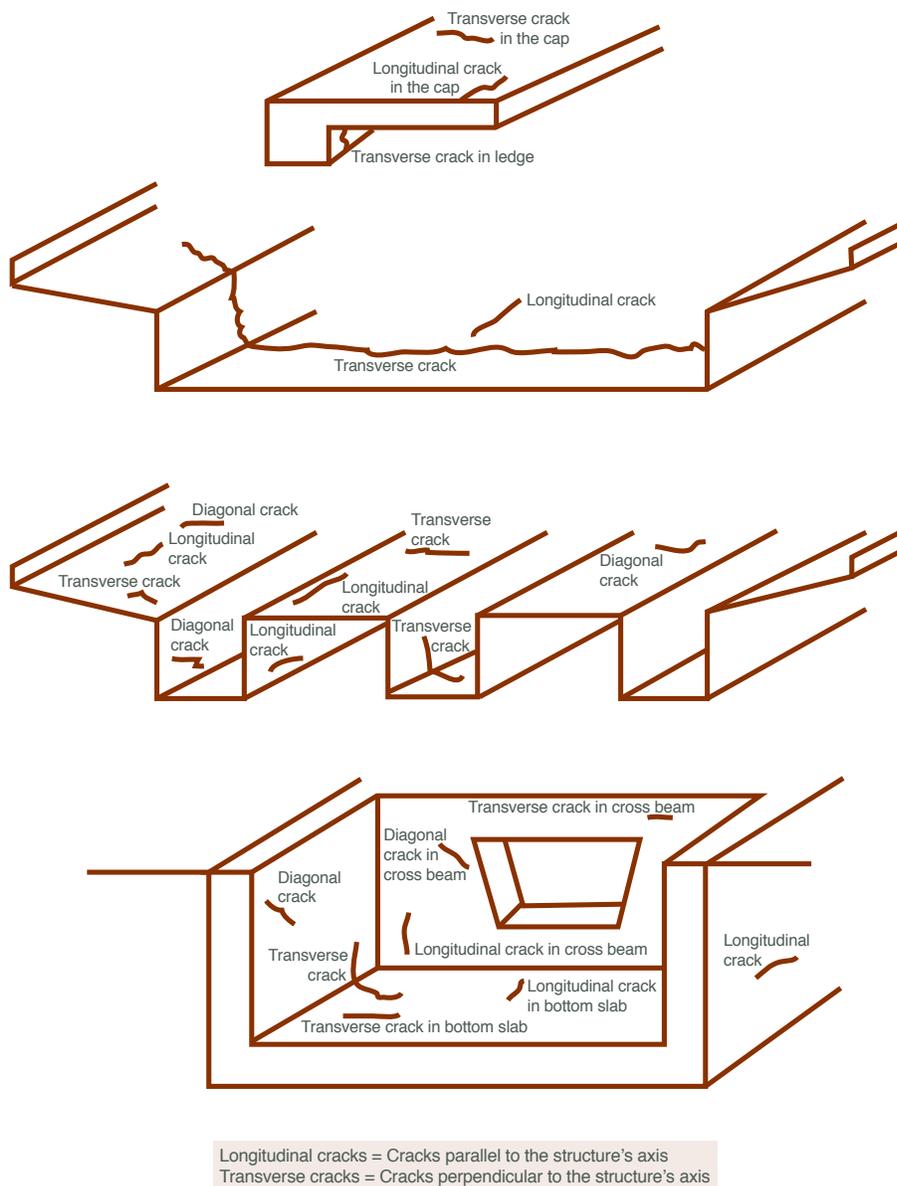
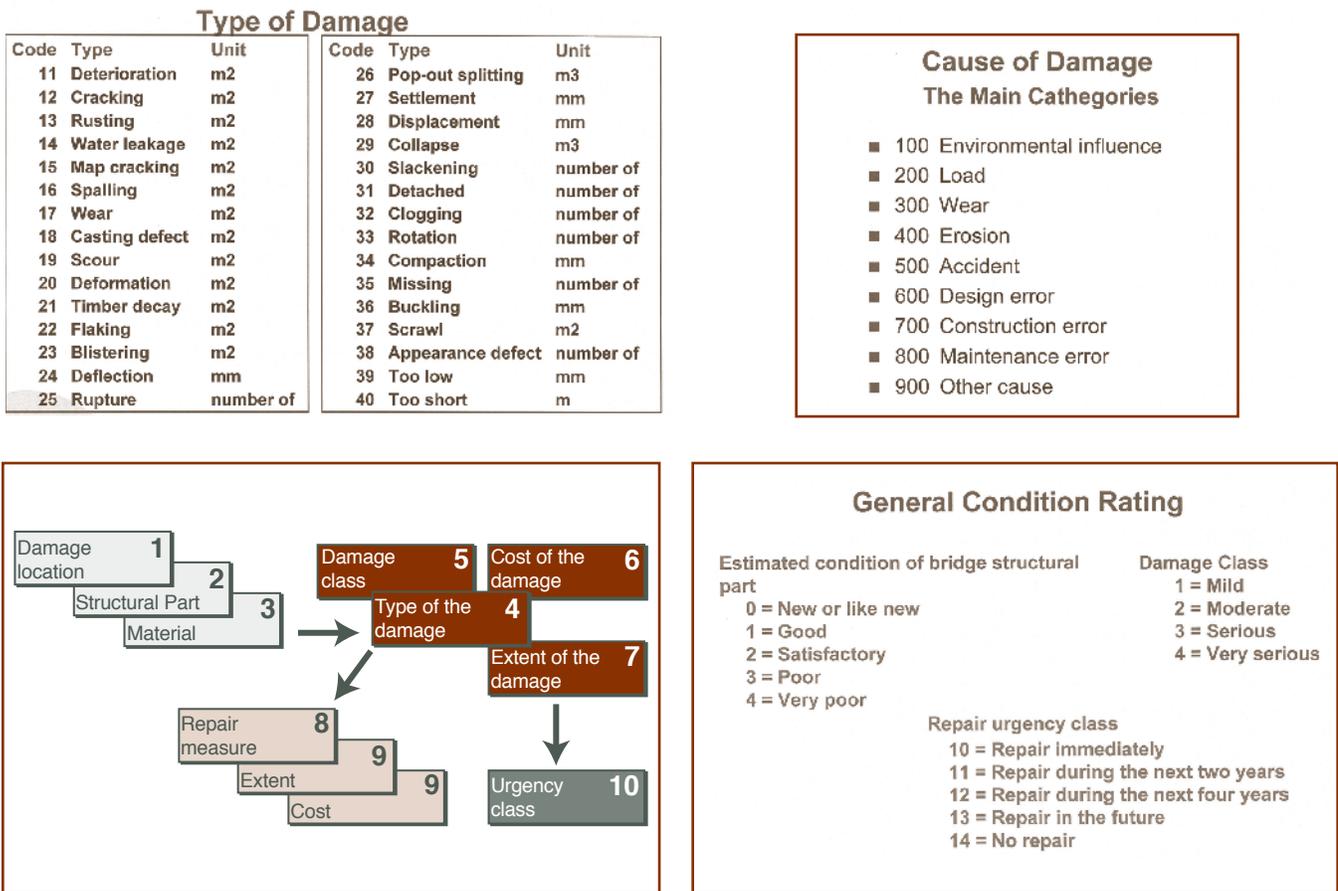


Figure 4. German federal guidance on describing cracks in superstructures.



**Figure 5.** Interior of German inspection vehicle showing conferring workspace.



**Figure 6.** Finnra guidelines for coding condition, damage type, and cause.

Based on the inspector's field observations, repair recommendations are included as part of the inspection report. Recommendations include the following:

- ❖ Repair urgency class
- ❖ Recommended repair measure, cost, and extent

The inspector's recommendations are used to initiate agency actions to correct deficiencies identified

based on recommended action, timing, and cost. The inspector, through immediate contact with Finnra, addresses critical needs.

#### Norway

In the Norwegian Public Roads Administration's bridge management system, BRUTUS, the inspector can

generate tailor-made inspection forms for every bridge. BRUTUS also provides previous inspection results to assist the inspector in reporting changes in structural conditions since the last report. Digital photographs are used extensively in Norwegian inspection reports. Sketches are more rarely used and, if used, they are scanned and included as a digital image.

Paper copies of reports from special inspections are filed in a traditional filing system for bridges. Data from routine inspections are maintained electronically in BRUTUS. Reports are generated and printed from the system as needed. Repair and maintenance

activities may be initiated by work orders prepared using BRUTUS as a result of inspection data provided. When the repair or maintenance is completed, it is possible to record the date, costs, name of contractor, and a brief description of the maintenance activity or to simply record the activity as accomplished.

In the field, the inspectors record a level of urgency for any required repair in their assessment of damage found. This level of urgency is used to determine annual fund allocations, program maintenance repairs, and track repair backlogs.

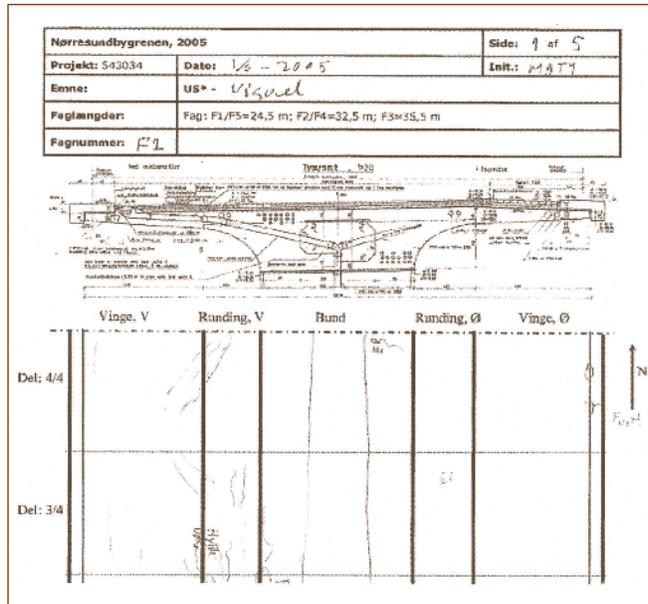


Figure 7. Standardized report form used by Danish firm Ramboll.

In Denmark, the existing bridge management system mainly targets the typical highway bridge or overpass structure. The management system has the ability to handle data for many structures. It includes data on typical components in a simply organized database. Separate asset management policies, systems, and practices have been identified as necessary for managing major structures to allow better decisionmaking for capital investments.

**Germany**

In Germany, a computer program, SIB-Bauwerke Release 2006, is in use. The program allows inspectors to select a structural condition from a pull-down menu that allows the program to generate a rating. The inspector is provided detailed guidance on assessing structural stability (table 3), traffic safety (table 4), and durability (table 5, see page 14). Based on these ratings, the inspection program calculates a condition index for the structural element (tables 6 and 7, see pages 15 and 16), automating the assessment provided in the report.

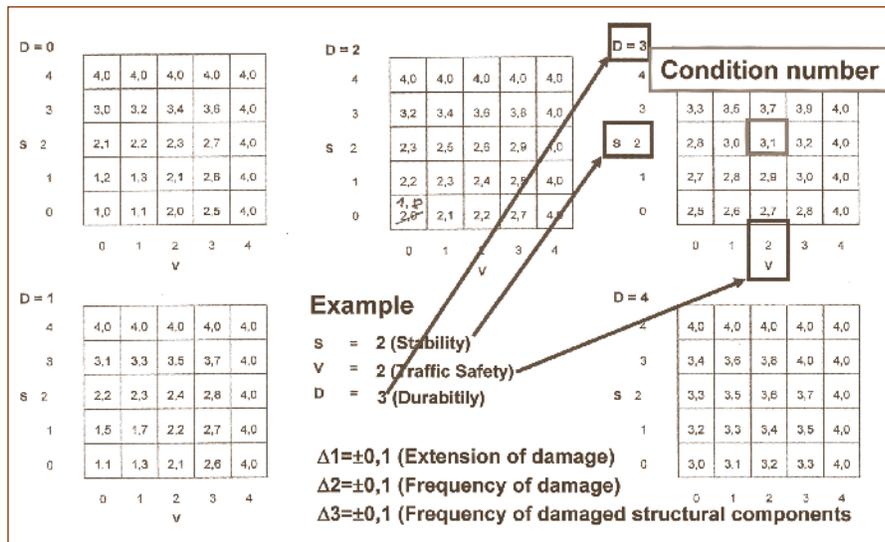


Figure 8. Calculation of Condition Index.

Damage assessment is aided by use of a detailed catalog of damage conditions contained in the software and available by keywords. A screen from the software showing cataloged damage to a bridge deck joint is shown in figure 9 (see page 14). An inspector has the ability to enter a rating not in the catalog, but a requirement is built into the software requiring justification for not using a standard. A screen from the software showing an inspector-generated rating page is shown in figure 10 (see page 16). There are now about 1,200 standards, and the number in the catalog was expected to grow to about 1,800 by the end of 2007. A permanent

**Table 3. Damage assessment—structural stability.**

Damage Assessment “Structural Stability”	
Assessment	Description
0	The defect/damage has <b>no effect on the structural stability</b> of the structural element/structure.
1	The defect/damage <b>negatively affects the structural stability of the structural element</b> ; however, it has <b>no effect on the structural stability of the structure</b> .  With respect to the as-planned utilization, <b>individually occurring, small deviations</b> in the condition of the structural element, the quality of the construction material, or the element’s dimensions are <b>still clearly within the scope of the admissible tolerances</b> .  Repairs to be carried out within the scope of <b>regular maintenance</b> .
2	The defect/damage <b>negatively affects the structural stability of the structural element</b> ; however, it has <b>little effect on the structural stability of the structure</b> .  The <b>deviations</b> in the condition of the structural element, the quality of the construction material, or the dimensions or the as-planned stresses resulting from the utilization of the structure are <b>still within the scope of the permissible tolerances</b> . In individual cases, the admissible tolerances of the structural element may be exceeded.  <b>Repairs must be undertaken within the medium term.</b>
3	The defect/damage <b>does affect the structural stability of the structural element negatively</b> ; <b>the deviations</b> with respect to the condition of the structural element, the quality of the construction material, or the dimensions or the as-planned stresses resulting from the utilization of the structure <b>exceed the permissible tolerances</b> .  The required restrictions on the use are not in place or are ineffective.  <b>The damage must be repaired at short notice. Restrictions regarding utilization must be put in place immediately.</b>
4	The <b>structural stability of the structural element and the structure no longer exists</b> .  <b>Immediate measures must be taken during the inspection of the structure. Restrictions regarding the utilization must be put into place immediately. The repair or renovation must be initiated.</b>

**Table 4. Damage assessment—traffic safety.**

Damage Assessment “Traffic Safety”	
Assessment	Description
0	The defect/damage has <b>no effect on traffic safety</b> .
1	The defect/damage <b>affects traffic safety only slightly; traffic safety is given</b> .  Repairs to be carried out within the scope of <b>regular maintenance</b> .
2	The defect/damage <b>affects traffic safety only slightly; traffic safety, however, is still given</b> .  <b>Repairs must be carried out or warning signs must be put up.</b>
3	The defect/damage <b>affects traffic safety</b> .  <b>Repairs must be carried out or warning signs must be put up at short notice.</b>
4	Due to the defect/damage, <b>traffic safety is no longer given</b> .  <b>Immediate measures must be taken during the inspection of the structure. Restrictions regarding the utilization must be put into place immediately. The repair or renovation must be initiated.</b>

Table 5. Damage assessment—durability.

Damage Assessment “Durability”	
Assessment	Description
0	The defect/damage has <b>no effect on the durability</b> of the structural element/structure.
1	The defect/damage <b>negatively affects the durability of the structural element</b> ; however, it has <b>no long-term effect on the durability of the structure</b> . An <b>expansion of the damages or consequential damages</b> to other structural elements is <b>not expected</b> .  Repairs to be carried out within the scope of <b>regular maintenance</b> .
2	The defect/damage <b>negatively affects the durability of the structural element and can, in the long term, also negatively affect the durability of the structure</b> . An <b>expansion of the damages or consequential damages</b> to other structural elements <b>cannot be excluded</b> .  Repairs to be undertaken within the <b>medium term</b> .
3	The defect/damage <b>negatively affects the durability of the structural element and affects, in the medium term, the durability of the structure in a negative manner</b> . An <b>expansion of the damages or consequential damages</b> to other structural elements <b>can be expected</b> .  Repairs <b>must be undertaken at short notice</b> .
4	Due to the defect/damage, <b>the durability of the structural element and of the structure is no longer given</b> .  The <b>expansion of the damages or consequential damages</b> to other structural elements <b>requires immediate repairs, restrictions on utilization, or a renovation of the structure</b> .

committee appointed to oversee this catalog reviews the ratings periodically to update it as required.

and field check of reports submitted by junior inspectors and vendors.

Another item of interest in European agencies is the practice of having senior office staff review a sampling of reports. Several agencies have processes for senior in-house inspectors’ review

The general practice of European agencies was not to use dedicated inspectors on bridges, but to rotate inspectors on subsequent inspections. This practice provides a fresh assessment of the bridge’s condition.

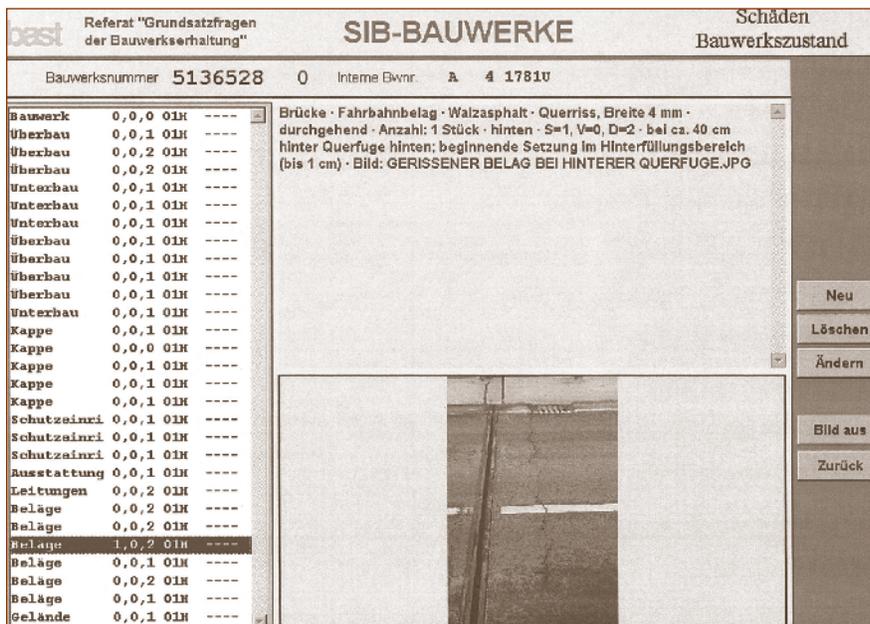


Figure 9. Screenshot of SIB-Bauwerke Release 2006 showing cataloged damage to bridge deck joint.

## Bridge Inspector Training and Certification

European countries use a variety of approaches to train and certify inspectors. All countries have technical education requirements for inspectors, and most require those who lead inspectors to have an engineering degree. Many have specialized training requirements for inspectors to ensure the quality of the inspection and the data provided. Specialized training at the program manager level and performance-based testing requirements were believed to be significant.

Maintaining a core of in-house staff with expertise in bridge inspection is

**Table 6. Condition Index (1).**

Grade	Description
1.0–1.4	<b>Very good structural condition</b>
	The structural stability, traffic safety and durability of the structure are given. <b>Continuous maintenance</b> is required.
1.5–1.9	<b>Good structural condition</b>
	The structural stability and traffic safety and durability of the structure are given. In the long term, the <b>durability</b> of the structure <b>may</b> be negatively <b>affected to a small degree</b> . <b>Continuous maintenance</b> is required.
2.0–2.4	<b>Satisfactory structural condition</b>
	It is possible that, in the long term, the <b>durability</b> of the structure <b>may</b> be negatively <b>affected</b> . <b>An expansion of the damage or consequential damages</b> which, in the long term, would lead to considerable deterioration of the structural stability and/or traffic safety and increased wear and tear is to be expected.
	<b>Continuous maintenance</b> is required.
	<b>Maintenance</b> is required in the <b>medium term</b> . <b>Measures to eliminate the damage or warning signs to maintain traffic safety</b> might be necessary <b>at the short notice</b> .
2.5–2.9	<b>Unsatisfactory structural condition</b>
	<b>The structural stability</b> of the structure <b>is given</b> .
	<b>Traffic safety</b> might be negatively affected.
	<b>The durability</b> of the structure <b>may</b> be negatively <b>affected</b> quite a bit. <b>An expansion of the damage or consequential damages</b> which, in the <b>medium term</b> , would lead to considerable deterioration of the structural stability and/or traffic safety and increased wear and tear is to be expected.
	<b>Continuous maintenance</b> is required.
<b>Maintenance at short notice</b> is required.	
<b>Measures to eliminate the damage or warning signs to maintain traffic safety</b> might be necessary <b>at short notice</b> .	

a high priority for European owners. Experienced staff provides a cadre of personnel to act as trainers and certifiers of new staff and vendors, provide quality assurance reviews of work performed on behalf of the agency, and develop reference materials in support of agency programs.

### **Finland**

In Finland, bridge inspector training is arranged by the Finnish Road Administration and involves a 3- or 4-day theoretical course of study with 1 day of onsite training. Training culminates in a 1-day performance evaluation involving inspection of a bridge and a written test. Finnra also provides a 2-day course in bridge register use that must be completed before an inspector is granted rights to update the data. Annually, inspectors are required to undergo a 1-day “calibration” involving a general inspection of two

bridges, after which candidates receive the official results of the inspections and discuss them with the examiner. To maintain certification, inspectors not only have to pass the hands-on bridge inspection assessment, but are also subject to a QA check involving a bridge inspection with two other inspectors. The results of the three inspectors are then checked for consistency. Personal quality points are assigned to each inspector and used in the procurement process. Candidates who repeatedly have weak test results can lose their certification.

Candidates for certification must have at least 2 years of experience as a member of a bridge inspection team. The lead inspector on a team must possess a master of science degree in bridge engineering or civil engineering and have experience in design of load-bearing structures or repair and rehabilitation

Table 7. Condition Index (2).

Grade	Description
3.0–3.4	<p><b>Critical structural condition</b></p> <p>The <b>structural stability or traffic safety</b> of the structure is negatively affected.</p> <p>Possibly, <b>durability</b> of the structure is <b>no longer given</b>. An expansion of the damage or <b>consequential damages</b> may, in the <b>short term</b>, lead to the fact that structural stability and traffic safety are no longer given.</p> <p><b>Continuous maintenance</b> is required.</p> <p><b>Immediate repairs</b> are required.</p> <p><b>Measures to eliminate the damage or warning signs to maintain traffic safety</b> or restrictions in its use might be required as soon as possible.</p>
3.5–4.0	<p><b>Inadequate structural condition</b></p> <p>The <b>structural stability or traffic safety</b> is negatively affected quite a bit or is no longer given.</p> <p>Possibly, <b>durability</b> of the structure is <b>no longer given</b>. An expansion of the damage or <b>consequential damages</b> may, in the <b>short term</b>, lead to the fact that structural stability and traffic safety are no longer given and that it will result in an irreparable deterioration of the structure.</p> <p><b>Continuous maintenance</b> is required.</p> <p><b>Immediate repairs or renovations</b> are required.</p> <p><b>Measures to eliminate the damage or warning signs to maintain traffic safety</b> or restrictions in its use might be required <b>immediately</b>.</p>



Figure 10. Screenshot of SIB-Bauwerke Release 2006 showing inspector-generated rating page.

of bridges. Other personnel must be familiar with inspection methods and use of inspection equipment.

**Norway**

Norway matches complexity of bridge inspection assignments to in-house and consultant inspectors based on education and experience. The number of bridge inspectors is not high, so the person in charge of ordering the inspections should be aware of inspectors' qualifications. Norway bridge inspectors are also knowledgeable about bridge design and construction. Knowledge and experience in bridge design are considered more important than material knowledge, but knowledge of the material being inspected and degradation processes is also integral to the inspection process.

## Sweden

The Swedish Road Administration has requirements for inspection personnel on education, knowledge about regulations and materials, etc., but no formal requirement for certification. No physical qualifications are required, either. The choice of inspector is based on the information submitted in the procurement document, which provides special personnel requirements for the specific inspection. However, common basic requirements for inspectors are the following:

- ❖ Engineering education
- ❖ Years of experience demonstrating knowledge of Swedish Road Administration inspection methodology or inspection education
- ❖ Experience in measuring and assessing physical and functional condition based on the measurement methods produced for the specific structure and its component
- ❖ Knowledge of durability and deterioration processes affecting the specific structure and its components
- ❖ Knowledge and experience in predicting damage development
- ❖ Knowledge and experience in developing corrective action recommendations for structural damages

The Swedish Road Administration sets the requirements for bridge inspection on the national road network. Other bridge managers or owners in Sweden comply with the same requirements, but may adjust special requirements higher or lower at their discretion.

The same requirements apply to underwater inspectors as other inspectors. In addition, the *Instructions for Diving* by the National Board of Occupational Safety and Health apply. Further, the diving equipment must be inspected and approved and appropriate diver safety practices must be used during the inspection.

For special situations, nationally or internationally known experts in the field may be hired. Requirements are identical for both in-house staff and vendors. Inspector data are maintained in the BMS, BaTMan, which tracks every inspector's individual performance.

## France

In France, qualification is targeted at the inspector and inspection or project manager through six modules of training. Individuals must pass an exam to qualify for a position in each level. The qualification procedure is part of the ISO 9001 quality process developed by the network of Ponts et Chaussées Regional Laboratories (Public Road and Bridges Laboratories) in the field of bridge, culvert, and retaining wall inspection. The 17 French laboratories perform inspections for the national network, departments, cities, and towns as consultants.

Private consultants also perform bridge inspection, and their activities will probably increase in the future.

Training modules are organized by the Ecole Nationale des Ponts et Chaussées and are open to public laboratories and private consultants. A questionnaire at the end of each module tests the knowledge acquired by the candidates. For the public laboratories, a minimum grade is required to validate the module.

The goals of the French inspection training modules and qualification process are as follows:

- ❖ To ensure a quality level of inspections
- ❖ To set a system of qualification for the inspection staff
- ❖ To complement the initial education of new inspectors
- ❖ To serve as a reference for the private profession

The course of qualification covers technical requirements only. Requirements for physical ability, health, and sanitary and safety conditions for inspectors are controlled by the director of the Regional Ponts et Chaussées Laboratory.

After a project manager makes a proposal, the training is delivered at the regional laboratory by the chief of the Bridge Service and, should the need arise, the director of the regional laboratory. Training is provided in six modules, the first five designed for bridge inspectors and the sixth required for project manager certification.

Modules 1 through 5 are as follows:

- ❖ Module 1: A 6-day course on basic knowledge (strength of materials, reinforced concrete bridges, common steel bridges, common prestressed concrete bridges, masonry bridges, culverts, common retaining walls)
- ❖ Module 2: A 1-day course on large prestressed concrete bridges
- ❖ Module 3: A 3-day course on uncommon retaining walls
- ❖ Module 4: A 2-day course on large steel bridges and cable bridges
- ❖ Module 5: A 3-day course on tunnels and underground structures

Module 6 is a 3-day project manager's course that includes the following:

- ❖ Methodology of detailed inspection
- ❖ Investigation techniques
- ❖ Monitoring and surveillance techniques
- ❖ Repair and strengthening techniques
- ❖ Actions to be proposed after an inspection

There are three levels of qualification: inspection agent, inspector, and project manager. The director of the regional laboratory certifies inspection agents locally.

Higher levels of certification (as inspector or project manager) require certain prerequisites, including the following:

- ❖ Level of the candidate's initial education
- ❖ Candidate's knowledge and professional experience in the inspection field
- ❖ Successful completion of qualifying training modules
- ❖ Experience working with another inspector or project manager

Certification of qualification as an inspector may be obtained two ways. The first is by completing at least module 1 of the training, passing a professional examination involving a bridge inspection with a statement of findings, writing a report, and undergoing review by an examining board. The second way is by undergoing a review of past experience (at least 5 years) acting as an inspector and review by an examining board. The qualification of the inspector may be extended with modules 2, 3, 4, and 5.

Certification of qualification as a project manager may also be obtained in one of two ways. The first is by completing modules 1 through 6 and passing a professional examination that involves checking a bridge report proposed by an inspector, writing the report conclusions, and undergoing review by an examining board. The second is by undergoing review of past experience acting as a project manager (at least 3 years) and review by an examining board.

### *Germany*

Germany has no mandatory professional training for engineers conducting bridge inspections. The German standard DIN 1076 requires only that an experienced engineer perform construction inspection. The minimum requirements are a completed study at a university or a university of applied sciences (bachelor or master of civil engineering or science degree) and experience in bridge building or construction engineering. Physical ability to perform the tasks associated with the job is assumed.

The lack of mandatory training requirements is rooted in Germany's history. During the post-World War II years, reconstruction was a priority for the country. Confidence in the state of technology and the quality of the materials being used in bridge construction led to public confidence in the ability of bridges in service to operate for decades without incident.

Periodic inspection of construction was performed, but the practice of construction inspection did not have the importance it now has. This changed because of two events in 1976. The first was the failure of the Reichsbrücke, a bridge in Vienna, Austria, originally built from

---

### Typical 1-Week Seminar Offered at Bochum University of Applied Science in Germany

- Day 1**
    - Introduction
    - Introductory video on bridge inspection
    - Judicial and technical rules
    - Causes of damage
    - Vulnerable details in special construction
  - DAY 2**
    - Organization and costs of inspection
    - Rules for accident prevention
    - Personal protective equipment
    - Acquisition of damage data with SIB-Bauwerke
    - Inspection vehicle and equipment management
  - Day 3**
    - Assessment of damage data of buildings—examples
    - Inspection of road signs for bridges
    - Inspection by special rules
    - Various topics (e.g., reconditioning of orthotropic decks)
  - DAY 4**
    - Assessment of damage data of bridge equipment
    - Detailed damage analysis (theory, methods)
    - Causes of damage—test methods
    - Causes of damage—technical, physical, and chemical
  - DAY 5**
    - Practical training
    - State of knowledge (test)
    - Presentation of certificate
    - Open discussion
- 

1872 to 1876 and completely restored from 1934 to 1937. On August 1, 1976, the bridge collapsed because of substructure damage, killing one person. The last documented general inspection before the failure was in 1952, almost 25 years earlier.

Also in 1976, considerable damage was detected on prestressed concrete bridges in Düsseldorf. Cracks 4 millimeters wide in the area of the coupling joints and several broken prestressing tendons were found. This led to a wider investigation that determined that a large number of similar bridges had comparable damage. As a result, both practitioner and public views on the need for bridge inspection changed.

The initial effort went into improving construction inspection, which has developed to a very high quality standard of practice for bridge construction in Germany today. In 2000 the German Federal Ministry of Transport

and the Road Administrations of the Federal States began an initiative to set up a professional development seminar for bridge inspectors. The purpose of the seminar was to establish a forum for the exchange of knowledge and experience among practicing bridge inspectors. The first of these 5-day courses took place in November 2002 at BAST in Bergisch-Gladbach.

From 2003 to 2005, 14 additional courses were held with 340 participants attending. The number of participants at each seminar was limited to 25. Seminar seats not occupied by employees of the road administrations could be allocated to interested engineers from the private sector, city agencies, waterway administrations, port administrations, and others.

Growing demand for this training required establishing two additional seminar locations at Feuchtwangen in Bavaria and the Bochum University of Applied Sciences in North Rhine Westphalia. A fourth location in Dresden was scheduled to begin offering seminars in 2007.

The following are prerequisites for seminar participation:

- ❖ Bachelor or master of science degree in civil engineering
- ❖ Several years' practical experience in construction engineering and building inspection
- ❖ Knowledge in operating the SIB-Bauwerke program

Staff at each site organizes the seminars, but seminar quality is ensured by a national coordinating committee. The coordinating committee consists of representatives of the German Federal Ministry of Transport, BAST, state road administrations, training locations, and a university lecturer. This body determines course content and speakers, coordinates scheduling, and oversees the quality of each seminar.

Seminar instructors are experienced bridge inspectors from the road administrations of the federal states. They are supported by speakers from BAST, German Materials Research Institute (BAM), universities, and private organizations, as well as by employees of municipal administrations.

An association, Verein zur Förderung der Aus- und Weiterbildung von Bauwerksprüfingenieuren (VFBI, or Association for the Support of the Training and Further Training of Building Inspectors), was scheduled to be formed in 2007. Association members will be bridge owners, including the German Federal Ministry of Transport, the Ministries of Transport of the Federal States, county and municipal agencies, and private companies. The intent is to integrate the coordinating committee into this association and ultimately turn the responsibility for inspector training over to VFBI.

After completing the seminar, attendees receive documents certifying their completion of the course. No examination is given before certification, although development of an examination is planned for the future. Anonymous tests are conducted, however, to assess quality of the training. While this certificate is considered in selecting consultants to perform bridge inspections, it is not required.

The following are also planned:

- ❖ Development of a curriculum leading to a designation as engineer of inspection
- ❖ Periodic reexamination for renewal of a certificate
- ❖ Development of training programs for technicians

## Inspection Types and Frequencies

All of the countries visited had clear definitions of inspection types, but a major finding was that each country has several well-defined scopes for their inspections. A typical finding was that European agencies have developed a technical decisionmaking process for determining inspection frequency.

Usually included in this process is the competency of the inspection crew. Host nations visited believed that inspector qualifications and experience requirements by agencies as previously presented provided confidence in allowing inspectors to determine the duration between cycles of inspections, typically up to 5 or 6 years but up to 9 years in France. Denmark and France use risk acceptance criteria to help determine inspection type and frequency.

In establishing their programs, the host nations chose inspection intervals based on the amount of detail of their inspections, interim maintenance inspections, documentation, and qualifications of their inspectors. However, the host nations allow the inspection frequency of any individual bridge to be shorter (or perhaps longer in the case of France) than the set frequency or maximum frequency, based on factors related to inventory such as condition, size, structure type, age, average daily traffic, complexity, and robustness.

### *Finland*

Inspections are conducted in Finland over the life of the structure are as follows:

- ❖ The constructor, owner, bridge designer, and other interested parties make acceptance inspections after completion of construction or repair work. All defects and faults found in the inspection are recorded in the bridge register.
- ❖ Road supervisors carry out annual inspections to ensure the safety of the bridge. Items of concern

are immediately reported to the appropriate agency bridge engineer.

- ❖ General inspection is the primary inspection of the bridge. Typically, a general inspection is conducted every 5 years, with larger bridges inspected every 8 years, depending on the bridge condition. Finnra-certified bridge inspectors conduct the inspection. The inspectors enter the findings of the inspection in the bridge register.
- ❖ A basic inspection is a general inspection supplemented with a variety of tests and core samples taken by the Research Centre of Finland (VTT). The results are stored in the database as well. The test results serve as material for improving bridge age behavior models for BMS use and quality control. The basic inspection is used for the reference bridge group and for large and long bridges. The inspection interval is typically 5 years. The inspectors are certified bridge inspectors with bachelor or master of science degrees or higher examinations.
- ❖ Special inspection is carried out when a general inspection could not determine the reason for damage or before a repair plan is made. The inspection is made by bridge specialists with a master of science in engineering or higher degree.
- ❖ Certified bridge inspectors conduct underwater inspections, which usually occur at 5-year intervals. Underwater inspections are made mainly of bridges over large rivers where the speed of water and risk of damage by ice are high. Observations routinely made during underwater inspections include the following:
  - Losses in components due to corrosion (steel), erosion (concrete), or rot (timber)
  - Damage to components resulting from collisions of vessels or debris
  - Bed profile around foundations.
  - Location and extent of undermining at foundations
  - Bed profile across the channel
- ❖ Intensified monitoring is implemented when a bridge is situated on a significant roadway used by heavy vehicles where no weight limits can be imposed and no acceptable detour exists. A regular inspection is carried out frequently to determine impacts to bridge bearing capacity, condition, and deterioration. The inspection is carried out by road supervisors or certified bridge inspectors, depending on the degree of damage to the bridge.

### Denmark

Denmark conducts four types of inspections on its highway structures. The first is a road network inspection, which maintenance forces perform one to three times a week or when crashes or other highway incidents occur. Description of any damage found and photos are transmitted by phone or via the Internet directly to the engineer in charge of routine maintenance.

A routine maintenance inspection, performed at least annually, is a visual inspection conducted by Danish Road Directorate (DRD) staff. This type of inspection is performed when damage is estimated to be less than US\$16,000. Repairs are handled as routine maintenance, and data on the activity are collected and stored in the Danish Road Directorate's bridge management system (Danbro).

Principal inspections are conducted every few months to every 6 years, depending on condition and the inspector's knowledge of the bridge. On average, these inspections occur every 5.5 years. The inspector determines frequency of inspection. This inspection, conducted by DRD staff, is mainly a visual inspection. Condition remarks, damage descriptions, and cost estimates are recorded in Danbro. This type of inspection is performed when damage is estimated to be more than US\$16,000. As a result of a principal inspection, a special inspection may be ordered.

A special inspection is a more detailed inspection conducted to study a structure condition in more detail. Physical testing may be ordered as part of the inspection, including sampling of concrete, core drilling, and evaluation, and development of a more accurate cost estimate and estimate of duration to the next inspection. Special inspection reports typically provide two to four strategies to address structural needs.

### Norway

The Norwegian Public Roads Administration performs inspections in a fashion similar to Sweden. Major inspections are conducted at least every sixth year and general inspections typically are done on an annual basis. The data collected include a description of any damage, photos, and a damage assessment. A repair recommendation with costs is also provided. The data are used to plan maintenance and, in some cases, to provide input for planned rehabilitation or replacement projects.

*The intention of our inspection system is to implement a risk-based inspection system in which the resources and the knowledge of the inspectors are optimized to fit every bridge. Bridges with short spans or total lengths and not crossing streaming water could be inspected less frequently than larger bridges, for instance; old bridges could have inspections more often; and so on. The responsible bridge engineer in every region could do this optimization within the limits given by the guideline.*

–NORWEGIAN PUBLIC ROADS ADMINISTRATION

**Sweden**

In Sweden, two main kinds of inspections are performed for bridges: major inspection and general inspection.

The purpose of a major inspection is to identify and estimate damage that can affect the function or safety of a structure within 10 years. The purpose is also to determine damage that may lead to increased maintenance and repair costs if not repaired or maintained within 10 years. The major inspection is performed for all structural components, including those components underwater in daylight or equivalently lit conditions and from a distance of an arm’s length. A major inspection is performed at least every 6 years. The inspector decides at the site when the next inspection shall be performed. It is important to emphasize that it is the condition of the bridge that is relevant for the frequency of the inspections. Deteriorating bridges are inspected more frequently.

The purpose of a general inspection is to follow up on damage identified during the last major inspection and repaired or corrected. Another purpose of the general inspection is to identify and estimate new damage that could lead to insufficient carrying capacity, traffic safety issues, or increased maintenance costs if not addressed until the next major inspection.

In addition to these two types of inspections, a special inspection may be routinely performed for mechanical and electrical equipment on movable bridges. Special inspections are also performed whenever a regular inspection has indicated a need to investigate in more detail a stated or presumed damage. Normally, only the specific damage or deficiency is investigated.

Other inspections include those performed by the contractor responsible for the maintenance contract for the segment of road containing the bridge. The purpose of these inspections is to identify damage that can affect traffic safety and the condition of the structure. Another purpose is to verify that the requirements of the maintenance contract are fulfilled.

**France**

In France, four types of bridge inspections are performed: routine visit, annual inspection, Image de la Qualité des Ouvrages (IQOA) evaluation inspection, and detailed inspection.

Maintenance forces make routine visits during their patrols of the highway system they are assigned.

Annual inspections are cursory, visual inspections

intended to identify new, significant defects in structures and to program routine maintenance.

IQOA evaluation inspections, performed every 3 years, are more detailed visual inspections of structures. The purpose of this inspection is to classify the condition of bridges by IQOA class. The significance of this inspection is the classification, which is used to make decisions on capital investments to correct deficiencies identified by the inspector in the field. IQOA classes are outlined in figure 11.

<b>Bridges in apparently good condition</b>	need nevertheless common maintenance <b>CLASS 1</b>
<b>Bridges with defects on equipment or protection elements or minor structural damages</b>	need specialized maintenance without urgency to repair <b>CLASS 2</b>
	need specialized maintenance with urgency to repair in order to prevent increase of defects in the structure <b>CLASS 2E</b>
<b>Damaged structure</b>	needs repair without urgency to repair <b>CLASS 3</b>
	needs repair with urgency to repair <b>CLASS 3U</b>

**Figure 11. IQOA grading scheme for bridge condition.**

Detailed inspections occur every 3 to 9 years, but typically every 6 years, based on the inspector’s recommendations. These are thorough visual inspections of bridges noting all defects. The detailed inspection is a brand-new inspection, often performed without reference to previous inspections, that establishes a bridge condition baseline to be used for inspections performed until the next detailed inspection is done.

**Germany**

Bridge inspections in Germany are defined as follows:

- ❖ Major inspections involve visual inspection and testing (material investigations) of all parts of a structure by inspection engineers. Generally, they are conducted every 6 years. Damage and condition assessment are performed according to RI-EBW-PRÜF, *Directive for Uniform Determination, Assessment, Recording, and Analysis of the Results of the Inspection of the Structures in Accordance*

*With DIN 1076.* The first major inspection is performed before the structure is opened to traffic and the second major inspection is done before the end of the guarantee period.

- ❖ Minor inspections, conducted every 3 years, are visual inspections by inspection engineers to check the results of the major inspection.
- ❖ Ad hoc inspections are performed by engineers to obtain an indepth view of a particular damage or deterioration process that has occurred at the bridge (accidents, flooding, etc.).
- ❖ Inspection in accordance with other regulations and standards may be required of machinery and electrical equipment forming part of highway structures, especially movable facilities and gantries.
- ❖ Superficial inspections are performed by maintenance personal. These types of inspections require no special knowledge of highway structures. The objectives are to detect major visible faults, check the functionality of components on a quarterly basis (visual), and perform an annual inspection of all accessible parts.
- ❖ Routine safety monitoring is performed on an ongoing basis by maintenance personnel as part of their routine superficial inspection of the highway.

As the above description shows, there is great dependence on road maintenance supervisors to routinely monitor and report issues of structural condition in all of the countries visited. This practice greatly enhances the ability of the agencies to manage their bridge assets.

Another factor of interest was that European road agencies typically require inspection of structures starting at spans of 2 meters (6.5 feet), which includes many culverts and smaller structures in their management systems.

## Use of Reference Bridges

Finland had a unique approach to insuring quality. The Finnish Road Administration uses 106 bridges and 26 steel culverts as a control sample or set of reference bridges. This pool of bridges is statistically chosen as a representative sample of Finland's bridge inventory. Baseline data are gathered from these bridges by experienced in-house bridge inspection staff to provide consistency.

Data gathered are used to fulfill a variety of needs, including the following:

- ❖ Provision of data on bridge serviceability and durability over time
- ❖ Trend analysis of data gathered on similar bridges

and updating of deterioration models in the bridge management system

- ❖ Quality control of inspection data from nonreference bridges by providing baseline data for comparison
- ❖ Training and refresher training of inspectors and evaluation of inspector condition ratings against condition ratings provided by in-house staff and the mean of all inspectors

A reference bridge is categorized either as a structure exposed to seawater or deicing salt or as an "other" structure. Field tests performed on reference bridges include the following:

- ❖ Carbonation depth of the concrete
- ❖ Acid-soluble chloride content
- ❖ Concrete deck cover
- ❖ Thickness of coatings in railings and steel structures
- ❖ Concrete compressive strength
- ❖ Relative humidity of the concrete

In addition to the above tests, additional lab tests are performed on samples removed from the structure as follows:

- ❖ Porosity of concrete
- ❖ Protecting porosity ratio
- ❖ Water penetration resistance factor
- ❖ Capillary factor
- ❖ Concrete compressive strength
- ❖ Concrete density and dry density
- ❖ Carbonation depth

As stated above, Finnra uses these reference bridges and data from their inspections several ways. New information is harvested about bridge behavior and durability through these reference bridge studies that can be used for various purposes. Data are used to improve deterioration models for both the network-level and project-level BMS by model simulation with real data as mean values. The data are used to adjust deterioration models of bridge materials, as well as to provide structural and environmental information on a specific structure at the project level. The data are used for quality control by comparing baseline data with inspection data entered in the register for similar bridges and identifying any anomalies in those data.

The Finnish Road Administration certifies bridge inspectors annually. Inspectors are required to perform a general inspection of a number of bridges determined by the number of bridges the inspector proposes to inspect during the upcoming year (table 8). The inspector's resulting condition assessment is compared against ratings determined by Finnra staff. The chosen sample bridges will have been previously rated by Finnra with damage points to be coded by the examinee. Inspectors are evaluated on how their proposed

condition ratings compare to condition ratings provided by in-house staff. This evaluation is also used to provide quality points for selection of consultant inspectors. If the examinee's scores exceed a set deviation range established by Finnra, an exception report is generated. Two quality parameters have been developed based on the examinee's deviation from the damage points of the nine main groups of structural members and the relative deviation from the sum of the repair cost of the bridge.

The results of these quality control inspections are used to determine personal quality points for an inspector. These quality points are then used in two ways of interest to the scan team. First, they are used as part of the Finnra procurement process to select bridge inspectors. Second, they are used to develop refresher training for inspectors when large differences from control ratings are noted.

**Table 8.** Number of reference bridges to be inspected versus anticipated inspector assignments.

Number of inspected bridges	Number of control inspections
1–100	2
101–300	3
>300	4

Finland also has a defined QC/QA plan that is part of its agreement for consultant services.

## Nondestructive Testing

During inspections, host nation bridge inspectors use nondestructive testing (NDT) to assist in their coding. Several agencies had detailed references outlining the appropriate use of NDT devices and methods, including terms and definitions, defects for which they are applicable, and, in Germany, independent evaluations of NDT products by users.

### Finland

In Finland, appropriate use of NDT and sampling for lab testing is incorporated into the inspection process and also used during basic inspections and inspections of reference bridges. The extent of investigation and quality requirements for the following tests are outlined in Finnra's inspection guidelines:

- ❖ Concrete cover
- ❖ Carbonation depth
- ❖ Chloride content
- ❖ Electrode potential
- ❖ Rebound hammer testing
- ❖ Microstructural analysis of concrete

- ❖ Tensile bond pull-off testing
- ❖ Moisture of concrete cover
- ❖ Opening of surface structures
- ❖ Coating depth of steel parapets

### Norway

The Norwegian Public Roads Administration's *Handbook for Bridge Inspection* provides specific guidance on tests used during various types of bridge inspections. The handbook provides specific guidance on tests to be performed based on such items as warrants for testing, type of inspection, bridge type, location and environmental conditions, and material being tested. The handbook gives more specific references to test procedures and protocols as appropriate.

### Germany

The Germans have linked their inspection manual to a compendium, ZfP-Bau Compendium, containing independently evaluated, available NDT methods that could be used during a bridge inspection. The compendium presents an evaluation of the various NDT methods available to end users and provides an independent opinion on the various items included. The compendium provides a detailed discussion on characteristics, applications, and evaluation of products. The report is a living document that allows updates as new items are evaluated.

The compendium was published in 1991 as BAM Research Report 177, *Study of the Application of Nondestructive Testing Methods for Engineering Structures*. The Germans had significant motivation for undertaking this effort. They found that knowledge about NDT methods was widely nonexistent and this lack of information was a major reason for not using NDT where appropriate. Further NDT training is not part of the engineering education of Germany's inspectors. Germany had a huge need, therefore, for an independent source of information about NDT to help inspectors determine which method to use for a given set of circumstances and to provide information on where the technology could be obtained.

The effort began in the late 1980s, when the work was first published as a Web document. Shortly thereafter, the Germans decided to create an interactive document, which is how the compendium exists today. The system is maintained in an expandable database, which allows for easy updating and generation of the compendium on a periodic basis.

As a result of the popularity of the compendium and the availability of the World Wide Web, an HTML version was created in 1997. The compendium was completely revised in 1999, and the latest revision was in 2004. The

hypertext format allows for intuitive interaction and links to other sites. The compendium can be distributed in various media such as XML, as a printed text, as an electronic file, via the Web, or on CD for local use.

The Germans have identified several needed improvements. These include better marketing of the compendium as a useful tool for the inspection community; additional support from manufacturers, researchers, and end users; and willingness to share case studies, including successes and issues associated with the use of the NDT technologies in the compendium.

Several unique applications of NDT technology were available in Germany. One such device was a specially configured ultrasonic shear wave transducer (shown in figure 12) for use in identifying defects. This device consists of 10 units with ceramic tip, dry point contact 55 kHz shear wave transducers mounted in a controller. Each transducer fires sequentially over a period of 350 milliseconds, providing a reflected image of the interior of the element examined. When mounted on a robotic trolley or “stepper,” developed by BAM, this device can be automated to provide an image across a length of deck or other element of interest.

BAM has developed several applications of scanning systems that allow measurements with NDT methods over large areas and with a high density of measurement points. It has used new tools available for data processing and visualization to improve the interpretation of resulting measurements obtained on concrete structures. Techniques developed to date allow the location and measurement of concrete structures up to

1.75 meters (5.7 feet) thick, tendon ducts up to 90 centimeters (35.4 inches) deep (including the location of tendon ducts in the second layer when ultrasonic echo is used), and nontensioned reinforcement using radar and grouting faults in tendon ducts.

A large concrete slab has been constructed in Germany for evaluating nondestructive evaluation (NDE) technologies. This slab includes embedded defects in the concrete (voids) and varying concrete thicknesses. The slab also includes post-tensioning ducts with grout voids of different characteristics. NDE methods intended to detect and quantify these embedded grout voids have been tested and evaluated. Advanced methods of scanning and imaging of NDE results have been developed using the slab, and a variety of acoustic and electromagnetic NDE technologies have been tested on the slab. Research has been conducted on fusion of data from different NDE methods to improve NDE capabilities. The slab has provided a test bed for researchers from around the world to evaluate and develop their technologies.

When possible, several agencies also use bridges scheduled for demolition to evaluate the effectiveness of NDT methods. NDT devices are used on these structures and data gathered are verified by actual field measurement during demolition or by lab tests off site.

## Cause of Damage Determination

Most of the agencies visited include a cause of damage investigation by the inspector as part of their bridge inspection procedure. Inspectors are trained to assess damage to a structural element based on structural stability, user safety, and effect on the damaged component’s durability and recommend corrective action to address the damage. Using the inspector’s knowledge of structures, coupled with a determination of urgency, an agency can calculate the immediate and short-term programming levels required.

The European agencies place a greater emphasis on determining the cause of a particular defect in the bridge. This is in contrast to the U.S. approach of characterizing the element or component, which essentially characterizes the effect of the defect. As a result, there is a greater integration of mitigation strategies (i.e., repair and rehabilitation activities specified by the inspector).

All agencies had procedures that would initiate actions based on the severity of the

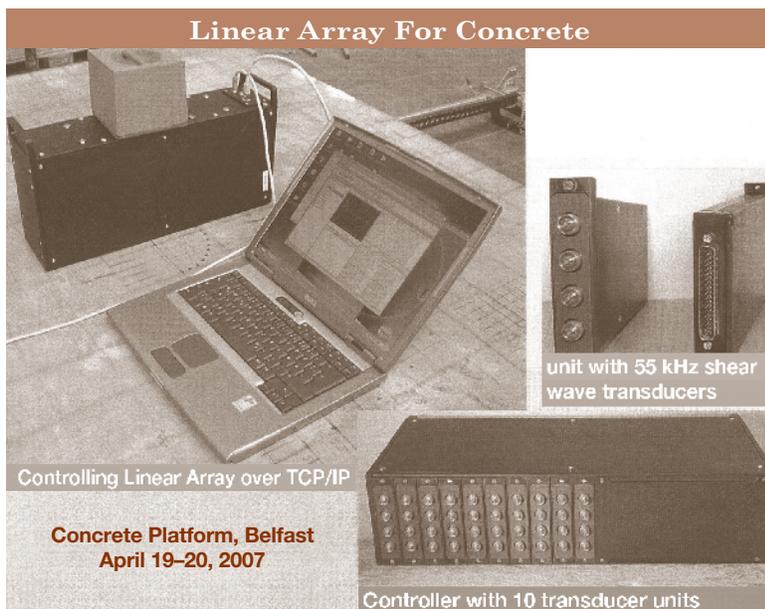


Figure 12. Ultrasonic shear wave transducer.

condition found, with or without a higher level of review and approval. In all cases in which critical structural conditions are found, immediate needs are addressed by immediate contact with the individual responsible for the facility, thus insuring public safety and protection of the facility from additional damage. Several other owners have procedures to initiate maintenance activities at the direction of the inspector.

One example of guidance provided to inspectors in making a level of urgency recommendation was found in Finland. The damage severity and a structural element's estimated condition are classified on a scale from 0 (no damage) to 4 (serious damage), according to guidance given in Finnra's *Bridge Inspection Manual*. The damage's repair urgency is to be described by Finish inspectors as follows:

- ❖ Repair must be done immediately.
- ❖ Repair will be done during the next 2 years.
- ❖ Repair will be done during the next 4 years.
- ❖ Repair will be done later in the future.
- ❖ No repair (the bridge will be used to the end of the service life).

The *Bridge Inspection Manual* recommends repair measures for each damage class and type of structure. The inspector is to make a recommendation for a repair measure based on his or her judgment of the observed damage to a bridge or element.

Another example was found in Sweden. The Swedish Road Administration (SRA) holds the inspector responsible for describing the condition of the entire structure, forecasting the deterioration rate, and proposing a suitable remedial action. SRA believes this is an extremely successful practice because the whole structure (i.e., all components) is systematically assessed during the inspection. It also requires that inspections involving several distinct evaluations (main inspection, steel inspection, underwater inspection, etc.) be completed in a relatively compressed timeframe to provide for the best possible overall assessment of the structure.

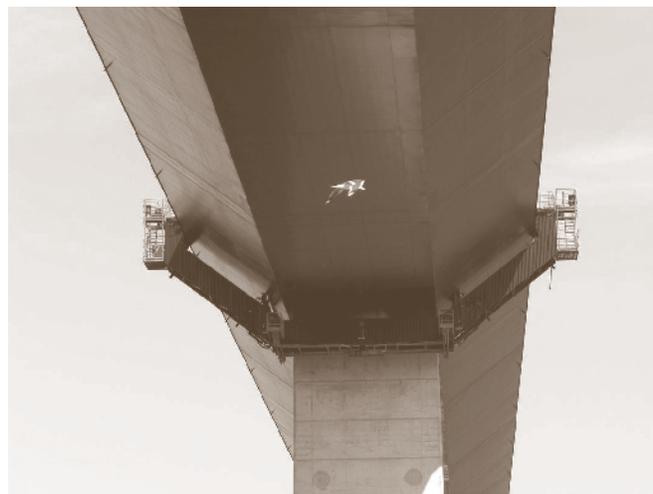
The scan team found that host country agencies generally tracked maintenance activities in their bridge records. This provided better management data on actual bridge conditions as well as costs associated with a structure.

## Other

An additional item of interest the team identified for consideration in the United States was a German DVD, "Inspection According to German Industrial Standard (DIN) No. 1076." The DVD is intended for viewing by the general public and outlines the reasons for bridge

and structure inspection. The DVD not only provides an informative overview of the inspection process, it also was reported to be a useful mechanism for maintaining support for bridge inspection activities from its audience.

During bridge inspection site visits, the team observed bridge details incorporated in the design process to facilitate bridge inspections. At the Great Link Bridge in Denmark, elevators allowed easy access to the towers. Inspectors used a monorail inside the tub girder to move through the structure and transport inspection equipment. A permanent traveler, shown in figure 13, was installed for inspection of the structure's exterior. In Germany, concrete steps were built along the wing wall to allow for safe traverse of the side slope. A measuring system integral with the bearing was used to determine bearing displacement. Also, the pier cap at the expansion end was designed to allow access to inspect the post tensioning anchor block and modular joint. These details would also be helpful in performing bridge maintenance activities.



**Figure 13.** *Permanent traveler on Great Link Bridge to provide inspection and maintenance access to underside of superstructure.*

## Recommendations

Based on the above findings, the team identified six primary topic areas for implementation:

1. Develop a rational basis for bridge inspection frequency.
2. Develop guidelines for developing QA/QC procedures for States.
3. Develop illustrations and reference photos for manuals.
4. Develop integrated inspection repair approaches.
5. Transfer technology discoveries from the scanning study.

6. Initiate a demonstration project on the ultrasonic shear wave transducer.

## **Planned Implementation Actions**

The scan team has developed a detailed implementation plan for the recommended initiatives and practices. Included in the plan are a number of technical presentations and papers at national meetings and conferences sponsored by FHWA, AASHTO, and other organizations to disseminate information from the scan. Also included in the plan is coordination with AASHTO and FHWA to advance these initiatives and practices, including assisting with the development of new FHWA and AASHTO standards and guidelines governing quality in bridge inspection. These and other planned activities are discussed in Chapter 3.

# Recommendations and Implementation Activities

## Introduction

Team members identified a number of bridge inspection initiatives or practices that varied from those in the United States in some respect. The team recommended that six of these initiatives or practices be further considered for study and possible implementation in the United States.

The six initiatives and practices the scan team identified are as follows:

1. Develop a rational basis for bridge inspection frequency.
2. Develop guidelines for developing QA/QC procedures for States.
3. Develop illustrations and reference photos for manuals.
4. Develop integrated inspection repair approaches.
5. Transfer technology discoveries from the scanning study.
6. Initiate a demonstration project on the ultrasonic shear wave transducer.

Each implementation topic has specific actions to enable the utilization of scan results within the context of existing bridge evaluation and inspection programs in the United States, with an emphasis on improving quality control and quality assurance practices.

## Key Items for Implementation

### *Develop a Rational Basis for Bridge Inspection Frequency*

All of the countries the team visited had clear definitions of inspection types. A major finding was that each country also has several well-defined scopes for its inspections. A typical finding was that most European agencies have developed a technical decisionmaking process for determining inspection frequency. This process considers the scope of the inspection to be conducted and identifies training and qualification requirements for inspectors. Generally, this consisted of comprehensive inspections at intervals of up to 6 years or more, with inspections of the lesser scope used more frequently.

The scan team recommends the development of a nationally accepted basis for determining bridge

inspection frequencies based on factors such as safety, condition, design, age of the structure, and engineering judgment. Different levels of inspection intensity and scope should be combined with clear standards for inspector education, training, and qualification. Combining different levels of inspection with more comprehensive and in-depth inspections at 6 years or other suitable frequency and inspections with a more limited scope at shorter intervals may provide more effective inspections, improve overall quality, and allow more effective use of resources. This could be implemented as an optional tool that a State or Federal agency could use for newer bridges, or it may be suitable for implementation on a wider scale. Ultimate implementation of the process will likely require FHWA to modify the National Bridge Inspection Standards (NBIS) regulation.

The implementation strategy includes review and modification of a problem statement under development entitled “Developing Reliability-Based Bridge Inspection Policies,” which provides a basis for study of the concepts and processes identified by the scan team. It also includes working with AASHTO, FHWA, TRB, and others to ensure approval and funding of the proposed project. Based on the recommendations of the project, AASHTO, working with FHWA, should develop proposed revisions to the current NBIS along with supporting references and National Highway Institute training modules.

### *Develop Guidelines for Developing QA/QC Procedures for States*

The scan team recommends the development of national guidelines for developing QC/QA procedures for use by State and local agencies. These guidelines would be for in-house staff and similar guidelines could be made part of bridge inspection services contracts. To develop these guidelines, it is suggested that a State DOT technical panel work in conjunction with a technical resource within the NCHRP framework to develop practical, implementable guidance that extends the existing FHWA framework. Clear descriptions of how to apply these guidelines within the context of an individual State inspection system will be required. Documentation and practices from other industries, such as the ISO 9001 process and other applicable documents, should be reviewed and

implemented if practicable, as well as existing research (e.g., ongoing NCHRP Synthesis Topic 37-05 on bridge inspection practices). Consideration of the reference bridge concepts and development of statistically based methods for measuring uniformity of bridge inspections (based on the Finnra model) should be considered, as well as an examination of reference photographs for use as a tool in a QA/QC program. Establishing a pilot program in one or more States may be appropriate. Funding sources for such a study may include FHWA, State DOTs, University Transportation Centers (UTCs), or NCHRP.

The implementation strategy includes development of an NCHRP 20-07 Problem Statement, “Guideline for Implementing Quality Control and Quality Assurance for Bridge Inspection,” to provide for the development of guidelines as described above and working with AASHTO, FHWA, TRB, and others on transferring the guidelines into practice in the States.

### ***Develop Illustrations and Reference Photos for Manuals***

Many detailed, heavily illustrated manuals and references were available as tools for bridge inspectors in many of the countries visited. These included inspection manuals, maintenance guides, repair manuals, and coding and recording data guides. The primary approach in the United States and the European countries the scan team visited is visually based inspection. The Europeans use visual aids to a greater extent in the recording and coding of data, damage assessment, and maintenance and repair. Many more manuals appeared to be readily available to inspectors than is typical in the United States. To focus inspectors and provide more uniform ratings, the types of damage with performance indices were clarified by accompanying photographs. These manuals contained many photos and drawings showing the damage and its corresponding rating levels.

The scan team recommends the expanded use of illustrations and reference photographs describing bridge conditions to improve accuracy and consistency of inspections. To support this recommendation, the scan team will survey FHWA Divisions to determine which States have photos and illustrations in their inspection manuals.

In addition, the scan team suggests that a study team be organized to frame the initiative and develop an approach to move toward expanded use of illustrations and reference documentation. The objectives of the study team will include the following:

- ❖ Provide a vision for future coding guide and inspection manual improvements.

- ❖ Explore the extent of State and local agency use nationwide of the AASHTO *Guide for Commonly Recognized Structural Elements* (CoRe Element Manual).
- ❖ Investigate the relevance of Pontis documentation in improving inspection processes and providing additional resources for inspectors.
- ❖ Review the state-of-the-art practices in other industries on improving QA/QC processes through the use of illustrations, photographs, and reference manuals.

The ultimate goal of implementation is to define a longer term project by FHWA or NCHRP to develop improved inspection resources, and implement photos and illustrations as tools for highway bridge inspection ratings across the country.

The implementation strategy includes developing an illustrated manual survey requesting information on State use of illustrations and photos to improve accuracy and consistency in bridge inspection and distributing the questionnaire to the FHWA Division offices. Upon completion of the survey, organize a group of subject matter experts from FHWA, AASHTO, academia, and the private sector to identify best practices and incorporate them into FHWA bridge inspection manuals and guides.

### ***Develop Integrated Inspection Repair Approaches***

Most of the European agencies visited include a cause of damage investigation by the inspector as part of their bridge inspection procedure. Inspectors are trained to assess damage to a structural element based on structural stability, user safety, and effect on the damaged component's durability. In many cases, inspectors were also charged with developing recommended corrective action to address the damage and evaluating the urgency of the repair need. Using the inspector's knowledge of structures and determination of urgency, an agency can calculate the immediate and short-term programming levels required.

The scan team observed a greater emphasis in Europe on determining the cause of deterioration or damage in the structure as part of the inspection process. This is in contrast to the U.S. approach of characterizing the element or component (i.e., rating the component), which essentially characterizes the effect of the damage but does not characterize its cause. Characterizing the cause of the deterioration during the inspection process may provide a better integration of mitigation strategies (i.e., repair and rehabilitation activities specified by the inspector).

Possible implementation actions include exploring the development of a manual that provides an array of recommended repairs linked to specific inspection conditions. Such a manual could be used for improving inspector training and improving inspection and maintenance of structures. A model for such a manual was observed in Finland, where the SILKO manual helps inspectors recognize the mechanisms behind observed damage and understand appropriate repair procedures. Such a manual would assist in developing a link between inspection rating and repair activities. An examination of how the AASHTO CoRe Element Manual could be used to achieve these objectives should be conducted.

Other implementation actions are recommended that could assist more generally in providing better tools for inspectors to assess the condition of bridges and integrate inspection and repair strategies. These include broader implementation of nondestructive evaluation (NDE) within the context of routine bridge inspections. Reintroduction of the National Highway Institute (NHI) training course on NDE for highway bridges should be explored. Also, scan team members should support the Structural Materials Technology: NDE for Highways and Bridges Conference to be held in Oakland, CA, in December 2008. This conference will include a workshop on NDE technologies for routine inspections.

The implementation strategy includes supporting the development of integrated inspection repair approaches and translation and dissemination of the SILKO manual, as well as other references and manuals discovered during the scanning tour and referenced in the final report. Also, FHWA and AASHTO should explore and support reintroduction of the NHI course on NDE for highway bridges, and support the Structural Materials Technology conference planned for 2008.

### ***Transfer Technology Discoveries From the Scanning Study***

A number of interesting and valuable items were discovered during the course of the scanning study that are appropriate for technology transfer activities in the United States. Many of these items are highlighted elsewhere in the report. Of particular interest are the following:

- ❖ Crack mapping using keys and 2-D scaled representations to better chart crack development over time in concrete structures. One method is described in a French document, *Report 47*.
- ❖ Documents that provide summary technical data on the application of NDE technologies to assist inspectors in identifying potential NDE solutions to inspection challenges. One example is the NDE toolbox data sheets from the European Union's

Sustainable Bridge project. Another example is an NDE methods compendium developed by the German Materials Research Institute.

- ❖ Bridge access vehicles were available that were different than those typically used in the United States. Information on the expanded inventory of access equipment for bridge inspection should be made available in the United States.
- ❖ The Sustainable Bridge project sponsored by the European Union has made some significant investments in exploring NDE for bridge condition assessment. A conference to be held in Poland will summarize many of the activities and research conducted under the project. Information on this conference should be made available in the United States.

Also, the scan team observed that Finland in particular was implementing some innovative QA/QC activities. Additional technical interchange with representatives of Finnra is recommended.

The implementation strategy includes development by FHWA of a reference Web site for scan data and recommendations. Included on this site should be the NDT compendium and other documents of interest discovered during the scanning study.

### ***Initiate a Demonstration Project on the Ultrasonic Shear Wave Transducer***

An ultrasonic shear wave transducer that enables the acoustic imaging of embedded features in concrete structures was demonstrated during the scanning study. This technology, developed and manufactured in Russia, has not been available in the United States. This technology has potential for application in the United States under several scenarios, including the detection of grout voids in post-tensioning ducts, as well as more traditional acoustic wave applications such as pulse velocity and delamination detection. A pilot or demonstration project could assist in transferring this technology to the United States.

The implementation strategy includes encouraging development of an NCHRP IDEA project or a State DOT-funded project to demonstrate this technology in the United States. Technology transfer activities to support the development of a project to demonstrate this technology in the United States should be undertaken.



## APPENDIX A:

# Amplifying Questions

BRIDGE OWNERS IN EUROPE AND THE United States depend on data from their respective bridge inspection programs to identify the condition of their bridges.

Assuring the quality and relevancy of the data collected is extremely important to maintaining a high level of safety for the traveling public, ensuring effective use of limited funds, and helping bridge owners achieve their safety, reliability, and mobility goals. Better knowledge of quality assurance and quality control (QA/QC) programs and data types collected by advanced countries would provide meaningful advice to our transportation community. To this end, the U.S. team has an interest in obtaining information on how quality is assured in other nations' bridge inspection programs. In particular, the team would like to observe how quality standards are maintained the following ways:

- ❖ By understanding laws, regulations, and standards governing bridge inspection
- ❖ By observing a routine inspection of a highway bridge
- ❖ By viewing any specialized equipment used for inspection
- ❖ In documentation of the results of the inspection
- ❖ Through inspector training and recertification

The scanning study team wishes to build on the information obtained during the 2003 bridge management and preservation scanning study and the subsequent National Cooperative Highway Research Program questionnaire sent to selected countries. We hope to accomplish that by focusing on specific questions listed in the six topics below.

## Topic #1: Organizational Structure and Background

1. Are there any laws or regulations that relate to inspection of highway structures or bridge safety? If so, what is the definition of a bridge and other highway structures covered by these regulations?
2. Are national standards, procedures, manuals, or guides governing data collection available?
3. How and at what level in an agency are the data collected, stored, managed, and maintained? How often are data updated? What data are used to initiate maintenance, operations, funding levels, or other actions by the agency?
4. Who owns highway structures in your jurisdiction and

what are their responsibilities for the overall safety of the public who use your bridges? Please provide statistics on your inventory, if possible.

5. How are inspectors or crews organized to perform the work? Is bridge inspection the only function performed by qualified individuals, or are other duties performed as part of their job?
6. What do you consider your best practices in bridge inspection?
7. What data are maintained on bridge or bridge component failures?

## Topic #2: Inspection Data

1. What different types of inspections are performed? What requirements exist for special inspections and what might they be?
2. What frequency and to what detail are inspections required to be performed? What is the basis for the inspection frequency?
3. What types and quantity of data items are collected and maintained? To what detail are the data collected? Are data collected beyond the requirements of laws and regulations, and what might that data be? Are the data numeric or descriptive?
4. What are the data used for? Are the inspection data integrated into a bridge management system for managing a maintenance, rehabilitation, and replacement program? Are they used on a network basis?
5. Do your regulations require safe load rating capacity of these structures? Are the data used for load posting, permitting, and controlling movements of nonstandard-size or -weight vehicles? What is the maximum unrestricted legal load?
6. Have standard data items, collected during field inspections, been added or eliminated? For what reason? How frequently does this occur?

## Topic #3: Personnel Qualifications

1. Are inspection personnel formally certified? Are educational and physical qualifications required of inspection personnel? Are there requalification requirements? Who sets these requirements?
2. Is there a career track for inspection personnel? What are the different levels of certification for inspectors, team leaders, and managers? Are there different

requirements for inspectors employed by private firms?

3. What special qualification requirements are there for those who perform unique inspections, such as underwater or fracture critical member inspections? (Fracture critical members (FCM) are defined as steel members in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse.)
4. How are qualifications tracked and verified? How are qualifications of private firm personnel tracked and verified?
5. To what extent is testing of inspectors required (e.g., exams, field demonstration of skills, performance testing, use of reference bridges, etc.)?
6. Is the inspector's performance tracked? Are incentives or corrective actions initiated based on job performance?

### Topic #4: Process Control

1. Are procedures documented in a procedures manual readily available to inspection personnel? Is there a specific procedures manual governing requirements for conducting the inspection? How often are the procedures updated? Are the QA/QC measures documented in a manual?
2. What manuals exist that define ratings and/or condition states? How are condition ratings calibrated to ensure all inspection teams have the same understanding of the definition of ratings and existing condition states?
3. How are updates to procedures and manuals disseminated to inspectors?
4. How is QC/QA applied to bridge inspection procedures, training, manuals, reports, and data?
5. Is there a process for reinspecting a sampling of bridges? If so, what is that process?
6. What role does your central ministry have in the process of insuring quality?
7. What processes are used to ensure data quality? Are automated data checks used? Are there any governmental regulations governing the data?
8. How soon after an inspection are data available for use in other processes?
9. What is the process for addressing critical issues found in the field?

### Topic #5: Equipment

1. What types of equipment are used to access the structure and its components and to conduct the inspection?
2. What training is provided to ensure proper use of this equipment?
3. Is any nondestructive evaluation, nondestructive

testing, or other advanced testing equipment available? What special requirements are associated with its employment (e.g., certification, equipment maintenance and calibration)?

4. Are remote monitoring technologies used to any extent (i.e., scour monitoring, strain gauges, tilt sensors, etc.)?
5. Are there employee occupational safety or environmental requirements governing inspection operations and locations? How do they affect inspection quality?
6. What specialized equipment, if any, is used to record data and document the results of the inspection?

### Topic #6: Documentation

1. What information is documented during inspections?
2. Are standard forms and report formats required?
3. How is the accuracy of the documentation verified?
4. How extensively are sketches and photographs used?
5. How are documents submitted, approved, and maintained? Are automated document handling processes used?
6. How are actions initiated because of inspection activities reported and recorded? How are completions of such actions reported and recorded?
7. Are other activities, such as maintenance, traffic, and capital investment, integrated into bridge inspection records?
8. How long are records kept?
9. Is access to the data and documentation controlled or open to the public or other public agencies?

## APPENDIX B:

# Team Members

## Contact Information

### **Thomas D. Everett**

#### **(FHWA Cochair)**

Principal Bridge Engineer  
FHWA Office of Bridge Technology  
1200 New Jersey Ave., SE  
Washington, DC 20590  
Telephone: (202) 366-4675  
Fax: (202) 366-3077  
E-mail: [thomas.everett@dot.gov](mailto:thomas.everett@dot.gov)

### **Peter Weykamp**

#### **(AASHTO Cochair)**

Bridge Maintenance Program  
Engineer  
New York State Department  
of Transportation  
50 Wolf Road, Pod 5-1  
Albany, NY 12232  
Telephone: (518) 457-8485  
Cell: (518) 265-7768  
Fax: (518) 457-4203  
E-mail: [pweykamp@dot.state.ny.us](mailto:pweykamp@dot.state.ny.us)

### **Harry A. Capers**

#### **(Report Facilitator)**

Corporate Bridge Engineer  
Arora and Associates  
3120 Princeton Pike, 3rd Floor  
Lawrenceville, NJ 08648-2372  
Telephone: (609) 219-6789  
Cell: (609) 462-9435  
Fax: (609) 844-9799  
E-mail: [hcapers@arorapc.com](mailto:hcapers@arorapc.com)

### **William R. (Randy) Cox, P.E.**

Director, Bridge Division  
Texas Department of Transportation  
125 E. 11th Street  
Austin, TX 78701  
Telephone: (512) 416-2183  
Cell: (512) 731-7269  
Fax: (512) 416-3144  
E-mail: [wrcox@dot.state.tx.us](mailto:wrcox@dot.state.tx.us)

### **Thomas S. Drda**

North Carolina Division Bridge  
Engineer  
Federal Highway Administration  
310 New Bern Ave., Suite 410  
Raleigh, NC 27601-1410  
Telephone: (919) 856-4760, ext. 129  
Cell: (919) 946-5897  
Fax: (919) 856-4353  
E-mail: [thomas.drda@fhwa.dot.gov](mailto:thomas.drda@fhwa.dot.gov)

### **Lawrence Hummel**

County Highway Engineer Manager  
Van Buren County Road  
Commission  
325 W. James Street, PO Box 156  
Lawrence, MI 49064  
Telephone: (269) 674-8011  
Cell: (269) 569-6218  
Fax: (269) 674-3770  
E-mail: [vbcrchummel@comcast.net](mailto:vbcrchummel@comcast.net)

### **Paul Jensen**

Bridge Management Systems  
Engineer  
Montana Department of  
Transportation  
2701 Prospect Ave.  
Helena, MT 59620-1001  
Telephone: (406) 444-9245  
Fax: (406) 444-6155  
E-mail: [pjensen@mt.gov](mailto:pjensen@mt.gov)

### **David A. Juntunen**

Engineer of Bridge Operations  
Michigan Department of  
Transportation  
Construction and Technology  
Division  
8885 Ricks Road  
Lansing, MI 48909  
Telephone: (517) 322-5688  
Cell: (517) 749-8036  
Fax: (517) 322-5664  
E-mail: [juntunend@michigan.gov](mailto:juntunend@michigan.gov)

### **Tod Kimball**

Design and Structures Engineer  
FHWA Vermont Division  
87 State Street, PO Box 568  
Montpelier, VT 05602  
Telephone: (802) 828-4575  
Fax: (802) 828-4424  
E-mail: [tod.kimball@dot.gov](mailto:tod.kimball@dot.gov)

### **Glenn A. Washer**

Department of Civil & Environmental  
Engineering  
University of Missouri–Columbia  
Lafferre Hall, Room E2503  
Columbia, MO 65211-2200  
Telephone: (573) 884-0320  
Cell: (573) 673-2207  
Fax: (573) 882-4784  
E-mail: [washerg@missouri.edu](mailto:washerg@missouri.edu)

## Biographic Sketches

TOM EVERETT (FHWA COCHAIR) is the Bridge Programs Team leader in the Federal Highway Administration's (FHWA) Office of Bridge Technology in Washington, DC. Everett manages the National Bridge Program, including the Highway Bridge Program, National Historic Bridge Preservation Program, and National Bridge Inspection Standards. He is a member of many committees and task forces, including the American Association of State Highway and Transportation Officials' (AASHTO) Technical Committee on Bridge Management, Evaluation, and Rehabilitation and the joint FHWA/AASHTO Wave Task Force. Before joining the Office of Bridge Technology, Everett served as a bridge management and inspection engineer in the FHWA Resource Center in Baltimore, MD, a bridge engineer in Tennessee, and a structural engineer in the former Regional Office for Structures in Baltimore. Everett is a graduate of Rutgers University and holds a master's degree in civil engineering from Johns Hopkins University. He is a licensed professional engineer in Rhode Island.

PETER WEYKAMP (AASHTO COCHAIR) is the Bridge Maintenance Program engineer for the New York State Department of Transportation (NYSDOT). His primary duties include development of network-level maintenance strategies, operations management, product evaluation, and technical supervision. He has been with NYSDOT for 23 years, holding positions in structural design, research, and construction. He has been in his current position since 1997. Weykamp chairs the Bridge Task Force on the AASHTO Subcommittee on Maintenance and is a member of the Transportation Research Board's (TRB) AHD-30 Structures Maintenance Committee. He holds bachelor's degrees in biology and civil engineering and a master's degree in public administration.

HARRY A. CAPERS, JR. (REPORT FACILITATOR) is the chief bridge engineer for a regional transportation engineering firm in the northeastern United States. In this role, he is responsible for oversight of all highway bridge work in the firm's six offices. He also serves as the quality assurance manager for the firm. He chairs TRB Committee AFF10 on General Structures and TRB Subcommittee AHD35-01 on Safety and Security of Bridges and Structures. He also chairs several National Cooperative Highway Research Program (NCHRP) expert panels and serves as an industry advisor to the New Jersey Institute of Technology and the Multidisciplinary Center for Earthquake Engineering at the State University of New York in Buffalo, NY. Before his retirement from public service in 2006, Capers served more than 32 years

with the New Jersey Department of Transportation as chief bridge engineer and was responsible for all highway structures and geotechnical design work. Capers has served as a member of the AASHTO Subcommittee on Bridges and Structures, chair of its Technical Committee on Loads and Load Distribution and Committee on Tunnel Design, and vice chair of the Technical Committee on Seismic Design. He received a master's degree in civil engineering from Polytechnic University in Brooklyn, NY, and a master of public administration degree from Rutgers University in Newark, NJ. He has written 24 papers for national and international publications. Capers is a registered professional engineer in New Jersey and New York.

RANDY COX is director of the Bridge Division of the Texas Department of Transportation in Austin, TX. Under his direction, the division develops policy, standards, manuals, and guidelines for the design, construction, maintenance, and inspection of the state bridge system. The division oversees and manages the federal bridge inspection program for about 49,000 bridges in Texas. Cox chairs the AASHTO Technical Committee for Bridge Management, Evaluation, and Rehabilitation for the Subcommittee on Bridges and Structures and is a member of several TRB committees. Cox is a graduate of the University of Texas at Austin with a bachelor's degree in civil engineering. He is a licensed professional engineer in Texas.

THOMAS DRDA is the structural engineer in FHWA's North Carolina Division. In this position, he serves as the lead specialist on all structural matters pertaining to design, construction, maintenance, and safety inspection of highway structures. Drda is responsible for ensuring that the bridge inspection program in North Carolina is in compliance with National Bridge Inspection Standards. Before joining FHWA in 2001, he served as a senior structural engineer for a private firm and as a project manager for a State department of transportation. Drda is a graduate of Pennsylvania State University and a licensed professional engineer.

LAWRENCE B. HUMMEL is the county highway engineer manager and director of public works and parks and recreation for the Van Buren County Road Commission in Michigan. In this role, he is responsible for oversight of the day-to-day operations of the road commission and implementation of the preservation, rehabilitation, and reconstruction of bridges and other highway structures. He serves on the Regional Bridge Council—Southwest Region, responsible for reviewing and rating the region's critical bridge applications. Hummel received his bachelor's degree in civil engineering from Michigan Technological University and his master of public administration degree from

Western Michigan University. He is a registered professional engineer and a licensed residential builder in Michigan and a member of the National Association of County Engineers, the American Public Works Association, and the American Society of Civil Engineers (ASCE).

PAUL JENSEN is a bridge management systems engineer for the Montana Department of Transportation (MDT) in Helena, MT. Jensen develops and administers the State's bridge inspection standards, policies, and procedures. His work includes developing and updating MDT's *Bridge Inspection Manual* and updating the policy and procedures in the quality control/quality assurance area. Since joining MDT in 1995, he has developed and implemented automated checking procedures for MDT's electronic bridge inspection inventory data. Before joining MDT, he developed quality control/quality assurance procedures on transportation design projects for a consulting firm. Jensen graduated from Montana State University. He is a licensed professional engineer in Montana and serves on several TRB technical committees and AASHTO's BRIDGEWare Task Force.

DAVID JUNTUNEN is the engineer of bridge operations for the Michigan Department of Transportation (MDOT) at the Construction and Technology Laboratory in Lansing, MI. Juntunen directs the Bridge Operations Section, which includes bridge inspection, load rating, structural fabrication, bridge construction, and bridge management. Juntunen is the system manager for MDOT's annual \$185 million capital bridge preservation program and is responsible for developing strategy to meet the goals on improving the overall condition of MDOT's 4,400 highway bridges. Juntunen has worked for MDOT since 1987 and has served as a bridge designer, bridge project manager, structural research engineer, and special structures engineer. Juntunen is a civil engineering graduate of Michigan Technological University and a licensed professional engineer in Michigan.

TOD KIMBALL is the design and structures engineer for the FHWA Vermont Division. In this role, he manages the division's Federal-aid bridge program and serves as the principal staff specialist for structural matters. Before joining the Vermont Division, Kimball served as the assistant structures engineer for the FHWA Pennsylvania Division, a structural engineer with the Bridge Inspection and Management Program of FHWA's Federal Lands Bridge Office in Virginia, and a bridge design engineer and regional bridge inspection engineer for the Georgia Department of Transportation in Atlanta. He has performed National Bridge Inspection Standards compliance reviews and has conducted bridge safety

inspections for more than 40 national parks and military bases throughout the United States. Before joining the civil engineering ranks, Kimball served short stints as a high school mathematics teacher, a computer programmer, and a laborer in light residential construction. Kimball holds bachelor's and master's degrees in civil engineering from the University of Maine, and a bachelor's degree in mathematics from Gordon College in Massachusetts. He is a licensed professional engineer in Georgia.

DR. GLENN WASHER is an assistant professor at the University of Missouri–Columbia. Before joining the university, Washer was with the FHWA Turner-Fairbank Highway Research Center, where he served as director of the Nondestructive Evaluation (NDE) Program. Washer has expertise in a wide variety of NDE technologies for the condition assessment of highway bridges. He has published more than 60 conference and journal papers on the development of NDE technologies and the reliability of bridge inspection practices. Washer received his Ph.D. in materials science and engineering from Johns Hopkins University in 2001. He received a master's degree in structural engineering from the University of Maryland in 1996 and a bachelor's degree in civil engineering from Worcester Polytechnic Institute in 1990. Washer is an active leader in the technical community, chairing several committees related to the condition assessment of highway bridges. He chairs the TRB Subcommittee on the Nondestructive Testing of Structures and the ASCE Committee on Bridge Management, Inspection, and Rehabilitation.



## APPENDIX C:

# Host Country Contacts

### FINLAND

**Ms. Marja-Kaarina Soderqvist**

Finnish Road Administration  
Opastinsilta 12 A, PO Box 33  
FI-00521 Helsinki  
Finland  
Telephone: 011-358-204-22-2632  
Fax: 011-358-204-22-2512  
E-mail: *marja-kaarina.soderqvist@FINNRA.fi*

**Mr. Jouko Lamsa**

Finnish Road Administration  
Opastinsilta 12 A, PO Box 33  
FI-00521 Helsinki  
Finland  
Telephone: 011-358-204-22-2624  
Fax: 011-358-204-22-2395  
E-mail: *jouko.lamsa@FINNRA.fi*

**Mr. Timo Tirkkonen**

Finnish Road Administration  
Opastinsilta 12 A, PO Box 33  
FI-00521 Helsinki  
Finland  
Telephone: 011-358-204-22-2486  
Fax: 011-358-204-22-2395  
E-mail: *timo.tirkkonen@tiehallinto.fi*

**Mr. Risto Kiviluoma**

WSP Finland, Ltd.  
Heikkilantie 7  
FI-00210 Helsinki  
Finland  
Telephone: 011-358-207-864-11  
Fax: 011-358-207-864-800  
E-mail: *risto.kiviluoma@wspgroup.fi*

### DENMARK

**Mr. Arne Henriksen**

Danish Road Directorate  
Thomas Helstedes Vej 11  
DK-8660 Skanderborg  
Denmark  
Telephone: 011-45-7244-2442  
Fax: 011-45-8652-2013  
E-mail: *arh@vd.dk*

**Mr. John Bjerrum**

Danish Road Directorate  
Niels Juels Gade 13  
DK-1059 Copenhagen K  
Denmark  
Telephone: 011-45-3341-3434  
Fax: 011-45-3315-6335  
E-mail: *job@vd.dk*

**Mr. Asger Knudsen**

Ramboll Danmark A/S  
Bredevej 2  
DK-2830 Virum  
Denmark  
Telephone: 011-45-4598-6302  
Fax: 011-45-4598-6302  
E-mail: *akn@ramboll.dk*

**Dr. Sven Engelund**

Ramboll Danmark A/S  
Bredevej 2  
DK-2830 Virum  
Denmark  
Telephone: 011-45-4598-6000  
Fax: 011-45-4598-6700

**Mr. John Jensen**

A/S Storebaelt  
Storebaeltsvej 70  
DK-4220 Korsor  
Denmark  
Telephone: 011-45-5830-3061  
Fax: 011-45-5830-3003  
E-mail: *jj@sbfdk*

**Mr. Leif Vincentsen**

A/S Storebaelt  
Vester Sogade 10  
DK-1601 Copenhagen  
Denmark  
Telephone: 011-45-3393-5200  
Fax: 011-45-3393-1025  
E-mail: *ljev@sbfdk*

### NORWAY

**Mr. Knut Grefstad**

Norwegian Public Roads  
Administration  
Grensleven 97, PO Box 8142 Dep  
N-0033 Oslo  
Norway  
Telephone: 011-47-2207-3412  
Fax: 011-47-2207-3866  
E-mail: *knut.grefstad@vegvesen.no*

**Mr. Gunnar Djuve**

Norwegian Public Roads  
Administration  
Askedalen 4  
N-6863 Leikanger  
Norway  
Telephone: 011-47-5551-6218  
E-mail: *gunnar.djuve@vegvesen.no*

### SWEDEN

**Mr. Bosse Eriksson**

Swedish Road Administration  
S-781 87 Borlange  
Sweden  
Telephone: 011-46-243-756-71  
Fax: 011-46-243-757-66  
E-mail: *bo-e.eriksson@vv.se*

**Ms. Christine Eriksson**

Swedish Road Administration  
S-781 87 Borlange  
Sweden  
Telephone: 011-46-243-750-86  
Fax: 011-46-243-757-66  
E-mail: *christine.eriksson@vv.se*

**FRANCE**

**Mr. Thierry Kretz**

SETRA  
46 ave. Aristide Briand  
BP-100  
92225 Bagneux Cedex  
France  
Telephone: 011-33-1-4611-3258  
Fax: 011-33-1-4611-3352  
E-mail: *thierry.kretz@equipement.gouv.fr*

**Mr. Gilles Lacoste**

SETRA  
46 ave. Aristide Briand  
BP-100  
92225 Bagneux Cedex  
France  
Telephone: 011-33-1-4611-3292  
Fax: 011-33-1-4611-3352  
E-mail: *gilles.lacoste@equipement.gouv.fr*

**Mr. Joel Raoul**

SETRA  
46 ave. Aristide Briand  
BP-100  
92225 Bagneux Cedex  
France  
Telephone: 011-33-1-4611-3225  
Fax: 011-33-1-4611-3474  
E-mail: *joel.raoul@equipement.gouv.fr*

**Ms. Nathalie Odent**

SETRA  
46 ave. Aristide Briand  
BP-100  
92225 Bagneux Cedex  
France  
Telephone: 011-33-1-4611-3599  
Fax: 011-33-1-4611-3352  
E-mail: *nathalie.odent@equipement.gouv.fr*

**Mr. Jean-Michel Lacombe**

SETRA  
46 ave. Aristide Briand  
BP-100  
92225 Bagneux Cedex  
France  
Telephone: 011-33-1-4611-3267  
Fax: 011-33-1-4536-8367  
E-mail: *jean-michel.lacombe@equipement.gouv.fr*

**Mr. Bruno Godart**

LCPC  
58 blvd. Lefebvre  
75732 Paris Cedex 15  
France  
Telephone: 011-33-1-4043-5332  
Fax: 011-33-1-4043-6520  
E-mail: *bruno.godart@lcpc.fr*

**Dr. Christian Cremona**

LCPC  
58 blvd. Lefebvre  
75732 Paris Cedex 15  
France  
Telephone: 011-33-1-4043-5344  
Fax: 011-33-1-4043-6515  
E-mail: *christian.cremona@lcpc.fr*

**Mr. Christian Tessier**

LCPC, Centre de Nantes  
BP 4129-44341 Bouguenais Cedex  
France  
Telephone: 011-33-2-4084-5944  
Fax: 011-33-2-4084-5992  
E-mail: *christian.tessier@lcpc.fr*

**Mr. Lamine Dieng**

LCPC, Centre de Nantes  
BP 4129-44341 Bouguenais Cedex  
France  
Telephone: 011-33-2-4084-5606  
Fax: 011-33-2-4084-5992  
E-mail: *lamine.dieng@lcpc.fr*

**GERMANY**

**Dr. Juergen Krieger**

BASt  
Bruederstr. 53  
D-51427 Bergisch-Gladbach  
Germany  
Telephone: 011-49-2204-43-800  
Fax: 011-49-2204-43-677  
E-mail: *juergen.kreiger@bast.de*

**Mr. Ralph Holst**

BASt  
Bruederstr. 53  
D-51427 Bergisch-Gladbach  
Germany  
Telephone: 011-49-2204-43-841  
Fax: 011-49-2204-43-673  
E-mail: *ralph.holst@bast.de*

**Mr. Rolf Kaschner**

BASt  
Bruederstr. 53  
D-51427 Bergisch-Gladbach  
Germany  
Telephone: 011-49-2204-43-842  
Fax: 011-49-2204-43-673  
E-mail: *kaschner@bast.de*

**Dr. Herbert Wiggenhauser**

BAM, Division VIII.2  
Unter den Eichen 87  
D-12205 Berlin  
Germany  
Telephone: 011-49-30-8104-1440  
Fax: 011-49-30-8104-1447  
E-mail: *herbert.wiggenhauser@bam.de*

**Prof. Martin Mertens**

FH Bochum  
Lennerstr. 140  
D-44801 Bochum  
Germany  
Telephone: 011-49-234-32-10246  
Fax: 011-49-234-32-14274  
E-mail: *martin.mertens@fh-bochum.de*

## APPENDIX D:

# Glossary of Terms

**Multitiered inspection program** An inspection program that includes periodic inspections conducted to different degrees of detail by inspectors of varying qualifications depending on the interval of time since the last indepth inspection, condition and age of the structure, or damage that has occurred to the structure from natural or manmade events.

**Quality assurance (QA)** The use of sampling and other measures to assure the adequacy of quality control procedures to verify or measure the quality level of the entire bridge inspection and load rating program (NBIS Regulation 23 CFR 650.305 Definitions).

**Quality control (QC)** Procedures intended to maintain the quality of a bridge inspection and load rating at or above a specified level (NBIS Regulation 23 CFR 650.305 Definitions).



## APPENDIX E:

# Abbreviated Index to the Finnish Road Administration Bridge Repair Directives (SILKO)

## Folder 1—General Guidelines (Red)

### 1.1 General

- 1.101 Purpose, use, and ordering of the guidelines (12/02)
- 1.102 Guidelines contents (12/02)
- 1.111 Work safety (11/00)
- 1.112 Environmental protection (11/99)

### 1.2 Concrete structures

- 1.201 Concrete as bridge repair material (9/87)
- 1.202 Polymers as bridge repair material (9/90)
- 1.203 Demolition and preparation methods (10/02)
- 1.231 Patching concrete (9/96)
- 1.232 Concreting using injection (10/94)
- 1.233 Repairing cracks (5/03)
- 1.251 Protecting concrete (9/98)

### 1.3 Steel structures

- 1.301 Metals as bridge repair material (8/95)
- 1.351 Surface treatment (4/01)
- 1.353 Degree of rusting Ri3 comparison scales (1/86)
- 1.354 Degree of rusting Ri4 comparison scales (1/86)
- 1.355 Degree of rusting Ri5 comparison scales (1/86)
- 1.356 Determination of repair operation for surface treatment
- 1.357 Determination of repair operation for surface treatment for steel pipe (8/92)

### 1.4 Wooden structures

### 1.5 Stone structures

- 1.501 Natural stone as covering material (1/89)

### 1.6 Desiccators

- 1.601 Drainage of bridge and bridge site (11/99)

### 1.7 Joints

- 1.701 Movement and shrinkage joints (12/93)

### 1.8 Waterproofing and coatings

- 1.801 Waterproofing (12/92)
- 1.802 Coatings (9/88)

### 1.9 Structures connected to bridge

- 1.901 Finishing bridge site (4/87)

## Folder 2—Repair Guidelines (Quality Demands) (Blue)

### 2.1 General

### 2.2 Concrete structures

- 2.211 Renewing edge beam (1/92)
- 2.231 Patching without molds (6/05)
- 2.232 Patching with molds (12/05)
- 2.233 Patching using ejector (3/95)
- 2.234 Repair by concrete spraying (11/92)
- 2.236 Force transmitting crack injection (2/03)
- 2.237 Cement injection (12/04)
- 2.239 Crack grouting (12/04)
- 2.240 Mending waterproofing underbody (9/93)
- 2.251 Chemical cleaning of concrete surfaces (12/92)
- 2.252 Impregnation of concrete surface (2/04)
- 2.253 Coating of concrete surfaces (12/93)
- 2.261 Anchoring tie bars (12/99)
- 2.262 Renewing reinforcement (6/83)

### 2.3 Steel structures

- 2.311 Renewing bridge railings (2/04)
- 2.331 Fixing guardrail post foot (1/03)
- 2.332 Fixing steel beam's upper flange (9/97)
- 2.341 Repairing steel pipe bridge, job-specific quality requirements (12/06)
- 2.351 Patch painting of railings (2/04)
- 2.352 Repainting of railings (10/82)
- 2.353 Maintenance treatment of steel bearing (12/04)
- 2.354 Painting of new and old zinc coating (12/05)

### 2.4 Wooden structures

- 2.421 Reinforcing wooden deck with steel sheet (12/06)
- 2.431 Injecting crack in gluelam beam (9/05)

### 2.5 Stone structures

### 2.6 Desiccators

- 2.611 Making drip pipe to pavement (3/90)
- 2.612 Making drip hole to guardrail post foot (3/90)
- 2.613 Making edge drain (12/06)
- 2.614 Making transverse drain (12/06)
- 2.615 Making water conducting devices for movement joint and bearing seat (10/88)
- 2.631 Lengthening drip pipe (9/90)
- 2.632 Lengthening drainpipes (5/91)
- 2.651 Making guiding devices for surface waters (12/04)

- 2.652 Making surface water pipe for ramp (9/94)
- 2.653 Making surface water canal for ramp (12/97)
- 2.654 Making filter holes (1/85)

### **2.7 Joints**

- 2.711 Sealing edge beam's movement joint with plastic strip (4/82)
- 2.712 Repairing mass movement joints (12/05)
- 2.713 Installing movement joint devices (8/90)
- 2.731 Sealing of edge beam's movement joint (8/01)
- 2.732 Sealing of joint between coating and concrete structure (11/98)

### **2.8 Waterproofing and coatings**

- 2.811 Renewing waterproofing—roll felt insulation (9/93)
- 2.812 Renewing waterproofing—mastic insulation (8/93)
- 2.813 Renewing waterproofing—mass insulation (11/90)
- 2.814 Renewing asphalt coatings (9/91)
- 2.815 Coating of wooden deck (12/92)
- 2.831 Patching waterproofing (5/00)
- 2.832 Sealing of crack in coating (12/05)
- 2.833 Patching of asphalt coating (11/05)

### **2.9 Structures connected to bridge**

- 2.911 Making rip-rap revetment (8/01)
- 2.912 Making stone slab covering (9/92)
- 2.913 Making concrete slab covering (12/02)
- 2.914 Making concrete stone covering (12/95)
- 2.915 Making turf covering and transferable lawns (5/03)
- 2.916 Making grass covering (11/97)
- 2.917 Making crushed stone covering (12/02)
- 2.918 Making rubble stone covering (8/01)
- 2.919 Making gabion revetment (5/03)
- 2.931 Planting trees and shrubs (1/86)
- 2.991 Making ramp step (3/85)

## **Folder 3—Materials (Green)**

### **3.1 General**

#### **3.2 Concrete structures**

- 3.211 Standard concretes (10/00)
- 3.231 Patching materials (10/00)
- 3.235 Injection, filtering, and barrier materials (6/02)
- 3.251 Daubing prevention and chemical surface cleaning materials (3/98)
- 3.252 Impregnation and sealing materials (12/05)
- 3.253 Coating materials (3/98)

#### **3.3 Steel structures**

- 3.352 Painting systems (3/98)
- 3.353 Bearing lubricants and sliding lacquers (11/04)

#### **3.4 Wooden structures**

#### **3.5 Stone structures**

- 3.511 Stone materials (11/92)

#### **3.6 Desiccators**

- 3.611 Bridge desiccators (3/91)
- 3.651 Desiccators for bridge site (3/91)

#### **3.7 Joints**

- 3.711 Movement joint equipment (6/02)
- 3.712 Movement mass joints (4/89)
- 3.731 Seaming masses (4/04)

#### **3.8 Waterproofing and coatings**

- 3.811 Roll felt insulation structures (4/04)
- 3.814 Insulation mastics and sealing materials of bridge edge (9/01)
- 3.815 Waterproofing masses (4/04)
- 3.821 Thin layer coatings (5/89)

#### **3.9 Supplies related to bridge**

- 3.913 Supplies for construction of green areas (6/88)
- 3.931 Sapling suppliers (6/88)

## **Folder 4—Work Equipment (Gray)**

### **4.1 General**

#### **4.2 Concrete structures**

- 4.201 Bridge repair contractors (12/94)
- 4.202 Building machinery rentals (12/92)
- 4.204 Materials testing institutes and research consultants (6/02)
- 4.231 Cutting and demolition equipment (12/00)
- 4.232 Injection equipment (11/98)
- 4.291 Person lifts (11/92)

#### **4.3 Steel structures**

- 4.301 Machine shops and metal workshops (6/89)
- 4.302 Surface treatment contractors (3/91)
- 4.303 Hot galvanizing and spray galvanizing contractors (8/92)
- 4.351 Surface treatment devices (12/92)

#### **4.4 Wooden structures**

#### **4.5 Stone structures**

#### ***4.6 Desiccators***

#### ***4.7 Joints***

4.711 Seaming devices (11/92)

#### ***4.8 Waterproofing and coatings***

4.801 Contractors for waterproofing (12/00)

4.802 Coating, milling, and seaming contractors (8/93)

4.803 Materials testing institutes (3/90)

4.811 Waterproofing equipment (3/90)

4.831 Melting pots (3/90)

#### ***4.9 Structures connected to bridge***

4.901 Constructors of green areas (6/88)







**OFFICE OF INTERNATIONAL PROGRAMS**

**FHWA/US DOT (HPIP)**

1200 New Jersey Avenue, SE

Washington, DC 20590

Phone: (202) 366-9636 • Fax: (202) 366-9626

[international@fhwa.dot.gov](mailto:international@fhwa.dot.gov)

[www.international.fhwa.dot.gov](http://www.international.fhwa.dot.gov)