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Chapter 1
Bridge Inspection Programs

Abbreviations Used in this Section

AASHO	-	American Association of State Highway Officials (1921 to 1973)
AASHTO	-	American Association of State Highway and Transportation Officials (1973 to present)
AASHTO Manual	-	*Manual for Maintenance Inspection of Bridges*
BIRM	-	*Bridge Inspector's Reference Manual*
BMS	-	Bridge Management System
Coding Guide	-	FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*
DOT	-	Department of Transportation
FCM	-	fracture critical member
FHWA	-	Federal Highway Administration
HBRR	-	Highway Bridge Replacement & Rehabilitation
HEC	-	*Hydraulic Engineering Circular*
ISTEA	-	Intermodal Surface Transportation Efficiency Act
Manual 70	-	*Bridge Inspector's Training Manual 70*
Manual 90	-	Bridge Inspector's Training Manual 90
MR&R	-	maintenance, repair and rehabilitation
NBI	-	National Bridge Inventory
NBIS	-	National Bridge Inspection Standards
NCHRP	-	National Cooperative Highway Research Program
NDT	-	nondestructive testing
NHI	-	National Highway Institute
NHS	-	National Highway System
NICET	-	National Institute for Certification in Engineering Technologies
TEA-21	-	Transportation Equity Act of the 21st Century
TRB	-	Transportation Research Board
TWG	-	Technical Working Group

Chapter 1
Bridge Inspection Programs

Topic 1.1 History of the National Bridge Inspection Program

1.1.1 Introduction

In the years since the Federal Highway Administration's landmark publication, *Bridge Inspector's Training Manual 90* (*Manual 90*), bridge inspection and inventory programs of state and local governments have formed an important basis for formal bridge management programs. During the 1990's, the state DOT's implemented comprehensive bridge management systems, which rely heavily on accurate, consistent bridge inspection data.

This manual, the *Bridge Inspector's Reference Manual (BIRM)*, updates *Manual 90* and reflects over 20 years of change.

Advances in technology and construction have greatly enhanced current bridge design. However, the emergence of previously unknown problem areas and the escalating cost of replacing older bridges make it imperative that existing bridges be evaluated properly to be kept open and safe.

There are four letters that define the scope of bridge inspections in this country: NBIS, meaning National Bridge Inspection Standards. The **National Bridge Inspection Standards (NBIS)** are Federal regulations establishing requirements for:

- Inspection procedures
- Frequency of inspections
- Qualifications of personnel
- Inspection reports
- Maintenance of bridge inventory

The **National Bridge Inventory (NBI)** is the aggregation of structure inventory and appraisal data collected by each state to fulfill the requirements of NBIS.

To better understand the **National Bridge Inventory Program (NBIP)**, it is helpful to review the development of the program.

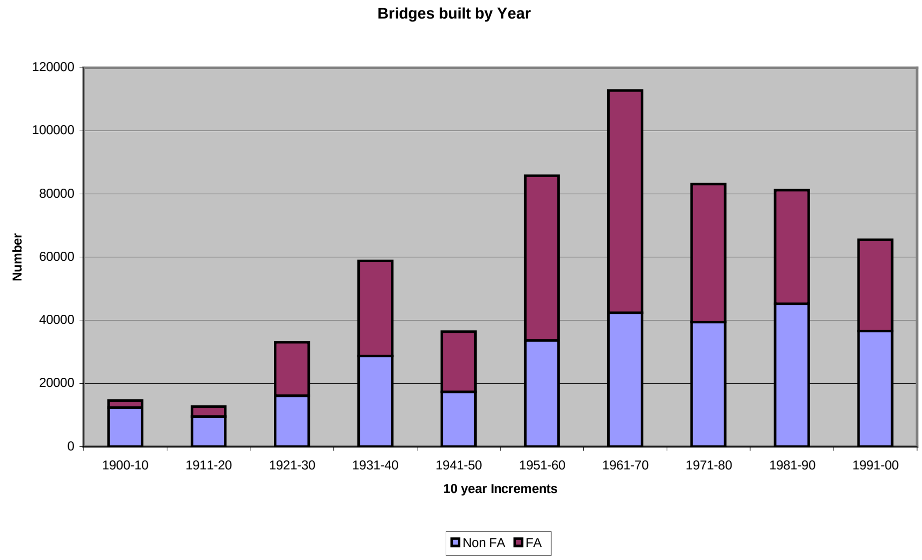

Figure 1.1.1 Number of Bridges Built since 1900

1.1.2 History of the National Bridge Inspection Program

Background

During the bridge construction boom of the 1950's and 1960's, little emphasis was placed on safety inspection and maintenance of bridges. This changed when the 2,235-foot Silver Bridge, at Point Pleasant, West Virginia, collapsed into the Ohio River on December 15, 1967, killing 46 people (see Figure 1.1.2).

Figure 1.1.2 Collapse of the Silver Bridge

This tragic collapse aroused national interest in the safety inspection and maintenance of bridges. The U.S. Congress was prompted to add a section to the "Federal Highway Act of 1968" which required the Secretary of Transportation to establish a national bridge inspection standard. The Secretary was also required to develop a program to train bridge inspectors.

The 1970's

Thus, in 1971, the National Bridge Inspection Standards (NBIS) came into being. The NBIS established national policy regarding:

- Inspection procedures
- Frequency of inspections
- Qualifications of personnel
- Inspection reports
- Maintenance of state bridge inventory

Three manuals were subsequently developed. These manuals were vital to the early success of the NBIS. The first manual was the Federal Highway Administration (FHWA) *Bridge Inspector's Training Manual 70* (*Manual 70)*. This manual set the standard for inspector training.

The second manual was the American Association of State Highway Officials (AASHO) *Manual for Maintenance Inspection of Bridges*, released in 1970. This manual served as a standard to provide uniformity in the procedures and policies for determining the physical condition, maintenance needs and load capacity of highway bridges.

The third manual was the FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (*Coding Guide*), released in July 1972. It provided thorough and detailed guidance in evaluating and coding specific bridge data.

With the publication of *Manual 70*, the implementation of national standards and guidelines, the support of AASHO, and a newly available FHWA bridge inspector's training course for use in individual states, improved inventory and appraisal of the nation's bridges seemed inevitable. Several states began in-house training programs, and the 1970's looked promising. Maintenance and inspection problems associated with movable bridges were also addressed. In 1977, a supplement to *Manual 70*, the *Bridge Inspector's Manual for Movable Bridges*, was added.

However, the future was not to be trouble free. Two predominant concerns were identified during this period. One concern was that bridge repair and replacement needs far exceeded available funding. The other was that NBIS activity was limited to bridges on the Federal Aid highway systems. This resulted in little incentive for inspection and inventory of bridges not on Federal Aid highway systems.

These two concerns were addressed in the "Surface Transportation Assistance Act of 1978." This act provided badly needed funding for rehabilitation and new construction and required that all public bridges over 20 feet in length be inspected and inventoried in accordance with the NBIS by December 31, 1980. Any bridge not inspected and inventoried in compliance with NBIS would be ineligible for funding from the special replacement program.

In 1978, the American Association of State Highway and Transportation Officials (AASHTO) revised their *Manual for Maintenance Inspection of Bridges* (*AASHTO Manual*). In 1979, the NBIS and the FHWA *Coding Guide* were also revised. These publications, along with *Manual 70*, provided state agencies with definite guidelines for compliance with the NBIS.

The 1980's

The National Bridge Inspection Program was now maturing and well positioned for the coming decade. Two additional supplements to *Manual 70* were published. First, culverts became an area of interest after several tragic failures. The 1979 NBIS revisions also prompted increased interest in culverts. The *Culvert Inspection Manual* was published July 1986. Then, an emerging national emphasis on fatigue and fracture critical bridges was sharply focused by the collapse of Connecticut's Mianus River Bridge in June 1983. *Inspection of Fracture Critical Bridge Members* was published in September 1986. These manuals were the products of ongoing research in these problem areas.

With the April 1987 collapse of New York's Schoharie Creek Bridge, national attention turned to underwater inspection. Of the over 593,000 bridges in the national inventory, approximately 86% were over waterways. The FHWA responded with *Scour at Bridges*, a technical advisory published in September 1988. This advisory provided guidance for developing and implementing a scour evaluation program for the:

- Design of new bridges to resist damage resulting from scour
- Evaluation of existing bridges for vulnerability to scour
- Use of scour countermeasures
- Improvement of the state-of-practice of estimating scour at bridges

Further documentation is available on this topic in the *Hydraulic Engineering Circular No. 18* (*HEC-18*).

In September 1988, the NBIS was modified, based on suggestions made in the "1987 Surface Transportation and Uniform Relocation Assistance Act," to require states to identify bridges with fracture critical details and establish special inspection procedures. The same requirements were made for bridges requiring underwater inspections. The NBIS revisions also allowed for adjustments in the frequency of inspections and the acceptance of National Institute for Certification in Engineering Technologies (NICET) Level III and IV certification for inspector qualifications.

In December 1988, the FHWA issued a revision to the *Coding Guide*. This time the revision would be one of major proportions, shaping the National Bridge Inspection Program for the next decade. The *Coding Guide* provided inspectors with additional direction in performing uniform and accurate bridge inspections.

The 1990's

The 1990's was the decade for bridge management systems (BMS). Several states, including New York, Pennsylvania, North Carolina, Alabama and Indiana, had their own comprehensive bridge management systems.

In 1991, the FHWA sponsored the development of a bridge management system called "Pontis" which is derived from the Latin word for bridge. The Pontis system has sufficient flexibility to allow customization to any agency or organization responsible for maintaining a network of bridges.

Simultaneously, the National Cooperative Highway Research Program (NCHRP) of the Transportation Research Board (TRB) developed a BMS software called "Bridgit." Bridgit is primarily targeted to smaller bridge inventories or local highway systems.

As more and more bridge needs were identified, it became evident that needed funding for bridge maintenance, repair and rehabilitation (MR&R) far exceeded the available funding from federal and state sources. Even with the infusion of financial support provided by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, funding for bridge MR&R projects was difficult to obtain. This was due in part to the enormous demand from across the nation. An October 1993 revision to NBIS permitted bridge owners to request approval from FHWA of extended inspection cycles of up to forty-eight months for bridges meeting certain requirements.

In 1994, the American Association of State Highway and Transportation Officials (AASHTO) revised their *Manual for Condition Evaluation of Bridges* (*AASHTO Manual*). In 1995, the FHWA *Coding Guide* was also revised. These publications, along with *Manual 90, Revised July 1995*, provided state agencies with continued definite guidelines for compliance with the NBIS and conducting bridge inspection.

Although later rescinded in the next transportation bill, the ISTEA legislation required that each state implement a comprehensive bridge management system by October 1995. This deadline represented a remarkable challenge since few states had previously implemented a BMS that could be considered to meet the definition of a comprehensive BMS. In fact, prior to the late 1980's, there were no existing management systems adaptable to the management of bridge programs nor was there any clear, accepted definition of key bridge management principles or objectives.

This flexibility in the system was the result of developmental input by a Technical Working Group (TWG) comprised of representatives from the FHWA, the Transportation Research Board (TRB) and the following six states: California, Minnesota, North Carolina, Tennessee, Vermont and Washington. The TWG provided guidance drawing on considerable experience in bridge management and engineering.

The National Highway System (NHS) Act of 1995 rescinded the requirement for bridge management systems. However, many of the states continued to implement the Pontis BMS.

The Transportation Equity Act of the 21st Century (TEA-21) was signed into law in June 1998. TEA-21 built on and improved the initiatives established in ISTEA and, as mentioned earlier, rescinded the mandatory BMS requirement.

The 2000's

In 2002, *Manual 90* was revised and updated as a part of a complete overhaul of the FHWA Bridge Safety Inspection training program. The new manual was named the *Bridge Inspector's Reference Manual (BIRM)* and incorporated all of *Manual 90*. The *BIRM* also incorporates manual 70 Supplements for culvert inspection and Fracture Critical Members. The *BIRM* was also updated in 2011.

On December 14, 2004, the revised NBIS regulation was published in the *Federal Register*. The updated NBIS took affect January 13, 2005. Implementation plans were to be developed by April 13, 2005 to be fully implemented by January 13, 2006.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law in August 2005. SAFETEA-LU represents the largest surface transportation investment in the Nation's history. SAFETEA-LU builds on and improves the initiatives established in ISTEA and TEA-21. Since being signed into law in August 2005, SAFETEA-LU has undergone several extensions past its original 2009 expiration, resulting in guaranteed funding until the end of Fiscal Year (FY) 2011. Multi-year legislation is expected to provide funding following FY 2011.

Over the years, varying amounts of federal funds have been spent on bridge projects, depending on the demands of the transportation infrastructure. Figure 1.1.3 illustrates the fluctuations in federal spending and shows current trends.

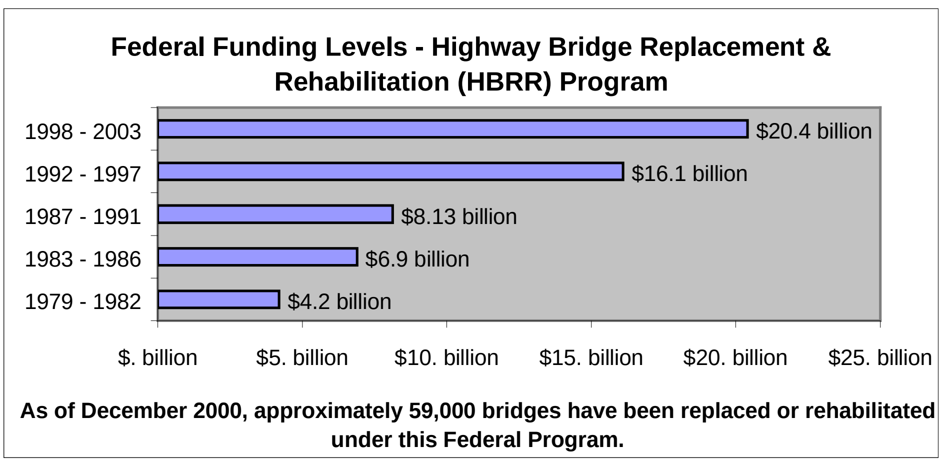

Figure 1.1.3 Federal Funding Levels (1979 – 2003)

1.1.3 Today's National Bridge Inspection Program

Much has been learned in the field of bridge inspection, and a national Bridge Inspection Training Program is now fully implemented. State and federal inspection efforts are more organized, better managed and much broader in scope. The technology used to inspect and evaluate bridge members and bridge materials has significantly improved.

Areas of emphasis in bridge inspection programs are changing and expanding as new problems become apparent, as newer bridge types become more common, and as these newer bridges age enough to have areas of concern. Guidelines for inspection ratings have been refined to increase uniformity and consistency of inspections. Data from bridge inspections has become critical input into a variety of analyses and decisions by state agencies and the Federal Highway Administration.

The NBIS has kept current with the field of bridge inspection. The 2005 National Bridge Inspection Standards appear in Appendix A. The standards are divided into the following sections:

- Purpose
- Applicability
- Definitions
- Bridge inspection organization
- Qualifications of personnel
- Inspection frequency
- Inspection procedures
- Inventory
- Reference manuals

The FHWA has made a considerable effort to make available to the nation's bridge inspectors the information and knowledge necessary to accurately and thoroughly inspect and evaluate the nation's bridges.

FHWA Training

The FHWA has developed and now offers the following training courses relative to structure inspection through the National Highway Institute (NHI):

- "Engineering Concepts for Bridge Inspectors" (NHI Course Number FHWA-NHI-130054)

  This one-week course is a pre-requisite for FHWA-NHI-130055 and presents engineering concepts, as well as inspection procedures and information about bridge types, bridge components, and bridge materials. The one-week course is for new inspectors with little or no practical bridge inspection experience.

- "Introduction to Safety Inspection of In-Service Bridges" (NHI Course Number FHWA-NHI-130101)

  This web-based course is another possible pre-requisite for FHWA-NHI-130055 and presents engineering concepts, as well as inspection procedures and information about bridge types, bridge components, and bridge materials. The course is for new inspectors with little or no practical bridge inspection experience.

- "Safety Inspection of In-Service Bridges" (NHI Course Number FHWA-NHI-130055)

This two-week course is for inspectors or engineers who perform or manage bridge inspections. Emphasis is on inspection applications and procedures. The uniform coding and rating of bridge elements and components is also an objective of the two-week course. A unique feature of this course allows for customization of the course content by the host agency. Some states use component rating based on NBIS while some states use element condition level evaluation. Lessons include critical findings identification and inspection of fracture critical members (FCM's), underwater inspection, culverts, field trips, case studies, and non-destructive evaluation. Several special bridge types may also be discussed at the host agency's request.

- "Bridge Inspection Refresher Training" (NHI Course Number FHWA-NHI-130053)

  This three-day course provides a review of the National Bridge Inspection Standards (NBIS) and includes discussions on structure inventory items, structure types, and the appropriate codes for the Federal Structure, Inventory and Appraisal reporting. A three-and-a-half day option is also available, which includes additional case studies.

- "Underwater Bridge Inspection" (NHI Course Number FHWA-NHI-130091)

  This four or five-day course provides an overview of diving operations that will be useful to agency personnel responsible for managing underwater bridge inspections. This course also fulfills the requirement due to the latest changes of the National Bridge Inspection Standards, which require bridge inspection training for all divers conducting underwater inspections.

- "Underwater Bridge Repair Rehabilitation and Countermeasures" (NHI Course Number FHWA-NHI-130091A)

  This two-day course provides training in techniques for selecting and executing repairs to below water bridge elements. The primary goal is to enable design engineers to select, design, and specify appropriate and durable repairs to below water bridge elements. The secondary goal of the course is to train staff in effective construction inspection of below water repairs.

- "Fracture Critical Inspection Techniques for Steel Bridges" (NHI Course Number FHWA-NHI-130078)

  This three and one-half day course provides an understanding of fracture critical members (FCM's), FCM identification, failure mechanics and fatigue and fracture in metal. Emphasis is placed on inspection procedures and reporting of common FCM's and non-destructive evaluation (NDE) methods most often associated with steel highway bridges.

- "Bridge Inspection Non-Destructive Evaluation Showcase (BINS)" (NHI Course Number FHWA-NHI-130099)

This one-day course allows bridge inspectors to identify the components of handheld NDE inspection tools and techniques, inspection strategies and NDE techniques. Inspection tools will include eddy current, ultrasonic, infrared thermography, impact echo, and ground penetrating radar.

- "Stream Stability and Scour at Highway Bridges" (NHI Course Number FHWA-NHI-135046)

  This three-day course provides training in the prevention of hydraulic-related failures of highway bridges by identifying stream stability and scour problems at bridges and defining problems caused by stream instability and scour. The magnitude of scour at bridge piers and abutments and in the bridge reach will be estimated.

- "Stream Stability and Scour at Highway Bridges for Bridge Inspectors" (NHI Course Number FHWA-NHI-135047)

  This one-day course concentrates on visual keys to detecting scour and stream instability problems. The course emphasizes inspection guidelines to complete the hydraulic and scour-related coding requirements of the National Bridge Inspection Standards (NBIS).

- "Pontis Bridge Management" (NHI Course Number FHWA-NHI-134056)

  This two and one-half day course covers the entering and editing of inspection data, developing a bridge preservation policy, performing bridge network level analyses, developing bridge projects, running Pontis and Infomaker reports, and refining Pontis results.

- "Pontis Bridge Management and InfoMaker Module" (NHI Course Number FHWA-NHI-134056A)

  This three and one-half day course covers the entering and editing of inspection data, developing a bridge preservation policy, performing bridge network level analyses, developing bridge projects, running Pontis and Infomaker reports, and refining Pontis results. It also includes an overview of InfoMaker 9.0 as it relates to Pontis. It covers those aspects most used by the Pontis users as well as the ability to query data, create new report libraries, modify existing Pontis structure list layout, and modify an existing Pontis report.

- "Pontis Bridge Management InfoMaker Module" (NHI Course Number FHWA-NHI-134056B)

  This one-day course provides an overview of InfoMaker 9.0 as it relates to Pontis. It covers those aspects most used by the Pontis users as well as the ability to query data, create new report libraries, modify existing Pontis structure list layout, and modify an existing Pontis report.

- "Inspection and Maintenance of Ancillary Highway Structures" (NHI Course Number FHWA-NHI-130087)

This two-day course provides training in the inspection and maintenance of ancillary structures, such as structural supports for highway signs, luminaries, and traffic signals. Its goal is to provide agencies with information to aid in establishing and conducting an inspection program in accordance with the FHWA "Guidelines for the Installation, Inspection, Maintenance, and Repair of Structural Supports for Highway Signs, Luminaries, and Traffic Signals".

- "Inspection of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes" (NHI Course Number FHWA-NHI-132080)

  This three-day course is part of a series to develop a training and qualification/certification program for field inspectors. A partial list of lessons addressed in the course are MSE wall and RSS types and durability; construction methods and sequences; alignment control; methods of fill and compaction control; plans, specifications, and the geotechnical report; shop drawings; and safety.

Throughout all the expansions and improvements in bridge inspection programs and capabilities, one factor remains constant: the overriding importance of the inspector's ability to effectively inspect bridge components and materials and to make sound evaluations with accurate ratings. The validity of all analyses and decisions based on the inspection data is dependent on the quality and the reliability of the data collected in the field.

Across the nation, the duties, responsibilities, and qualifications of bridge inspectors vary widely. The two keys to a knowledgeable, effective inspection are training and experience in performing actual bridge inspections. Training of bridge inspectors has been, and will continue to be, an active process within state highway agencies for many years. This manual is designed to be an integral part of that training process.

Current FHWA Reference Material

- NBIS. *Code of Federal Regulations.* 23 Highways Part 650, Subpart C – National Bridge Inspection Standards.

- AASHTO. *LRFD Bridge Design Specifications, 5th Edition.* Washington, D.C.: American Association of State Highway and Transportation Officials, with 2010 Interims.

- FHWA. *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges.* Washington, D.C.: United States Department of Transportation, 1995, Errata Sheet 03/ 2004.
  - http://www.fhwa.dot.gov/bridge/mtguide.pdf

- FHWA. *Bridge Inspector's Reference Manual.* Washington, D.C.: United States Department of Transportation, 2002, Revised 2006, 2011.

- AASHTO. *Manual for Bridge Evaluation, Second Edition.* Washington, D.C.: American Association of State Highway and Transportation Officials, 2011.

- AASHTO. *Guide Manual for Bridge Element Inspection.* Washington, D.C.: American Association of State Highway and Transportation Officials, 2011.

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Bridge Inspection Programs

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Topic 1.2 Responsibilities of the Bridge Inspector

1.2.1 Introduction

Bridge inspection has played, and continues to play, an increasingly important role in providing a safe infrastructure for the United States. As the nation's bridges continue to age and deteriorate, an accurate and thorough assessment of each bridge's condition is critical in maintaining a safe, functional and reliable highway system.

This topic presents the responsibilities of the bridge inspector/engineer and qualifications for bridge inspection personnel.

1.2.2 Responsibilities of the Bridge Inspector and Engineer

There are five basic responsibilities of the bridge inspector and engineer:

- Maintain public safety and confidence
- Protect public investment
- Provide bridge inspection program support
- Maintain accurate bridge records
- Fulfill legal responsibilities

Maintain Public Safety and Confidence

The primary responsibility of the bridge inspector is to maintain public safety and confidence. The general public travels the highways and bridges without hesitation. However, when a bridge fails, the public's confidence in the bridge system is violated (see Figure 1.2.1).

The engineer's role is:

- To incorporate design safety factors.
- To provide cost-effective designs.
- To review and evaluate reports.
- Rate each bridge as to its safe load capacity

Engineers include a margin of safety in their designs to compensate for variations in the quality of materials and unknowns in vehicular traffic loadings through the life of the structure. In older bridges, especially those designed prior to the use of computer software programs and modern design codes, margin of safety also compensated for a lack of precise calculations and construction loading conditions.

The inspector's role is:

- To provide thorough inspections identifying bridge conditions and defects.
- To prepare condition reports documenting deficiencies and alerting supervisors or engineers of any findings which might impact the safety of the roadway user or the integrity of the structure.

Figure 1.2.1 Mianus Bridge Failure

Protect Public Investment

Another responsibility is to protect public investment in bridges. Be on guard for minor problems that can be corrected before they lead to costly major repairs. Also, be able to recognize bridge elements that need repair in order to maintain bridge safety and avoid replacement costs.

The current funding available to rehabilitate and replace deficient bridges is not adequate to meet the needs. It is important that preservation activities be a part of the bridge program to extend the performance life of as many bridges as possible and minimize the need for costly repairs or replacement.

The engineer's role is:

- To continually upgrade design standards to promote longevity of bridge performance such as the implementation of high performance materials and better performing bridge joints.

The inspector's role is:

- To continually be on guard for minor problems that can become costly repairs.
- To recognize bridge components that need repair in order to maintain bridge safety and avoid the need for costly replacement.
- To make recommendations to close a bridge if necessary.

Provide Bridge Inspection Program Support

Subpart C of the National Bridge Inspection Standards (NBIS) of the *Code of Federal Regulations*, 23 Highways Part 650, mandates:

- Purpose
- Applicability
- Definitions
- Bridge inspection organization

- Qualifications of personnel
- Inspection frequency
- Inspection procedures
- Inventory
- Reference manuals

Bridge Inspection Programs are funded by public tax dollars. Therefore, the bridge inspector is financially responsible to the public.

The "Surface Transportation Act of 1978" established the funding mechanism for providing Federal funds for bridge replacement. The Act also established criteria for bridge inspections and requirements for compliance with the NBIS.

The "Intermodal Surface Transportation Efficiency Act" (ISTEA) of 1991 and the Transportation Equity Act for the 21st Century (TEA-21) of 1998 establish funding mechanisms for tolled and free bridges for bridge maintenance, rehabilitation and replacement to adequately preserve the bridges and their safety to any user.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law in August 2005. SAFETEA-LU represents the largest surface transportation investment in the Nation's history. SAFETEA-LU builds on and improves the initiatives established in ISTEA and TEA-21. Since being signed into law in August 2005, SAFETEA-LU has undergone several extensions past its original 2009 expiration, resulting in guaranteed funding until the end of Fiscal Year (FY) 2011. Multi-year legislation is expected to provide funding following FY 2011. Information on SAFETEA-LU can be found on the FHWA website:

http://www.fhwa.dot.gov/safetealu/factsheets/bridge.htm

Maintain Accurate Bridge Records

There are three major reasons why accurate bridge records are required:

a. A structure history file facilitates the identification and/or monitoring of deficiencies.

   For example, two bridge abutments are measured for tilt during several inspection cycles, and the results are as follows:

Year	Abutment A	Abutment B
2011	4-3/16"	3-1/2"
2009	4-3/16"	2-1/4"
2007	4-1/8"	1-1/8"
2005	4"	1"

   Looking at year 2011 measurements only indicate that Abutment A has a more severe problem. However, examining the changes each year, it is noted that the movement of Abutment A is slowing and may have stopped, while Abutment B is changing at a faster pace each inspection cycle. At the rate it is moving, Abutment B probably surpasses Abutment A by the next inspection.

b. To identify and assess bridge deficiencies and to identify and assess bridge repair requirements. Be able to readily determine, from the records, what repairs are needed as well as a good estimate of quantities. Maintain reports on the results of the bridge inspection together with notations of any action taken to address the findings of such inspections.

c. To identify and assess minor bridge deficiencies, to identify and assess bridge maintenance needs, and preservation needs in a similar manner to the repair requirements. Maintain relevant maintenance and inspection data to allow assessment of current bridge condition.

d. To be able to quickly obtain pertinent structure information to respond to emergency events such as fire on or below the structure, severe flooding, and navigational or vehicular collision.

e. To maintain load carrying capacity to facilitate the routing of overweight/over-height vehicles.

To ensure accurate bridge records, proper record keeping needs to be maintained. Develop a system to review bridge data and evaluate quality of bridge inspections. Bridge files are to be prepared as described in the *AASHTO Manual for Bridge Evaluation*. Record the findings and results of bridge inspections on standard State or Federal agency forms.

Fulfill Legal Responsibilities

A bridge inspection report is a legal document. Make descriptions specific, detailed, quantitative (where possible), and complete. Do not use vague adjectives such as good, fair, poor, and general deterioration, without concise descriptions to back them up. To say “the bridge is OK” is just not good enough.

Example of inspection descriptions:

Bad description: “Fair beams”

Good description: “Reinforced concrete tee-beams are in fair condition with light scaling on bottom flanges of Beams B and D for their full length.”

Bad description: “Deck in poor condition”

Good description: “Deck in poor condition with spalls covering 50% of the top surface area of the deck as indicated indicated on field sketch, see Figure 42.”

Bad description: “The bridge is dangerous”

Good description: “Section loss exists on Girder G5 at 10 feet north of centerline of bearing at Pier 1. Original flange thickness 1.5 inches. Measured thickness 0.991 inches.”

Include phrases such as “no other apparent defects” or “no other defects observed” in any visual assessment.

Do not alter original inspection notes without consultation with the inspector who wrote the notes.

A bridge inspection report implies that the inspection was performed in accordance with the National Bridge Inspection Standards, unless specifically stated otherwise in the report. Use the proper equipment, methods, and qualified. If the inspection is a special or interim inspection, explained explicitly in the report.

Current NBIS Requirements

The National Bridge Inspection Standards (NBIS) are regulations that were first established in 1971 to set national requirements regarding bridge inspection frequency, inspector qualifications, report formats, and inspection and rating procedures.

The NBIS can be found in the Code of Federal Regulations, Part 65, Title 23, Subpart C which is on the Bridge Technology site located on the FHWA website:

http://www.fhwa.dot.gov/bridge/nbis.htm

The NBIS set minimum, nationwide requirements. States and other owner agencies can establish additional or more stringent requirements.

1.2.3 Qualifications of Bridge Inspectors

The NBIS are very specific with regard to the qualifications of bridge inspectors. The *Code of Federal Regulations*, Title 23, Part 650, Subpart C, Section 650.309, (23 *CFR* 650.309), lists the qualifications of personnel for the National Bridge Inspection Standards (Appendix B of this Manual). These are minimum standards; therefore, state or local highway agencies can implement higher requirements.

Program Manager

The program manager is in charge of the organizational unit that has responsibility for bridge inspection, reporting, and inventory. The minimum qualifications are as follows:

1) Be a registered Professional Engineer, or have ten years bridge inspection experience; and
2) Successfully complete a Federal Highway Administration (FHWA) approved comprehensive bridge inspection training course.

Team Leader

The team leader is responsible for planning, preparing, and performing the inspections of individual bridges as well as the day-to-day aspects of the inspection. NBIS calls for a team leader to be present at all times during each initial, routine, in-depth, fracture critical and underwater inspection. There are five alternative ways to qualify as a team leader:

1) Have the qualifications specified for the Program Manager; or
2) Have five years bridge inspection experience and have successfully completed an FHWA-approved comprehensive bridge inspection training course; or
3) Be certified as a Level III or IV Bridge Safety Inspector under the National Society of Professional Engineer's program for National Certification in Engineering Technologies (NICET) and have successfully completed an FHWA-approved comprehensive bridge inspection training course, or
4) Have the following:
    i) A bachelor's degree in engineering from a college or university accredited by or determined as substantially equivalent by the Accreditation Board for Engineering and Technology;

   - ii) Successfully passed the National Council of Examiners for Engineering and Surveying Fundamentals of Engineering examination;
   - iii) Two years of bridge inspection experience; and
   - iv) Successfully completed an FHWA-approved comprehensive bridge inspection training course, or

5) Have the following:
   - i) An associate's degree in engineering or engineering technology from a college or university accredited by or determined as substantially equivalent by the Accreditation Board for Engineering and Technology;
   - ii) Four years of bridge inspection experience; and
   - iii) Successfully completed an FHWA-approved comprehensive bridge inspection training course.

Inspector Qualifications

There are no specific federal guidelines for bridge inspectors. The main responsibility of a bridge inspector is to assist the team leader in day-to-day aspects of the inspection. Training is not required but it is recommended for non-team leaders. Any technical background is obtained through education and hands-on experience enables the inspector to successfully complete the tasks at hand. The goal is for the inspector to learn the correct inspection methods and to evaluate bridge components and elements consistently.

1.2.4 Liabilities

The dictionary defines tort as “a wrongful act for which a civil action lie except one involving a breach of contract.”

In the event of negligence in carrying out the basic responsibilities described above, an individual, including department heads, engineers, and inspectors, is subject to personal liability. Strive to be as objective and complete as possible. Accidents that result in litigation are generally related, but not necessarily limited, to the following:

- Deficient safety features
- Failed members
- Failed substructure elements
- Failed joints or decks
- Potholes or other hazards to the traveling public
- Improper or deficient load posting

Anything said or written in the bridge file could be used in litigation cases. In litigation involving a bridge, the inspection notes and reports may be used as evidence. A subjective report may have negative consequences for the highway agency involved in lawsuits involving bridges. The report scrutinized to determine if conditions are documented thoroughly and for the “proper” reasons. Therefore, be as objective and complete as possible. State if something could not be inspected and the reason it was not inspected.

Example of liabilities:

In a recent case, a consulting firm was found liable for negligent inspection practices. A tractor-trailer hit a large hole in a bridge deck, swerved, went through the bridge railing, and fell 30 feet to the ground. Ten years prior to the accident, the consulting firm had noted severe deterioration of the deck and had recommended tests to determine the need for replacement. Two years prior to the accident, their annual inspection report did not show the deterioration or recommend repairs. One year before the accident, inspectors from the consultant checked 345 bridges in five days, including the bridge on which the accident occurred. The court found that the consulting firm had been negligent in its inspection, and assessed the firm 75% of the ensuing settlement.

In another case, four cars drove into a hole 12 feet deep and 30 feet across during the night. Five people were killed and four were injured. The hole was the result of a collapse of a multi-plate arch. Six lawsuits were filed and, defendants included the county, the county engineer, the manufacturer, the supplier, and the consulting engineers who inspected the arch each year. The arch was built and backfilled, with mostly clay, by a county maintenance crew 16 years prior to the accident. Three years later, the county engineer found movement of three to four inches at one headwall. The manufacturer sent an inspector, who determined that the problem was backfill-related and recommended periodic measurements. These measurements were done once, but the arch was described as “in good condition” or “in good condition with housekeeping necessary” on subsequent inspections. Inspection reports documented a six inch gap between the steel plate and the headwall. A contractor examined the arch at the county engineer’s request to provide a proposal for shoring. The county engineer discussed the proposal with the consulting engineers a month before the accident. A total of 13 inspections were conducted on the structure. An engineering report accuses the county engineer of poor engineering practice.

1.2.5 Quality Control and Quality Assurance

The NBIS requires Quality Control (QC) and Quality Assurance (QA) procedures to maintain a high degree of accuracy and consistency in the highway bridge inspection program. Accuracy and consistency are important since the bridge inspection process is the foundation to the bridge management systems. FHWA has developed a recommended framework for a bridge inspection QC/QA program (see Topic 1.3).

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Chapter 1
Bridge Inspection Programs

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Topic 1.3 Quality Control and Quality Assurance

1.3.1 Introduction

Title 23, *Code of Federal Regulations (CFR)*, Part 650, Subpart C, Section 313, paragraph (g), Quality Control and Quality Assurance, requires each state to assure that systematic Quality Control (QC) and Quality Assurance (QA) procedures are being used to maintain a high degree of accuracy and consistency in their inspection program. The FHWA has developed a recommended framework for a bridge inspection QC/QA program to assist bridge owners in developing their QC / QA programs.

Accuracy and consistency of the data is important since the bridge inspection process is the foundation of the entire bridge management operation and bridge management systems. Information obtained during the inspection is used for determining needed maintenance and repairs, for prioritizing rehabilitations and replacements, for allocating resources, and for evaluating and improving design for new bridges. The accuracy and consistency of the inspection and documentation is vital because it not only impacts programming and funding appropriations, it also affects public safety.

1.3.2 Quality Control

Quality Control (QC) is the establishment and enforcement of procedures that are intended to maintain the quality of the inspection at or above a specific level. If an inspection program is decentralized, the state program manager is still responsible for QC.

1.3.3 Quality Assurance

Quality Assurance (QA) is the use of sampling and other measures to assure the adequacy of quality control procedures in order to verify or measure the quality level of the entire bridge inspection and load rating program. This is accomplished by the re-inspection of a sample of bridges by an independent inspection team. For decentralized state inspections or delegated inspection programs, the QA program can be performed by the central staff or their agent (e.g., consultants). If the inspections are centralized within the state, consultants or a division are to perform the QA program separate and independent of the inspection state organization.

The quality of the inspection and reports rests primarily with the inspection team leaders and team members and their knowledge and professionalism in developing a quality product. A QC/QA program is a means by which periodic and independent inspections, reviews, and evaluations are performed in order to provide feedback concerning the quality and uniformity of the state's or agency's inspection program. The feedback is then used to enhance the inspection program through improved inspection processes and procedures, training, and quality of the inspection report.

1.3.4 Quality Control and Quality Assurance Framework

The FHWA has developed the following recommended framework for a bridge inspection QC/QA program.

A. **Documentation of QC/QA Program**:

1. Develop, document, and maintain a bridge inspection manual that contains Quality Control/Quality Assurance (QC/QA) procedures in accordance with this recommended framework.
2. Elaborate on the purpose and benefits of the QC/QA program.
3. Provide appropriate definitions.

B. **Quality Control (QC) Procedures**

1. Define and document QC roles and responsibilities.
2. Document qualifications required for Program Manager, Team Leader, Team Member, Load Rater and Underwater Bridge Inspection Diver.
3. Document process for tracking how qualifications are met, including:
    a. Years and type of experience.
    b. Training completed.
    c. Certifications/registrations.
4. Document required refresher training, including:
    a. NHI training courses, other specialized training courses, and/or periodic meetings.
    b. Define refresher training content, frequency, and method of delivery.
5. Document special skills, training, and equipment needs for specific types of inspections.
6. Document procedures for review and validation of inspection reports and data.
7. Document procedures for identification and resolution of data errors, omissions and/or changes.

C. **Quality Assurance (QA) Procedures**

1. Define and document QA roles and responsibilities.
2. Document procedures for conducting office and field QA reviews, including:

a. Procedures for maintaining, documenting, and sharing review results; including an annual report.

b. Establish review frequency parameters. Parameters should include:

   i. Recommended review frequency for districts/units to be reviewed (e.g. review each district once every four years). Or establish number of districts/units to be reviewed annually.

   ii. Recommended number of bridges to review.

c. Procedures and sampling parameters for selecting bridges to review. Procedure should consider:

   i. Whether the bridge is or is not posted.

   ii. Bridge's deficiency status.

   iii. Whether the bridge is programmed for rehabilitation or replacement.

   iv. Whether the bridge has had critical findings and the status of any follow-up action.

   v. Bridges with unusual changes in condition ratings (e.g. more than 1 appraisal rating change from previous inspection).

   vi. Bridges that require special inspections (underwater, fracture critical, other special).

   vii. Location of bridge.

d. Procedures for reviewing current inspection report, bridge file, and load rating.

e. Procedures to validate qualifications of inspector and load rater.

f. Define "out-of-tolerance" for condition rating and load rating. (e.g. rating of +/- 1 or load ratings that differ by more than 15%)

g. Checklists covering typical items to review as part of QA procedures.

   i. Bridge file.

   ii. Field inspection.

   iii. Load rating analysis.

h. Others.

3. Document disqualification procedures for team leaders and consultant inspection firms that have continued record of poor performance.

4. Document re-qualification procedures for previously disqualified team leaders and consultant inspection firms that demonstrate they have acceptable performance.

5. Document procedures for conducting inspections on a "control" bridge.

6. Document procedures to validate the QC procedures.

Examples of Commendable State practices and additional resources regarding QC/QA programs are available at the following link: http://www.fhwa.dot.gov/bridge/nbis/nbisframework.cfm

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Chapter 2
Safety Fundamentals for Bridge Inspectors

Chapter 2

Safety Fundamentals for Bridge Inspectors

Topic 2.1 Duties of the Bridge Inspection Team

2.1.1 Introduction

Bridge inspection plays an important role in providing a safe infrastructure for the nation. As the nation's bridges continue to age and deteriorate, an accurate and thorough assessment of each bridge's condition is critical in maintaining a dependable highway system.

There are seven basic types of inspection:

- Initial (inventory)
- Routine (periodic)
- Damage
- In-depth
- Fracture critical
- Underwater
- Special (interim)

These inspection types are presented in Article 4.2 of the AASHTO *Manual for Bridge Evaluation*. Although this topic is organized for "in-depth" inspections, it applies to any inspection type. However, the amount of time and effort required for performing each duty vary with the type of inspection performed.

This topic presents the duties of the bridge inspection team. It also describes how the inspection team can prepare for the inspection and some of the major inspection procedures. For some duties, the inspection program manager may be involved.

2.1.2 Duties of the Bridge Inspection Team

There are five basic duties of the bridge inspection team:

- Planning the inspection
- Preparing for the inspection
- Performing the inspection
- Preparing the report
- Identifying items for repairs and maintenance
- Communicate the need for immediate follow-up for critical findings

2.1.3 Planning the Inspection

Planning is necessary for a safe, efficient, cost-effective inspection effort which results in a thorough and complete inspection of in-service bridges.

Basic activities include:

- Determination of the type of inspection
- Selection of the inspection team, which includes a qualified team leader on site for all initial, routine, in-depth, fracture critical and underwater inspections. Although not required by NBIS, it is a good practice to provide a team leader for damage and special inspections.
- Evaluation of required activities (e.g., nondestructive evaluation, traffic control including use of flaggers, utilities, confined spaces, permits, hazardous materials such as pigeon droppings, lead paint and asbestos removal, etc.)
- Establishment of a schedule which includes the inspection duration

2.1.4 Preparing for Inspection

Preparation measures needed prior to the inspection include organizing the proper tools and equipment, reviewing the bridge structure files, and locating plans for the structure. The success of the on-site field inspection is largely dependent on the effort spent in preparing for the inspection. The major preparation activities include:

- Review the bridge structure file
- Identify the components and elements
- Develop an inspection sequence
- Prepare and organize notes, forms, and sketches
- Arrange for temporary traffic control
- Arrange staging areas and access locations
- Reviewing safety precautions
- Organizing tools and equipment
- Arranging for subcontracting special activities
- Account for other special considerations

Review the Bridge Structure File

The first step in preparing for a bridge inspection is to review the available sources of information about the bridge, such as:

- Plans, including construction plans, shop and working drawings, and as-built drawings
- Specifications
- Correspondence
- Photographs
- Materials and tests, including material certification, material test data, and load test data
- Maintenance and repair history
- Coating history
- Accident records
- Posting
- Permit loads
- Flood and scour data
- Traffic data
- Inspection history
- Inspection requirements
- Structure Inventory and Appraisal sheets
- Inventories and inspections
- Rating records

Each of these sections of the bridge structure file is presented in detail in Topic 4.4.2.

Identify Components and Elements

Another important activity in preparing for the inspection is to establish the structure orientation, as well as a system for identifying the various components and elements of the bridge (see Figure 2.1.1). If drawings or previous inspection reports are available, use the same identification system during the inspection as those used in these sources.

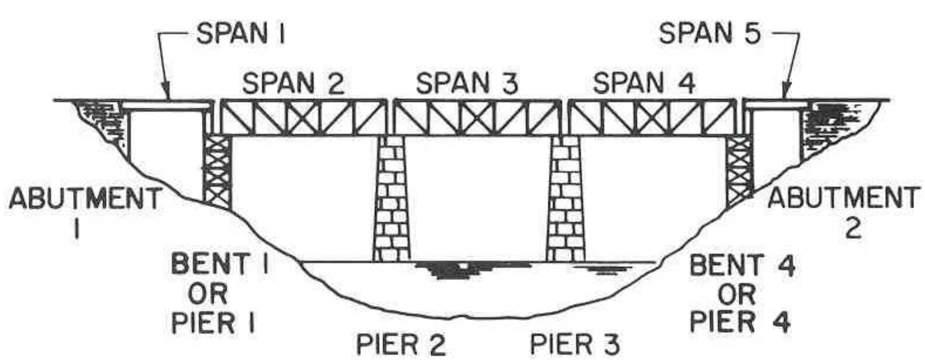

Figure 2.1.1 Sample Bridge Numbering Sequence

Establish an identification system if there are no previous records available. The numbering system presented in this topic is one possible system, but some states may use a different numbering system.

This route direction information can be used to identify the location of the bridge.

Route direction would be north, south, east or west. Mile markers, stationing or segments are the locations along the route. Location of the bridge can be identified by the route direction along with mile marker, stationing or segment information. The route direction can be determined based on mile markers, stationing, or segments, and use this direction to identify the location of the bridge.

Deck Element Numbering System

The deck sections (between construction joints), expansion joints, railing, parapets, and light standards are included in the deck element numbering system. Number these elements consecutively, from the beginning to the end of the bridge.

Superstructure Element Numbering System

The spans, the beams, and, in the case of a truss or arch, the panel points are included in the superstructure element numbering system. Number the spans consecutively, with Span 1 located at the beginning of the bridge. Multiple beams are to be numbered consecutively from left to right facing in the route direction. Similar to spans, floorbeams are also numbered consecutively from the beginning of the bridge, with the first floorbeam labeled as Floorbeam 0. This coordinates the floorbeam and the bay numbers such that a given floorbeam number is located at the end of its corresponding bay.

For trusses, number the panels similarly to the floorbeams, beginning with Panel Point 0. Label both the upstream and downstream trusses. Points in the same vertical line have the same number. If there is no lower panel point in a particular vertical line, the numbers of the lower chord skip a number (see Figure 2.1.2). Some design plans number to midspan on the truss and then number backwards to zero using prime numbers (U9'). However, this numbering system is not recommended for field inspection use since the prime designations in the field notes may be obscured by dirt.

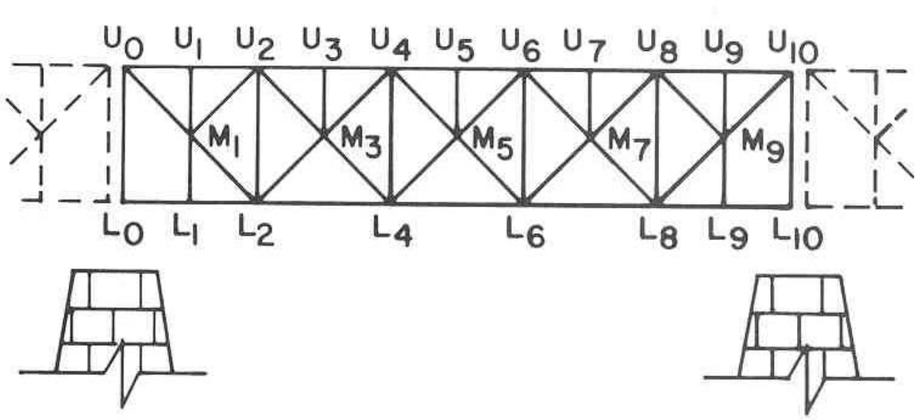

Figure 2.1.2 Sample Truss Numbering Scheme

Substructure Element Numbering System

The abutments and the piers are included in the substructure element numbering system. Abutment 1 is located at the beginning of the bridge, and Abutment 2 is located at the end. Number the piers consecutively, with Pier 1 located closest to the beginning of the bridge (see Figure 2.1.2). Alternatively, the substructure units may be numbered consecutively without noting abutments or piers.

AASHTO Bridge Elements

The *AASHTO Guide Manual for Bridge Element Inspection* provides a comprehensive set of bridge elements, designed to be flexible in nature to satisfy needs of all agencies. This set of elements capture the components necessary for any agency to manage the aspects of the bridge inventory and allows the full utilization of a Bridge Management System (BMS).

There are two different element types included in the element set which are identified as National Bridge Elements (NBEs) or Bridge Management Elements (BMEs). These two element sets combined comprise the full AASHTO element set.

Develop Inspection Sequence

An inspection normally begins with the deck and superstructure elements and proceeds to the substructure. However, there are many factors to be considered when planning a sequence of inspection for a bridge, including:

- Type of bridge
- Condition of the bridge components
- Overall condition
- Inspection agency requirements
- Size and complexity of the bridge
- Traffic conditions
- Special considerations

A sample inspection sequence for a bridge of average length and complexity is presented in Figure 2.1.3. While developing an inspection sequence is important, it is of value only if following it ensures a safe, complete and thorough inspection of the bridge.

1) Roadway Elements

- Approach roadways
- Traffic safety features
- General alignment
- Approach alignment
- Deflections
- Settlement

2) Deck Elements

- Bridge deck: top and bottom
- Expansion joints
- Sidewalks and railings
- Drainage
- Signing
- Electrical-lighting
- Barriers, gates, and other traffic control devices

3) Superstructure Elements

- Primary load-carrying members
- Secondary members and bracings
- Utilities and their attachments
- Anchorages
- Bearings

4) Substructure Elements

- Abutments
- Piers
- Footings
- Piles
- Curtain walls
- Skewbacks (arches)
- Slope protection

5) Channel and Waterway Elements

- Channel profile and alignment
- Channel streambed
- Channel embankment
- Channel embankment protection
- Hydraulic opening Fenders
- Water depth scales
- Navigational lights and aids
- Dolphins
- Hydraulic control devices

Figure 2.1.3 Sample Inspection Sequence

Prepare and Organize Notes, Forms, and Sketches

Preparing notes, forms, and sketches prior to the on-site inspection reduces work in the field. Obtain copies of the agency's standard inspection form for use in recordkeeping and as a checklist to ensure that the condition of all elements is noted.

Create copies of sketches from previous inspection reports so that defects previously documented can simply be updated. Preparing extra copies provides a contingency for sheets that may be lost or damaged in the field.

If previous inspection sketches or design drawings are not available, then pre-made, generic sketches may be used for repetitive features or members. Possible applications of this timesaving method include deck sections, floor systems, bracing members, abutments, piers, and retaining walls. Numbered, pre-made sketches and forms can also provide a quality control check on work completed.

Arrange for Temporary Traffic Control

Bridge inspection, like construction and maintenance activities on bridges, often presents motorists with unexpected and unusual situations (see Figure 2.1.4). Most state agencies have adopted the Federal *Manual on Uniform Traffic Control Devices for Streets and Highways* (*MUTCD*). Some state and local jurisdictions, however, issue their own manuals. When working in an area exposed to traffic, check and follow the governing standards. These standards prescribe the minimum methods for a number of typical applications and the proper use of standard traffic control devices, such as cones, signs, and flashing arrow boards.

Figure 2.1.4 Temporary Traffic Control Operation

Principles and methods, which enhance the safety of motorists and bridge inspectors in work areas, include the following:

- Traffic safety is a high priority element on every bridge inspection project where the inspectors' activities are exposed to traffic or likely to affect normal traffic movements.
- Route traffic through work areas with geometrics and traffic control devices comparable to those employed for other highway situations.
- Inhibit traffic and pedestrian movement as little as practicable.
- Guide approaching motorists in a clear and positive manner throughout the bridge inspection site.
- On long duration inspections, perform routine inspection of temporary traffic control devices.
- Adequately train personnel responsible for the performance of temporary traffic control operations.

In addition, schedules may have to be adjusted to accommodate temporary traffic control needs. For example, the number of lanes that can be closed at one time may require conducting the inspection operation with less than optimum efficiency. While it might be most efficient to inspect a floor system from left to right, traffic control may dictate working full length, a few beams at a time. Some agencies require inspections to be performed during low tow traffic (i.e. at night).

Special Considerations

Time Requirements

The total time required to complete an inspection can vary from what may be documented on a previous inspection report or separately in the bridge file due to the various tasks for completing the inspection. Breaking down and recording the time to complete the various tasks (office preparation, travel, on-site, report preparation) separately benefits future planning and preparation efforts. Break down the inspection time requirements in to office preparation, travel time, field time, and report preparation. The overall condition of the bridge plays a major role in determining how long an inspection takes. Previous inspection reports provide an indication of the bridge's overall condition. It generally takes more time to inspect and document a deteriorated element (e.g., measuring, sketching, and photographing) than it does to simply observe and document that an element is in good condition.

Peak Travel Times

In populated areas, an inspection requiring traffic restrictions may be limited to certain hours of the day, such as 10:00 AM to 2:00 PM. Some days may be banned for inspection work altogether. Actual inspection time may be less than a 40-hour work week in these situations, so adjust the schedules accordingly.

Set-up Time

Consider set-up time both before and during the inspection. For example, rigging efforts may require several days before the inspectors arrive on the site. Also, other equipment, such as compressors and cleaning equipment may require daily set-up time. Provide adequate time in the schedule for set-up and take-down time requirements. Also, consider the time to install and remove temporary traffic control devices.

Access

Consider access requirements when preparing for an inspection. Bridge members may be very similar to each other, but they may require different amounts of time to gain access to them. For example, it may take longer to maneuver a lift device to gain access to a floor system near utility lines than for one that is free of obstructions. On some structures, access hatches may need to be opened to gain access to a portion of the bridge.

Weather

Adverse weather conditions may not halt an inspection entirely, but may play a significant role in the inspection process. During adverse weather conditions, avoid climbing on the bridge structure. An increased awareness of safety hazards is required, and keeping notes dry can be difficult. During seasons of poor weather, adopt a less aggressive schedule than during the good weather months.

Safety Precautions

While completing the inspection in a timely and efficient manner, the importance of taking safety precautions cannot be overlooked. Review general safety guidelines for inspection and any agency or bridge specific safety precautions such as for hazardous material and confined space entry. Confined space entry methods are in accordance with OSHA and the owners’ requirements. For climbing inspections, the three basic requirements covered in topic 2.2.5 for safe climbing are to be followed. For additional information about safety precautions, refer to Topic 2.2.5.

Permits

When inspecting a bridge crossing a railroad, obtain an access permit before proceeding with the field inspection. Also obtain a permit when inspecting bridges passing over navigable waterways. Environmental permits and permits to work around endangered species may be required for some bridges and bridge sites.

Tools

To perform a complete and accurate inspection, use the proper tools and equipment. Bridge location and type are two main factors in determining required tools and equipment. Refer to Topic 2.4 for a complete list of inspection tools and equipment.

Subcontract Special Activities

Give consideration to time requirements when special activities are scheduled. These activities may include one or more of the following:

- Maintenance and protection of traffic (M.P.T.)
- Access, including rigging, inspection vehicle(s), or a combination there of
- Coordination with various railroads, including obtaining the services of railroad flagmen
- Non-destructive evaluation/testing

2.1.5 Performing the Inspection

This duty is the on-site work of accessing and examining bridge components and waterway, if present.

Perform inspections in accordance with the *National Bridge Inspection Standards (NBIS) and AASHTO Manual for Bridge Evaluation (MBE)*.

Basic activities include:

- Visual examination of bridge components
- Physical examination of bridge components
- Evaluation of bridge components
- Examination and evaluation of the waterway beneath the structure, if any, and approach roadway geometry

General Inspection Procedures

Duties associated with the inspection include maintaining the proper structure orientation and member numbering system, and following proper inspection procedures.

The procedures used to inspect a bridge depend largely on the bridge type, the materials used, and the general condition of the bridge. Therefore, be familiar with the basic inspection procedures for a wide variety of bridges.

A first step in the inspection procedure is to establish the orientation of the site and of the bridge. Include the compass directions, the direction of waterway flow, and the direction of the inventory route in the orientation. Also record inspection team members, air temperature, weather conditions, and time.

After the site orientation has been established, the inspector is ready to begin the on-site inspection. Be careful and attentive to the work at hand, and do not overlook any portion of the bridge. Give special attention to those portions that are most critical to the structural integrity of the bridge. (Refer to Topic 6.4 for a description of fracture critical members in steel bridges.)

Combine the prudence used during the inspection with thorough and complete recordkeeping. Careful and attentive observations are to be made, and record every deficiency. A very careful inspection is worth no more than the records kept during that inspection.

Place numbers or letters on the bridge by using crayon or paint to identify and code components and elements of the structure. The purpose of these marks is to keep track of the inspector's location and to guard against overlooking any portion of the structure.

Note the general approach roadway alignment, and sight along the railing and edge of the deck or girder to detect any misalignment or settlement.

Approaches and Decks

Check the approach pavement for unevenness, settlement, or roughness. Also check the condition of the shoulders, slopes, drainage, and approach guardrail.

Examine the deck and any sidewalks for various deficiencies, noting size, type, extent, and location of each deficiency. Reference the location using the centerline or curb line, the span number, and the distance from a specific pier or joint.

Examine the expansion joints for sufficient clearance and for adequate seal. Record the width of the joint opening at both curb lines, noting the air temperature and the general weather conditions at the time of the inspection.

Finally, check that safety features, signs (load restrictions), and lighting are present, and note their condition.

Superstructures

Inspect the superstructure thoroughly, since the failure of a primary load-carrying member could result in the collapse of the bridge. The primary method of bridge inspection is visual, requiring the removal of dirt, leaves, animal waste, and debris to allow close observation and evaluation of the primary load-carrying members. The most common forms of primary load-carrying members are:

- Beams and girders
- Floorbeams and stringers
- Trusses
- Cables (suspension, stay, suspender)
- Eyebar chains
- Arches
- Frames
- Pins and hanger assemblies

Bearings

Inspect the bearings thoroughly, since they provide the critical link between the superstructure and the substructure. The primary method of bearing inspection is a visual inspection, which requires removing dirt, leaves, animal waste, and debris to allow close observation and evaluation of the bearings. Record the difference between the rocker tilt and a fixed reference line, noting the direction of tilt, the air or bearing material temperature, and the general weather conditions at the time of the inspection.

Substructures

The substructure, which supports the superstructure, is made up of abutments, piers, and bents. If "design" or "as-built" plans are available, compare the dimensions of the substructure units with those presented on the plans. Since the primary method of bridge inspection is visual, remove the dirt, leaves, animal waste, and debris to allow close observation and evaluation. Check the substructure units for settlement by sighting along the superstructure and noting any tilting of vertical faces. In conjunction with the scour inspection of the waterway, check the substructure units for undermining, noting both its extent and location.

Culverts

Inspect culverts regularly to identify any potential safety problems and maintenance needs. Examine the culvert for various deficiencies, noting size, type, extent, and location of each deficiency. Reference the location using the centerline. In addition to the inspection of the culvert and its components, look for high-water marks, changes in drainage area, scour, and settlement of the roadway.

Waterways

Waterways are dynamic in nature, with their volume of flow and their path continually changing. Therefore, carefully inspect bridges passing over waterways for the effects of these changes.

Maintain a historical record of the channel profile and cross-sections. Record and compare current measures to initial (base line) measures, noting any meandering of the channel both upstream and downstream. Report any skew or improper location of the piers or abutments relative to the stream flow.

Scour is the removal of material from the streambed or streambank as a result of the erosive action of streamflow. Scour is the primary concern when evaluating the effects of waterways on bridges (see Figure 2.1.5). Determine the existence and extent of scour using a grid system and noting the depth of the channel bottom at each grid point.

Figure 2.1.5 Inspection for Scour and Undermining

Note the embankment erosion both upstream and downstream of the bridge, as well as any debris and excessive vegetation. Record their type, size, extent, and location. Note also the high water mark, referencing it to a fixed elevation such as the bottom of the superstructure.

Inspection of Bridge Elements

There are several general terms used to describe bridge deficiencies:

- Corrosion – section loss
- Cracking - breaking away without separating in to parts
- Splitting - separating in to parts
- Connection slippage – relative movement of connected parts
- Overstress - deformation due to overload
- Collision damage - damage caused when a bridge is struck by vehicles or vessels

Refer to Chapter 6 for a more detailed list and description of types and causes of deterioration for specific materials. As described in Chapter 6, each material is subject to unique deficiencies. Therefore, be familiar with the different inspection methods used with each material.

Timber Inspection

When inspecting timber structures, determine the extent and severity of decay, weathering and wear, being specific about dimensions, depths, and locations. Sound and probe the timber to detect hidden deterioration due to decay, insects, or marine borers.

Note any large cracks, splits, or crushed areas. While collision or overload damage may cause these deficiencies, avoid speculation as to the cause and be factual. Note any fire damage, recording the measurements of the remaining sound material. Document any exposed untreated portions of the wood, indicating the type, size, and location.

Concrete Inspection

When inspecting concrete structures, note all visible cracks, recording their type, width, length, and location. Also record any rust or efflorescence stains. Concrete scaling can occur on any exposed face of the concrete surface, so record its area, location, depth, and general characteristics. Inspect concrete surfaces for delamination or hollow zones, which are areas of incipient spalling, using a hammer or a chain drag. Carefully document any delamination using sketches showing the location and pertinent dimensions.

Unlike delamination, spalling is readily visible. Document any spalling using sketches or photos, noting the depth of the spalling, the presence of exposed reinforcing steel, and any deterioration or section loss that may be present on the exposed reinforcement.

Metal Inspection: Steel, Iron and Others

When inspecting metal structures, determine the extent and severity of corrosion, carefully measuring the amount of cross section remaining. Note all cracks, recording their length, size, and location. Document all bent or damaged members, noting the type of damage and amount of deflection.

Loose rivets or bolts can be detected by striking them with a hammer while holding a thumb on the opposite end of the rivet or bolt. Movement can be felt if it is loose. In addition, note any missing rivets or bolts.

Note any frozen pins, hangers, or expansion devices. One indication of this is if the hangers or expansion rockers are inclined or rotated in a direction opposite to that expected for the current temperature. In cold weather, rocker bearings lean towards the fixed end of the bridge, while in hot weather, they lean away from the fixed end. A locked bearing is generally caused by heavy rust on the bearing elements.

For the evaluation to be substantiated, document and record all inspection findings. Documentation is referred to as the “condition remarks” on the inspection form or in the inspection report.

Masonry Inspection

The examination of stone masonry and mortar is similar to that of concrete. Carefully inspect the joints for cracks and other forms of mortar deterioration. Inspection techniques are generally the same as for concrete.

Check masonry arches or masonry-faced concrete arches for mortar cracks, vegetation, water seepage through cracks, loose or missing stones or blocks, weathering, and spalled or split blocks and stones.

Fiber Reinforced Polymer Inspection

When inspecting Fiber Reinforced Polymers (FRP), note any blistering, voids and delaminations, discoloration, wrinkling, fiber exposure and any scratches. Document all visible cracks, recording their width, length, and location.

Critical Findings

Critical findings are any structural or safety-related deficiency that requires immediate follow-up inspection or action. When a critical finding is discovered, immediately communicate and document the critical finding according to agency procedures.

Refer to Topic 4.5 for a detailed description of critical findings and the methods required to address any critical findings discovered.

2.1.6 Preparing the Report

Documentation is essential for any type of inspection. Gather enough information to ensure a comprehensive and complete report. Report preparation is a duty, which reflects the effort that the inspector puts in to performing the inspection. Both documentation and preparation are to be comprehensive. The report is a record of both the bridge condition and the inspector's work.

Basic activities in preparing the inspection report include:

- Completion of agency forms
- Objective written documentation of all inspection findings
- Providing photo references and sketches
- Objective evaluation of the bridge, roadway and waterway components and elements
- Recommendations and cost estimates (refer to Topic 2.1.7 for further details)
- Summary

A sample bridge inspection report can be found in Appendix B of this manual. Follow the procedures of the agency responsible for the bridge.

2.1.7 Identifying Items for Preservation and Follow-up for Critical Findings

Another common duty is to identify work recommendations for bridge preservation and follow-up to critical findings. Recommend work items that promote public safety and maximize useful bridge life. Refer to Topic 4.5 for details on follow-up to critical findings.

Work recommendations are commonly aligned with an agency’s bridge preservation program and are included in preservation work plans. These work recommendations are condition driven or cyclical. Examples of preservation activities include: deck or bridge washing, flushing the scuppers and down spouts, lubricating the bearings and painting the structure.

Carefully consider the benefits to be derived from completing the work recommendation and the consequences if the work is not completed. Also, check the previous report recommendations to see what work was recommended and the priority of such items. If work was scheduled to be completed before the next inspection, note if the work was completed and the need for any follow-up work.

The NBIS regulation requires the establishment of a statewide or Federal agency wide procedure to assure that critical finds are addressed in a timely manner. Additionally, the NBIS requires that FHWA be periodically notified of actions taken to resolve or monitor critical findings. The duty of the inspection team is to follow statewide or Federal agency-wide procedures for the follow-up on critical findings. It is the responsibility of Bridge Owners to implement procedures for addressing critical deficiencies, including:

- Immediate critical deficiency reporting steps
- Emergency notification of police and the public
- Rapid evaluation of the deficiencies
- Rapid implementation of corrective or protective actions
- A tracking system to ensure adequate follow-up
- Provisions for identifying other bridges with similar structural details for follow-up inspections

Critical findings are presented in detail in Topic 4.5.

2.1.8 Types of Bridge Inspection

The type of inspection may vary over the useful life of a bridge to reflect the intensity of inspection required at the time of inspection. The seven types of inspections identified in the AASHTO Manual for Bridge Evaluation are described below and allow a Bridge Owner to establish appropriate inspection levels consistent with the inspection frequency and the type of structure and details.

Initial (Inventory)

An initial inspection is the first inspection of a bridge as it becomes a part of a bridge file, but the elements of an initial inspection may also apply when there has been a change in configuration of the structure (e.g., widening, lengthening, supplemental bents, etc.) or a change in bridge ownership. The initial inspection is a fully documented investigation and is accompanied by load capacity ratings. The purpose of this inspection is two-fold. First, an initial inspection provides all Structure Inventory and Appraisal (SI&A) data. Second, it provides baseline structural conditions and identification of existing problems.

Routine (Periodic)

Routine inspections are regularly scheduled inspections consisting of observations and/or measurements needed to determine the physical and functional condition of the bridge, to identify any changes from “initial” or previously recorded conditions, and to ensure that the structure continues to satisfy present service conditions. Inspection of underwater portions of the substructure is limited to observations during low-flow periods and/or probing for signs of scour and undermining. The areas of the structure to be closely monitored are those determined by previous inspections and/or load rating calculations to be critical to load-carrying capacity. Follow the plan of action for scour critical bridges.

According to the NBIS, inspect each bridge at regular intervals not to exceed 24 months. However, certain bridges require inspection at less than the 24-month interval. Establish criteria to determine inspection frequency and intensity based on such factors as age, traffic characteristics, and known deficiencies. Certain bridges may be inspected at greater than 24-month intervals, not to exceed 48 months, with prior FHWA-approval. This may be appropriate when past inspection findings and analysis justifies the increased inspection interval.

Damage

A damage inspection is an unscheduled inspection to assess structural damage resulting from environmental factors or human actions. The scope of inspection is sufficient to determine the need for emergency load restrictions or closure of the bridge to traffic and to assess the level of effort necessary for an effective repair.

In-Depth

An in-depth inspection is a close-up, inspection of one or more members above or below the water level to identify any deficiencies not readily detectable using routine inspection procedures. Hands-on inspection may be necessary at some locations. When appropriate or necessary to fully ascertain the existence of or the extent of any deficiencies, nondestructive field tests may need to be performed. The inspection may include a load rating to assess the residual capacity of the member or members, depending on the extent of the deterioration or damage. This type of inspection can be scheduled independently of a routine inspection, though generally at a longer interval, or it may be a follow-up for other inspection types. For small bridges, the in-depth inspection includes all critical members of the structure. For large and complex structures, these inspections may be scheduled separately for defined segments of the bridge or for designated groups of elements, connections, or details.

According to the NBIS, establish criteria to determine the level and frequency of this type of inspection.

Fracture Critical

A fracture critical member (FCM) inspection is performed within arm's length of steel members in tension, or with a tension element, who failure would probably cause a portion of or the entire bridge to collapse. The FCM inspection uses visual methods that may be supplemented by nondestructive testing. A very detailed visual hands-on inspection is the primary method of detecting cracks. This may require that critical areas be specially cleaned prior to the inspection and additional lighting and magnification be used. Other nondestructive methods may be used at the discretion of the Bridge Owner. Where the fracture toughness of the steel is not documented, some tests may be necessary to determine the threat of brittle fracture at low temperatures.

According to the NBIS, fracture critical members (FCMs) are to be inspected at regular intervals not to exceed 24 months. However, certain FCMs require inspection at less than 24-month intervals. Establish criteria to determine the inspection level and frequency to which these members are inspected considering such factors as age, traffic characteristics, and known deficiencies.

Underwater

An underwater inspection is the inspection of the underwater portion of a bridge substructure and the surrounding channel, which cannot be inspected visually at low water by wading or probing, generally requiring diving or other appropriate procedures. Underwater inspections are an integral part of a total bridge inspection plan. Scour evaluations are conducted for all bridges over water. Determine the severity and extent of scour, immediately communicating and documenting critical findings. Follow the plan of action for scour critical bridges.

Structural damage, scour and erosion due to water movement, drift, streambed load, ice loading, navigation traffic collision, and deleterious effects of water movement or of elements, are typical occurrences that could result in the decision to conduct underwater inspections at shorter intervals.

According to the NBIS, underwater structural elements are inspected at regular intervals not to exceed 60 months. However, certain underwater structural elements require inspection at less than the 60-month intervals. Establish criteria to determine the level and frequency to which these members are inspected considering such factors as construction material, environment, age, scour characteristics, condition rating from past inspections and known deficiencies. Certain underwater structural elements may be inspected at greater than 60-month intervals, not to exceed 72 months, with written FHWA-approval. This may be appropriate when past inspection findings and analysis justifies the increased inspection interval.

Special (Interim)

A special inspection is an inspection scheduled at the discretion of the Bridge Owner. It is used to monitor a particular known or suspected deficiency, such as foundation settlement or scour, fatigue damage, or the public's use of a load posted bridge. These inspections are not usually comprehensive enough to meet NBIS requirements for routine inspections.

According to the NBIS, establish criteria to determine the level and frequency of this type of inspection. Guidelines and procedures on what to observe and/or measure are provided, and a timely process to interpret the field results is in place.

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Chapter 2
Safety Fundamentals for Bridge Inspectors

Topic 2.2 Safety Fundamentals for Bridge Inspectors

2.2.1 Importance of Bridge Inspection Safety

While completing the inspection in a timely and efficient manner is important, safety is also a major concern in the field. Bridge inspection is inherently dangerous and therefore requires continual watchfulness on the part of each member of the inspection team. Attitude, alertness, and common sense are three important factors in maintaining safety. To reduce the possibility of accidents, bridge inspectors need to be concerned about safety.

Five key motivations for bridge inspection safety:

- Injury and pain - Accidents can cause pain, suffering, and even death. Careless inspectors can severely injure or even kill themselves or others on the inspection team. Resulting pain and discomfort can hamper the inspector for the rest of their life.

- Family hardship - A worker’s family also suffers hardship when an accident occurs. Not only is there loss of income, but there is also the inability to participate in family activities. In the case of major disability, the burden of caring for the injured person falls on family members.

- Equipment damage - The repair or replacement of damaged equipment can be very costly. There is also a cost associated with the loss of time while the equipment is not available for use.

- Lost production - The employer loses revenues associated with the employee’s work, and also loses time and money spent on safety training and equipment. Training additional inspectors to replace the injured worker contributes to lost production. Lost production also affects the bridge owner in terms of loses in revenue, time and money if a bridge is closed longer than expected after an inspection accident.

- Medical expenses - Whether coverage is an employee benefit, personal insurance, or out of pocket, someone has to pay for medical expenses. Ultimately, everyone is impacted by accidents through higher insurance premiums.

Constantly be aware of safety concerns. Spending the effort to be safe pays big dividends in avoided expenses and grief.

2.2.2 Safety Responsibilities

The employer is responsible for providing a safe working environment, including:

- Clear safety regulations and procedures
- Safety training
- Proper tools and equipment

The supervisor is responsible for maintaining a safe working environment, including:

- Supervision of established job procedures
- Training in application of safety procedures
- Training in proper use of equipment
- Enforcement of safety regulations

Bridge inspectors are ultimately responsible for their own safety. The bridge inspector's responsibilities include:

- Recognition of physical limitations – Recognize your limitations and communicate them to your supervisor and inspection team members.
- Knowledge of rules and requirements of job – Verify that you understand a particular task and that you are qualified to perform that task. If a procedure appears to be unsafe, question it and constructively try to develop a safer procedure.
- Safety of fellow workers – Do not act in a manner that endangers fellow inspectors. Warn co-workers if they are doing something unsafe.
- Reporting an accident – If there is an accident, it is essential to report it to a designated individual in your agency or company within the prescribed time frame, usually within 24 hours. Promptly report any injury in order to assure coverage, if necessary, under workmen's compensation or other insurance.

2.2.3 Personal Protection

Proper Inspection Attire

It is important to dress properly for the job. Be sure to wear field clothes that are properly sized and appropriate for the climate. For general inspection activities, wear boots with traction lug soles. For climbing of bridge components, wear boots with a steel shank (with non-slip soles without heavy lugs), as well as gloves. Wearing a tool pouch enables the inspector to carry tools and notes with hands free for climbing and other inspection activities.

Inspection Safety Equipment

Safety equipment is designed to prevent injury. Use the equipment correctly in order for it to provide protection. The following are some common pieces of safety equipment:

Hard Hat

A hard hat can prevent serious head injuries in two ways. First, it provides protection against falling objects. The bridge site environment during inspection activities is prone to falling objects. Main concerns are:

- Deteriorated portions of bridge components dislodged during inspection
- Equipment dropped by coworkers overhead
- Debris discarded by passing motorists

Secondly, a hard hat protects the inspector's head from accidental impact with bridge components. When inspections involve climbing or access equipment, the inspector is frequently dodging various configurations of superstructure elements. These superstructure elements can be sharp edged and are always unyielding. If the inspector makes a mistake in judgement during a maneuver and impacts the structure, a hard hat may prevent serious injury.

It is a good practice to always wear a hard hat (see Figure 2.2.1). Also, if the inspector is free climbing, it is a good practice to wear a chinstrap with the hard hat.

Figure 2.2.1 Inspector Wearing a Hard Hat

Reflective Safety Vest

When performing activities near traffic, the inspector is required to wear a safety vest. Be sure the vest conforms to current OSHA and MUTCD standards. The combination of bright color and reflectivity makes the inspector more visible to passing motorists. Safety is improved when the motorist is aware of the inspector's presence (see Figure 2.2.2).

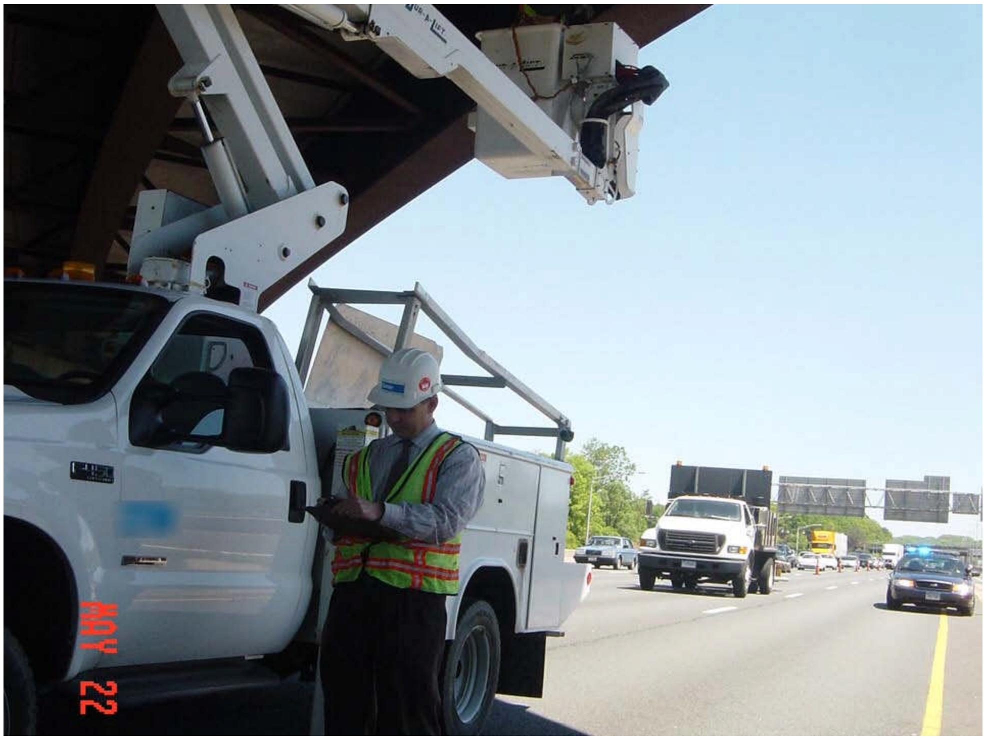

Figure 2.2.2 Inspector Wearing a Reflective Safety Vest

Safety Goggles

Eye protection is necessary when the inspector is exposed to flying particles. Glasses with shatterproof lenses are not adequate if side protection is not provided. It is also important to note that only single lens glasses be worn when climbing (no bifocals).

Wear eye protection during activities such as:

- Using a hammer
- Using a scraper or wire brush
- Grinding
- Shot or sand blasting
- Power tools

Gloves

Although one may not immediately think of gloves as a piece of safety equipment, they can prove to be an important safety feature. Wearing gloves protect the inspector's hands from harmful effects of deteriorated members (see Figure 2.2.3). In many inspections, structural members have been deteriorated to the point where the edges of the members have become razor sharp. These edges can cause severe cuts and lacerations to the inspector's hands that may become infected.

Figure 2.2.3 Inspector Wearing Safety Goggles and Gloves

Life Jacket

Always wear a life jacket when working over water or in a boat (see Figure 2.2.4). If an accident occurs, good swimmers may drown if burdened with inspection equipment. Also, if knocked unconscious or injured due to a fall, a life jacket keeps the inspector afloat. Also wear a life jacket when wearing hip or chest waders. If an inspector slips or steps in an area that is too deep, their waders can fill with water and drag them under, making swimming impossible.

Figure 2.2.4 Inspector Wearing a Life Jacket

Dust Mask / Respirator

A respirator or dust mask can protect the inspector from harmful airborne contaminants and pollutants (see Figure 2.2.5). Consult agency or OSHA regulations for approved types and appropriate usage.

Conditions requiring a respirator include:

- Sand blasting
- Painting
- Exposure to dust from pigeon droppings (exposure to pigeon droppings may result in histoplasmosis, a potentially very serious illness)
- Work in closed or constricted areas
- Hammering, scraping or wire brushing steel members with lead based paints.

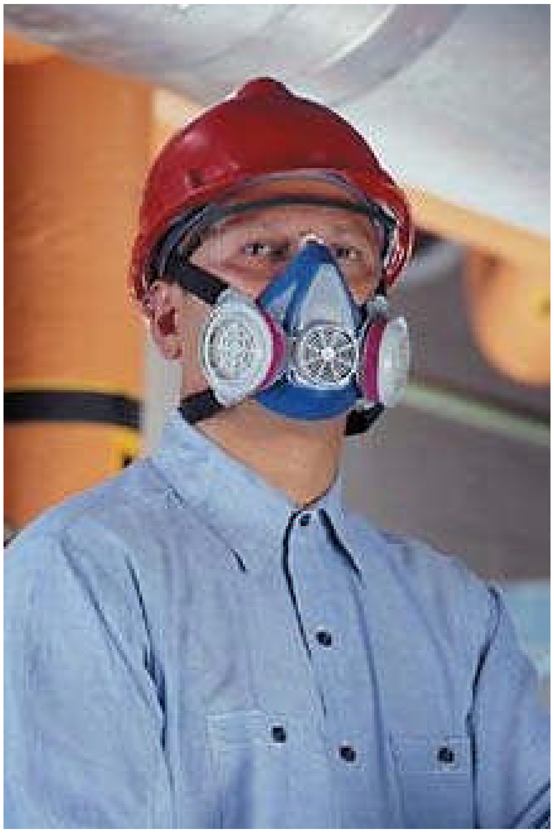

Figure 2.2.5 Inspector Wearing a Respirator

Safety Harness and Lanyard

The safety harness and lanyard is the inspector's lifeline in the event of a fall (see Figure 2.2.6). Use this equipment as required by conditions. Make sure you satisfy agency and OSHA requirements.

For example, some agencies require a safety harness be worn in the following situations:

- At heights over 20 feet
- Above water
- Above traffic

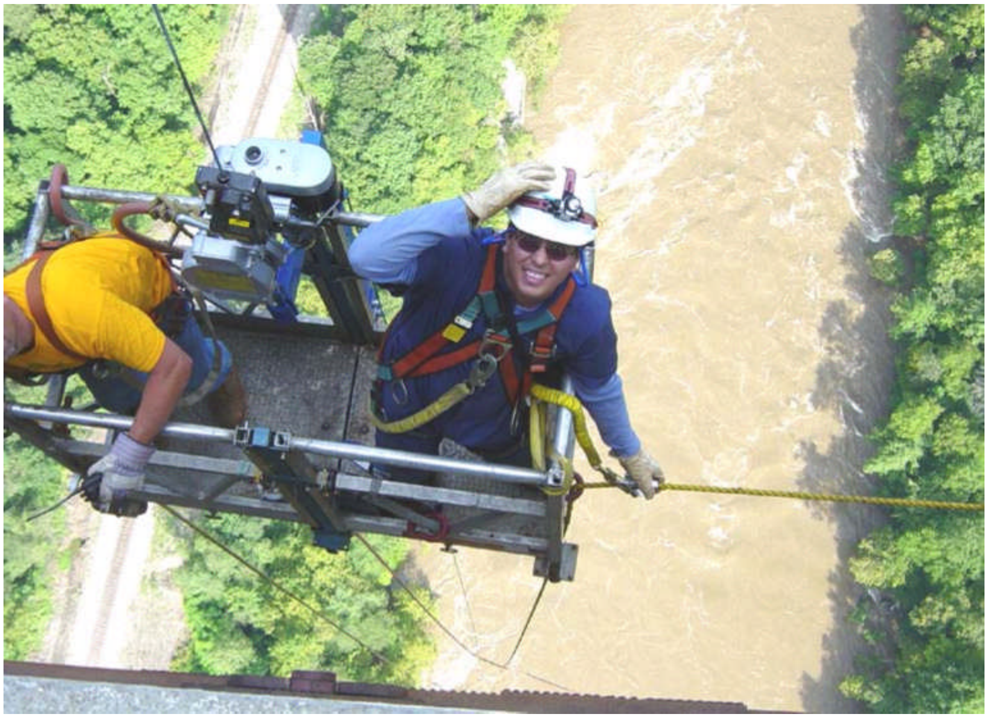

Figure 2.2.6 Inspector with Safety Harness with a Lanyard

To reduce the possibility of injury, the maximum lanyard length limits a fall to 6 feet per OSHA regulations. Further protection can be achieved using a shock absorber between the lanyard and the safety harness. The shock absorber reduces g-forces through the controlled extension of nylon webbing, which is pre-folded and sewn together. Two lanyards are required with one lanyard being tied off to a solid structural member or to a safety line rigged always for this purpose. Use the second lanyard to allow safe movement around obstacles connecting the second lanyard before disconnecting the first lanyard in order to safely move along the structure.

Do not tie off to scaffolding or its supporting cable. One of the reasons for tying off is to limit your fall in case the rigging or scaffold fails. When working from a under bridge inspection vehicle or bucket truck, tie off to the structure if possible. Exercise extreme caution not to allow the equipment to be moved out from under someone tied to the bridge. If the machine is being moved frequently, it is best to tie off to the bucket or boom.

Boats/Skiff

There must be one rescue person present and specifically assigned to respond to water emergencies at all times when the inspection over water is active. Whenever possible, a manned boat/skiff should be in the water. Whenever possible, a manned boat/skiff should be in the water. In the event of an accident in which someone was to fall in to the water, the boat can rescue them quickly. This is especially important if the individual has been rendered unconscious. In addition, it can also be used to retrieve any equipment that may have been accidentally dropped by an inspector. In situations where the use of a boat/skiff is not practical, a rescue person should be stationed on the river bank with a life ring.

2.2.4 Causes of Accidents

General Causes

Accidents are usually caused by human error or equipment failure. Part of safety awareness is acknowledging this and planning ahead to minimize the effects of those errors or failures.

Accidents caused by equipment failure can often be traced to inadequate or improper maintenance. Inspection, maintenance, and update of equipment can minimize failures. Accidents caused by people are usually caused by an error in judgment, thoughtlessness, or trying to take shortcuts.

Specific Causes

Specific causes of accidents include the following:

- Improper attitude – distraction, carelessness, worries over personal matters.
- Personal limitations – lack of knowledge or skill, exceeding physical capabilities.
- Physical impairment – previous injury, illness, side effect of medication, alcohol or drugs.
- Boredom – falling into an inattentive state while performing repetitive, routine tasks.
- Thoughtlessness - lack of safety awareness and not recognizing hazards.
- Shortcuts - sacrificing safety for time.
- Faulty equipment – damaged ladder rungs, worn rope, frayed cables or access equipment not inspected regularly.
- Inappropriate or loose fitting clothing.

2.2.5 Safety Precautions

Safety precautions can be divided in to several categories: General Precautions, Climbing Safety, Confined Spaces, Vegetation, Night Work, Working Around Water, and Culverts.

General

Mental Attitude

The inspector has to be mentally prepared to do a climbing inspection. A good safety attitude is of foremost importance. Address the following three precautions:

- Avoid emotional distress – Do not climb when emotionally upset. The inspector who climbs needs to have complete control; otherwise the chances of falling increase.
- Awareness of surroundings – Always be aware of dangers associated with inspection location when climbing. Do not become as engrossed in the job as to step into mid-air.
- Realize limitations – An inspector is to be confident the job can be performed safely. If there is a feature that cannot safely be inspected with the equipment available, do not inspect it. Highlight this fact in the notes so that appropriate equipment can be scheduled if necessary. Do not hide the fact that a particular bridge member was not inspected.

General Guidelines

Some general guidelines for safe inspections are as follows:

- Keeping well rested and alert – Working conditions encountered during an inspection are varied and can change rapidly requiring the inspector be fit and attentive.
- Maintaining proper mental and physical condition – Inspection tasks require a multitude of motor skills. To perform at acceptable levels, the inspector is to be physically fit and free from mental distractions.
- Using proper tools – Do not try to use tools and equipment not suited for the job.
- Keeping work areas neat and uncluttered – Tools and equipment scattered carelessly about the work area present hazards that can result in injury.
- Establishing systematic methods – Establish methods early in the job and utilize them so everyone knows what to expect of one another.
- Follow safety rules and regulations – Adhere to the safety rules and regulations established by the OSHA, the agency, and your employer.
- Use common sense and good judgment – Do not engage in horseplay, and do not take short cuts or foolish chances.
- Do not use of intoxicants or drugs – Intoxicants impair judgment, reflexes, and coordination.
- Medication – Prescription and over-the-counter medications can cause drowsiness or other unwanted and potentially dangerous side effects.

- Electricity – This is a potential killer. Assume cables and wires to be hot (live) even if they appear to be only telephone cables. The conditions encountered on many bridges are conducive to electric shock. These conditions include steel members, humidity, perspiration, and damp clothing. Identify transmission lines on a structure prior to the inspection. Shut down power lines. In rural areas, avoid electric fences since they can be a hazard. Be aware that fiberglass posts eliminate the need for the distinctive porcelain insulation, which once identified electric fences.
- Inspection over water – A safety boat is to be provided when working over water. Be sure the boat is equipped with a life ring and radio communication with the inspection crew.
- Waders – Use caution when wearing waders. If the inspector falls into a scour hole, the waders can fill with water, making swimming impossible.
- Inspection over traffic – It is best to avoid working above traffic. If it cannot be avoided, tie off equipment, such as hand tools and clip boards.
- Entering dark areas – Use a flashlight to illuminate dark areas prior to entering as a precaution against falls, snakebites, and stinging insects.
- Vagrant people – Exercise caution when approaching a bridge where homeless people are present. Explain to them an inspection of the bridge is taking place, and the inspection team leaves the site as soon as possible. Leave the bridge site immediately if there are any illegal activities or perceived danger.

Working in Teams

Work in pairs. Do not take any action without someone else there to help in case of an accident. Make sure someone else knows where you are. If someone seems to be missing, locate that person immediately.

First Aid Training is recommended for bridge inspectors and is available through organizations such as OSHA or the American Red Cross.

If an inspector is injured during an inspection, it is important to know First Aid and/or cardiopulmonary resuscitation (CPR). The American Red Cross offers training for First Aid, CPR and AED (automatic external defibrillator). Local fire departments and the American Heart Association (AHA) can also provide training for CPR.

Climbing Safety

There are two primary areas of preparation necessary for a safe climbing inspection:

- Organization
- Inspection Equipment

Figure 2.2.7 Inspection Involving Extensive Climbing

Organization

Organization of the Inspection **-** A good inspection procedure incorporates a climbing strategy that minimizes climbing time. For example, beginning the day with an inspection of a truss span from one bent and finishing at the next bent by lunch time eliminates unproductive climbing across the span.

The inspection procedure needs to have an inspection plan so the inspection team knows where to go, what to do, and what tools are needed to perform the inspection. An organized inspection reduces the chance of the inspectors falling or getting stuck in a position in which they are unable to get down.

Weather conditions are a primary consideration when organizing a climbing inspection. Moderate temperatures and a sunny day are desirable.

Rain conditions warrant postponement of steel bridge inspections, as wet steel is extremely slippery.

After a rainy day, be sure that your boots are free of mud, and use extreme caution in areas where debris accumulation may cause a slippery surface.

Inspection Equipment

The inspection team needs to be well equipped to properly complete their inspection.

Check personal attire for suitability to the job:

- Clothing – proper for climbing activities and temperature.

- Jewelry – Avoid wearing rings, bracelets, and necklaces. In an accident, jewelry can become snagged and cause additional injury.
- Eyeglasses – wear only single lens glasses; do not wear bifocals because split vision impairs ability to climb safely.

Check inspection equipment for proper use and condition.

Ladders

Accidents involving ladders are the most common type of inspection-related accident. Refer to and follow OSHA for rules applicable to stairways and ladders.

In order to use a ladder properly, consider the following:

- Proper ladder length for the job.
- 4 to 1 tilt with blocked and secured bottom (see Figure 2.2.8).
- An assistant for ladders over 25 feet, and making sure the top is tied off.
- Inspecting the ladder, prior to use, for cracked or defective rungs and rails.
- Correct climbing technique using both hands, facing the ladder, and keeping the inspector's center of gravity or belt buckle over the rungs.
- Using a hand line to lift equipment or tools.

Figure 2.2.8 Proper Use of Ladder

Scaffolding

Refer to and follow OSHA for rules applicable to scaffolding. Check scaffolding for the height and load capacity necessary to support the inspection team.

Load tests can be performed on the ground with planned equipment and personnel. Perform a daily inspection for cracks, loose connections, and buckled or weak areas prior to use.

Timber Planks

Never use single planks. Use two or more planks securely cleated together. Securely attach plank ends to their supports. Inspect planks for knots, splits, cracks, and deterioration prior to use.

Inspection Vehicles

Use of platform trucks, bucket trucks, and underbridge inspection vehicles may be necessary to access elements during an inspection (see Figure 2.2.9). Confirm that they are in safe operating condition. Only use such equipment when placed on a firm surface at a slope not exceeding the manufacturer's recommendations. Use extreme caution when operating near traffic.

Figure 2.2.9 Bucket Truck

Catwalks and Travelers

Permanent inspection access devices are ideal. However, be on guard for misalignment and deterioration of elements, such as flooring, hand-hold rods, and cables (see Figure 2.2.10).

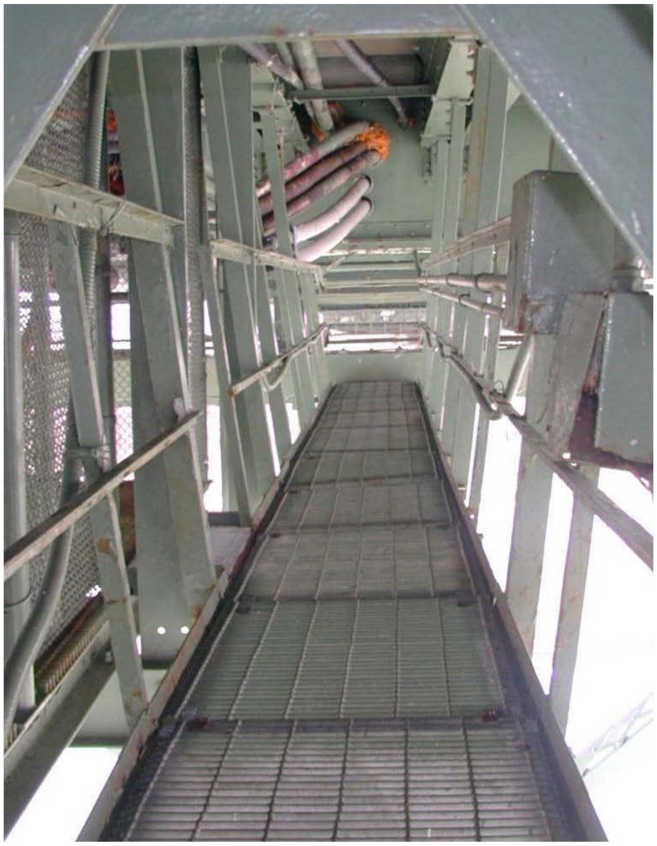

Figure 2.2.10 Inspection Catwalk

Rigging

Be familiar with proper rigging techniques. The support cables need to be at least one-half inch in diameter. The working platform or "stage" need to be at least 20 inches wide. Use a line or tie-off cable separate from the primary rigging.

Use common sense with regard to rigging. Do not blindly trust the people arranging the rigging. Mistakes by riggers can cause life threatening accidents. If a method is unsafe or doubtful, question it and get it changed if necessary. Do not rely on ropes or planks left on the bridge by prior work. They may be rotted or not properly attached.

Figure 2.2.11 Inspection Rigging

Confined Spaces Precautions

Safety Concerns

Inspection of box girder bridges, steel box pier caps, steel arch rings, arch ties, cellular concrete structures, and long culverts is often categorized as confined spaces. Confined space entry is regulated by Occupational Safety and Health Administration (OSHA) and requires proper training, equipment, and permitting.

There are four major concerns when inspecting a confined space:

- Lack of oxygen – an oxygen content above 19% is needed for the inspectors to remain conscious
- Toxic gases – generally produced by work processes such as painting, burning, and welding or by operation of internal combustion engines
- Explosive gases – natural gas, methane, or gasoline vapors may be present naturally or due to leaks
- Lack of light – many confined spaces are totally dark (inspector cannot see any potential hazards such as depressions, drop-offs, or dangerous animals)

Safety Procedures

When inspecting a confined area, use the safety standards prescribed by OSHA and any additional agency or employer requirements. The following is a general description of the basic requirements. Refer to OSHA for specifics.

Pre-entry air tests:

- Test for oxygen with an approved oxygen testing device
- Test for other gases, such as carbon monoxide, hydrogen sulfide, methane, natural gas, and combustible vapors

Mechanical ventilation:

- Pre-entry – Check oxygen and gas levels and verify acceptability for a minimum prescribed time prior to entry.
- During occupancy – Regardless of activity, use continuous ventilation. Test for oxygen and other gases at prescribed intervals during occupancy.

Basic safety procedures:

- Avoid use of flammable liquids in the confined area.
- Position inspection vehicles away from the area entrance to avoid carbon monoxide fumes.
- Perform operations that produce toxic gases "down-wind" of the operator and the inspection team.
- Position gasoline powered generators "down-wind" of operations.
- Carry approved rescue air-breathing apparatus.
- Use adequate lighting with an appropriate backup system and lifelines when entering dark areas, such as box girders and culverts.
- Perform the inspection in pairs, with a third inspector remaining outside of dark or confined areas with means to communicate with inspectors.

Vegetation

Be aware of any vegetation located around any substructures. Poison ivy, oak and sumac are examples of vegetation which can cause skin irritations if touched by someone. Also, it is important to be aware of any tall vegetation which could hide holes in the ground and lead to possible injury if not found. Tall vegetation can also hide other tripping hazards.

Night work

When working at night, it is important to be properly dressed. This is necessary so the inspectors can be more visible by passing motorists. It can be accomplished by wearing a safety vest which has both bright colors and reflectivity. The use of proper temporary traffic control also helps motorists be aware that there are workers ahead.

Working Around Water

Wading

When wading in water, it is important to be aware of any scour holes and be careful not slip or fall on objects in the water. If an inspector slips or steps into a scour hole, their waders can fill with water and drag them under, making swimming impossible. It is also important to wear a life vest while wading to help prevent the inspector from being pulled down if the waders were to fill up with water. It is beneficial for the inspector to carry and use probing rod to locate scour holes and soft stream bed material. Be mindful of potentially dangerous aquatic life.

Drowning

Extensive streambed scour may result in channel depressions. During periods of low flow the depth of water in these holes may be significantly greater than the remainder of the streambed. This could give the inspector the impression that wading is safe. It is advisable that the inspector use a probing rod to check water depth wherever he/she plans to walk.

Storms may generate high flows in culverts very quickly. This creates a dangerous situation for the inspectors. It is not uncommon for culverts to carry peak flow long before a storm reaches the culvert site. Be cautious whenever storms appear imminent.

Underwater

When performing an underwater inspection, particularly in low visibility and/or high current situations, use extreme care and be sure to watch for drift and debris at any height in the water. See Topic 13.3.2, for additional safety concerns.

Culverts

There are several hazards that can be encountered when performing a culvert inspection. Being aware of these situations and exercising proper precautions protect the inspector from these dangerous and potentially life threatening hazards. The following are some of the hazardous conditions an inspector may encounter.

- Inadequate Ventilation
- Drowning
- Quick Sand Conditions at the Outlet
- Potentially dangerous wildlife

Inadequate Ventilation

Culverts with inadequate ventilation can develop low oxygen levels or high concentrations of toxic and/or explosive gases. This is a big concern when one culvert end may be blocked or inspection is being performed on a long culvert.

If air quality is suspect, perform tests to determine the concentration of gases. Testing devices may be as simple as badges worn by inspectors that change colors when in the presence of a particular gas. Devices may also be sophisticated instruments that measure the concentration of several gases.

Observe confined space entry requirements when inspecting a long culvert or any culvert with restricted ventilation.

Quicksand Conditions at the Outlet

Quicksand conditions can occur in sandy streambeds, especially at the outlet end of the culvert. Be aware of these conditions and proceed with caution in geographical areas known to have these problems.

Working Around Traffic

Do not obstruct traffic during bad weather. Avoid the inspection of the top of concrete decks during or just after it rains (see Figure 2.2.12).

Figure 2.2.12 Inclement Weather Causing Slippery Bridge Members and Poor Visibility for Motorists

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Topic 2.3 Temporary Traffic Control

2.3.1 Introduction

Bridge inspection usually only requires traffic control procedures for a relatively short term closure Long term closures for construction activity which use concrete barriers are not included in this topic.

Figure 2.3.1 Temporary Traffic Control Operation

Bridge inspection, like construction and maintenance activities on bridges, often presents motorists with unexpected and unusual situations. Most state agencies have adopted the *Federal Manual on Uniform Traffic Control Devices for Streets and Highways* (*MUTCD*). Some states and local jurisdictions, however, issue their own standard manuals or drawings.

When working in an area exposed to traffic, check and follow the existing agency standards. These standards prescribe the minimum procedures for a number of typical applications and the proper use of standard temporary traffic control devices such as cones, signs, and flashing arrow-boards (see Figure 2.3.1). Sometimes after initial installation, temporary traffic control may need revised to provide adequate protection to motorists, pedestrians or inspectors.

2.3.2 Philosophy and Fundamental Principles

Temporary traffic control devices used on street and highway construction or maintenance work need to conform to the applicable standards of the *MUTCD* and the agency.

Minimize inspection time to reduce exposure to potential hazards without compromising the thoroughness of the inspection. Principles and procedures which have been shown to enhance the safety of motorists, pedestrians, and bridge inspectors in the vicinity of work areas include the following:

Inform the Motorists

Traffic safety in work zones is an integral and high priority element of every inspection project, from the planning stage to performance of the inspection. Keep in mind the safety of the motorist, pedestrian, and worker.

The basic safety principles governing the design of temporary traffic control for roadways and roadsides, govern the design of inspection sites. The goal is to route traffic through such areas with geometrics and temporary traffic control devices comparable to those for normal highway situations. Clearly communicate to the driver the notice of work site locations and guidance through these sites.

A temporary traffic control plan, in detail appropriate to the complexity of the work project, is prepared and understood by the responsible parties before the site is occupied. The official trained in safe traffic control practices approves any changes in the temporary traffic control plan.

Control The Motorists

Inhibit traffic movement as little as practical. Design temporary traffic control in work sites on the assumption that motorists only reduce their speeds if they clearly perceive a need to do so. Avoid reducing the speed zoning as much as practical.

The objective is a traffic control plan that uses a variety of temporary traffic control measures and devices in whatever combination necessary to assure smooth, safe vehicular movement past the work area and at the same time provide safety for the equipment and the workers on the job. Avoid frequent and abrupt changes in geometrics, such as lane narrowing, dropped lanes, or main roadway transitions that require rapid maneuvers.

Make provisions for the safe operation of work vehicles, particularly on high speed, high volume roadways. This includes the use of roof mounted flashing lights or flashers when entering or leaving the work zone. This also includes considering the number of lanes that can be closed at one time for an operation. While it might be most cost efficient to inspect the entire floor system from left to right, temporary traffic control may dictate working partial width, a few stringers at a time.

Provide a Clearly Marked Path

A good traffic control plan provides safe and efficient movement of motorists and pedestrians and the protection of bridge inspectors at work areas.

Provide adequate warning, delineation, and channelization to assure the motorist positive guidance in advance of and through the work area. Use proper signing and other devices which are effective under varying conditions of light and weather.

The maintenance of roadside safety requires constant attention during the life of the work because of the potential increase in hazards. Remove temporary traffic control devices immediately when no longer needed.

To accommodate run-off-the-road incidents, disabled vehicles or other emergency situations, it is desirable to provide an unencumbered roadside recovery area that is as wide as practical.

Accomplish the channelization of traffic by the use of cones, barricades, and other lightweight devices which yield when hit by errant vehicles.

Store equipment and materials in such a manner as not to be vulnerable to run-off-the-road vehicle impact, whenever practical. Also, provide adequate attenuation devices when safe storage is not available.

2.3.3 Inspector Safety Practices

Work Zone

Traffic represents as great, or even greater, threat to the inspector's safety than climbing high bridges. The work zone is intended to be a safe haven from traffic so the inspectors can concentrate on doing their jobs.

As such, the work zone needs to be clearly marked so as to guide the motorist around it and, insofar as possible, prevent errant vehicles from entering (see Figure 2.3.2). To minimize traffic disruption, the work zone needs to be as compact as possible, but wide enough and long enough to permit access to the area to be inspected and allow for safe movement of workers and equipment. The end of the work zone is to be clearly signed as a courtesy to the motorist.

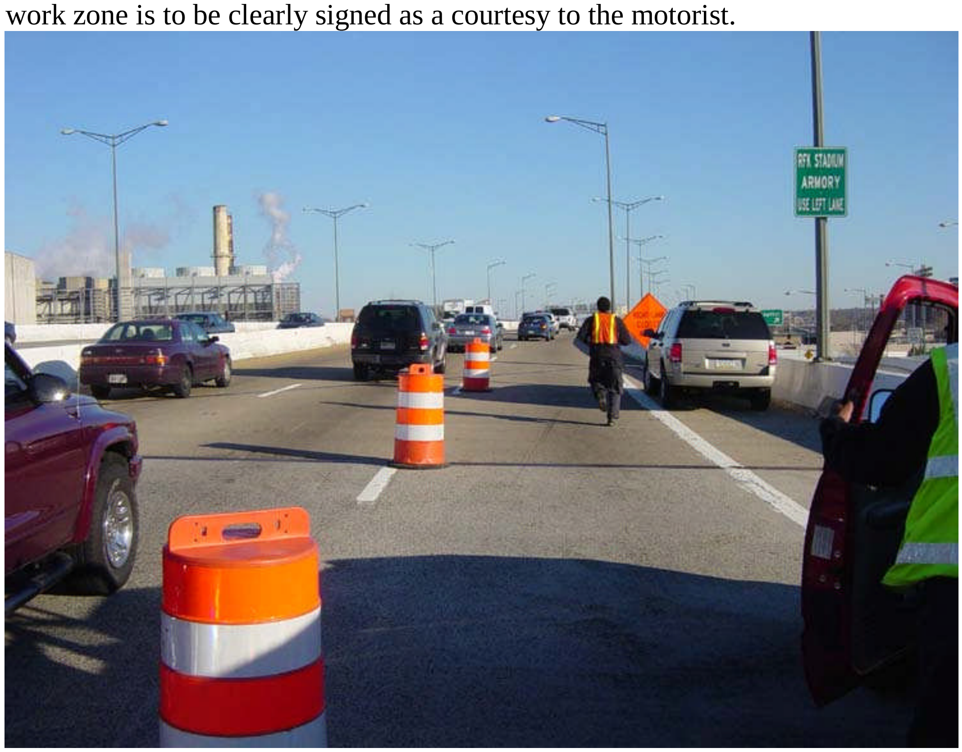

Figure 2.3.2 Work Zone

Vehicles and Equipment

Inspection vehicles and equipment need to be made visible to the motorists with flashing marker lights or arrow boards as appropriate (see Figure 2.3.3).

Use roof mounted flashing lights or flashers on vehicles entering and exiting the work zone to distinguish them from other motorists' vehicles. Also, vehicles are to use extreme caution when moving in and out of the work zone. Allow motorists ample time to react to the vehicle's movements.

Figure 2.3.3 Inspection Vehicles with Flashing Light

Workers

Individuals in a work zone are to wear approved safety vests and hard hats for visibility and identification. They also help make the inspector look "official" to the public. Also, it is important for the inspector to stay within the work zone for their own safety.

2.3.4 Principles of Temporary Traffic Control Devices

Each bridge inspection project is different and has traffic concerns that are unique to that location. Selection of the proper temporary traffic control devices for each location is dependent upon many factors. Though there are several different types of temporary traffic control devices, there are some basic principles for efficient temporary traffic control devices:

1. Temporary traffic control devices are to be visible and attention getting. Devices in good condition are preferred.

   - Bright colors make devices easier for motorists to see. Standard colors are orange and white (*MUTCD*).
   - Signs that are legible and color distinguishable at night as well as during the day. Nighttime sign visibility is provided through retroreflectivity, which is accomplished by spherical glass beads or prismatic reflectors in the sign material, or illumination.
   - Properly sized for the roadway so they can be seen by the motorists.

2. Temporary traffic control devices are to give clear direction.

3. Temporary traffic control devices are to command respect and be official (*MUTCD*). These devices need to look professional and be geared to the class of highway, speeds and traffic involved. Haphazard traffic control gives the public a bad perception of the rest of the project as well.

   State agencies have been mandated to adopt the Federal *MUTCD*. When working in an area exposed to traffic, check and follow the agency standards. These standards prescribe the minimum methods for a number of typical applications and the proper use of standard traffic control devices.

4. Temporary traffic control devices are to elicit the proper response at the proper time.

   - The decision process includes the classical chain of sensing, perceiving, analyzing, deciding, and responding.
   - The average perception-reaction time of a driver is 2.5 seconds. At 60 mph, the 2.5 seconds translates to 220 feet. Additional time and distance is required for a specific action taken such as “hitting the brakes”.
   - Temporary traffic control accommodates a wide range of vehicles (from small compact cars to large combination tractor-trailers) and driver skills, which may be impaired by alcohol, drugs, drowsiness, or use of cell phones.

   Advance warning is essential to get the right response from drivers. The *MUTCD* provides guidance on the positioning of advance warning signs for specific traffic control applications.

These basic principles for temporary traffic control devices have been factored into the various agencies' procedures for work area traffic control. These procedures represent efforts by trained people. Do not change traffic patterns without consulting the *MUTCD*, agency standards or traffic control personnel.

2.3.5 Types of Temporary Traffic Control Devices

Signs

Types of temporary traffic control signs include the following:

- Regulatory – Inform motorists of traffic laws or regulations and indicate the applicability of legal requirements that are not apparent. These signs are authorized by the public agency or official having jurisdiction. Examples include "Speed Limit", "DO NOT PASS", which may require special authority (see Figure 2.3.4).
- Warning – Notify road users of specific situations or conditions on or adjacent to a roadway that might not be apparent. They may be used by themselves or in combination with other advance warning signs. Examples include "Bridge Inspection", "Work Area Ahead", and "Slow" messages (see Figure 2.3.5).
- Guide Signs - Directional and destination signs that provide motorists with information to help them through a temporary traffic control zone. They are not used for bridge inspection traffic control unless a detour is established (see Figure 2.3.6).
- Arrow boards – Used to advise approaching motorists of a lane closure along major multi-lane roadways in situations involving heavy traffic volumes, and/or limited sight distances, or at other location and under other conditions where road users are less likely to expect such lane closures. Use them in combination with the appropriate signing, channelization devices and other temporary traffic control devices (see Figure 2.3.7)
- Changeable message signs – Provide motorists with the notice of unexpected situations. They may present the motorist with complex messages, important information, and real time conditions.(see Figure 2.3.8)

Figure 2.3.4 Regulatory Sign

Figure 2.3.5 Warning Sign

Figure 2.3.6 Examples of Guide Signs

Figure 2.3.7 Arrow Board

Figure 2.3.8 Changeable Message Sign

Channelizing Devices

The functions of channelizing devices are to warn and alert drivers of hazards created by construction or maintenance activities in or near the traveled way and to guide and direct drivers safely past the hazards.

Devices used for channelization provide a smooth and gradual transition in moving traffic from one lane to another, onto a bypass or detour, or in reducing the width of the traveled way. They need to be constructed so as not to inflict any undue damage to a vehicle that inadvertently strikes them.

Channelizing devices are elements in a total system of traffic control devices for use in highway construction and maintenance operations. These elements are preceded by a subsystem of warning devices that are adequate in size, number, and placement for the type of highway on which the work is to take place.

Typical channelizing devices include the following:

- Cones – Used to channelize motorists, divide opposing traffic lanes, divide lanes when two or more lanes are kept open in the same direction, and delineate short duration maintenance and utility work including bridge inspections. Predominately orange and made of material that can be struck without causing damage to the impacting vehicle and are primarily used during the day. Consult the appropriate governing agency and *MUTCD* to determine the specific requirements for cones, such as size and features, which depend on the application. (see Figure 2.3.9) Drums – Used for road user warning or channelization and are constructed from lightweight, deformable materials. They provide the motorist a highly visible and respectable warning of upcoming conditions. For the bridge inspector, drums are portable enough to be shifted place to place within a work zone to accommodate changing conditions (see Figure 2.3.10).

- Tubular markers – Predominately orange and made of a material that can be struck without causing damage to an impacting vehicle. Consult the appropriate governing agency and *MUTCD* to determine the specific requirements for tubular markers, which depends on the application. These devices are not as common for bridge inspection as cones (see Figure 2.3.11).

- Vertical panels – May be used to channelize vehicular traffic, divide opposing lanes, or replace portable lightweight barricades. The diagonal orange and white stripes pointing downward indicate the direction motorists are to pass (see Figure 2.3.12).

- Temporary traffic barrier – Not considered temporary traffic barriers by themselves. When placed in a position identical to a line of channelizing devices and marked and/or equipped with appropriate channelization features to provide guidance, they serve as traffic control devices. Not only do they serve to direct motorists, but they also protect the workers. These are seldom applicable to bridge inspection due to the short duration of the work (see Figure 2.3.13).

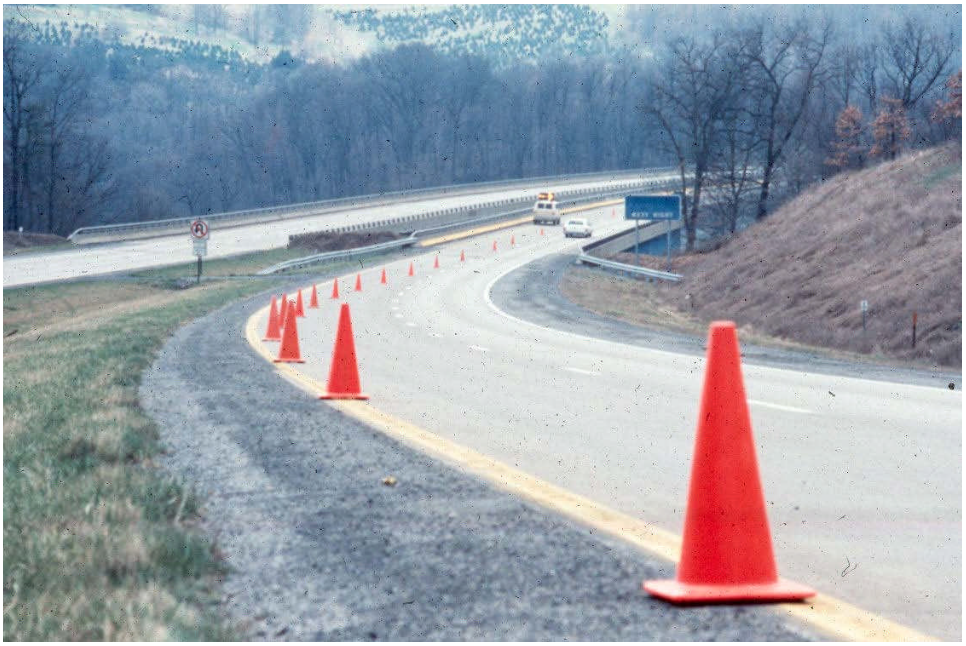

Figure 2.3.9 Cones

Figure 2.3.10 Drums

Figure 2.3.11 Tubular Marker

Figure 2.3.12 Vertical Panel

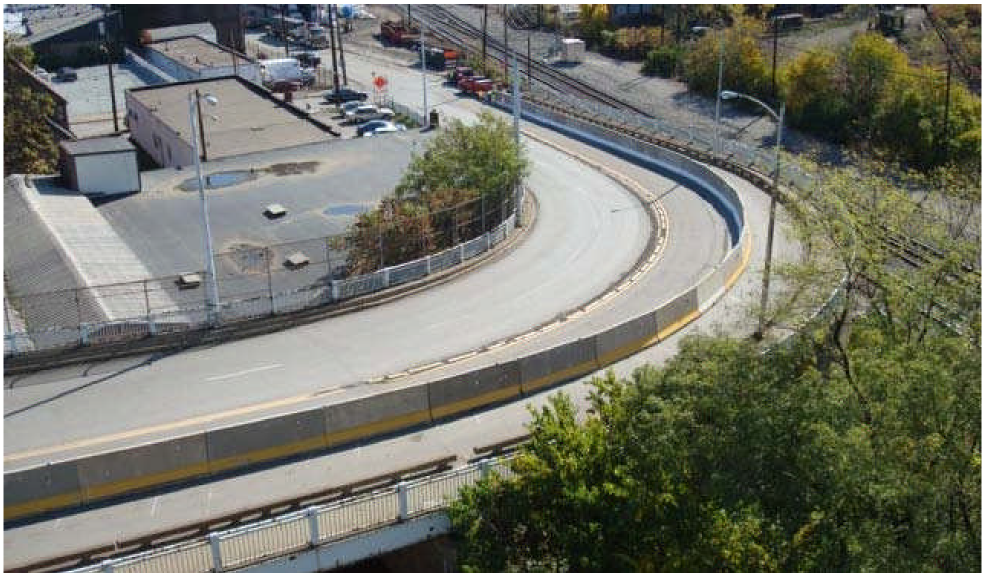

Figure 2.3.13 Temporary Traffic Barriers

Lighting Devices

Another type of control device is lighting. Lighting devices are used to supplement retroreflectorized signs, barriers, and channelizing devices. Examples of lighting include the following:

- Warning lights **-** Attached to signs or other devices to attract attention or for night visibility. Flashers are commonly placed on maintenance and inspection vehicles, as well as drums, vertical posts, and other channelization devices (see Figure 2.3.14).
- Floodlights – Inspection, utility, maintenance, or construction activities are sometimes conducted during nighttime periods when vehicular traffic volumes are lower. Bridge inspections may be conducted during these hours on high volume roadways to avoid additional congestion from daytime traffic. During these periods, floodlights used to illuminate the work area, equipment crossings, and other areas.

Figure 2.3.14 Warning Lights

Flaggers

A number of hand signalizing devices, such as STOP/SLOW paddles, flashing lights, flashlights, and red flags, are used to control traffic through work zones. The sign paddle bearing the clear messages “STOP" or "SLOW" provides motorists with more positive guidance than flags and is generally the primary hand signaling device. If permitted by the agency, limit flag use to emergency situations and at spot locations that can best be controlled by a single flagger.

Since flaggers are responsible for human safety and make the greatest number of public contacts of any inspection personnel, it is important that qualified personnel be selected. The following are qualifications for a flagger:

- Ability to receive and communicate specific instructions clearly, firmly, and courteously
- Ability to move and maneuver quickly in order to avoid danger from errant vehicles
- Ability to control signaling devices (such as paddles and flags) in order to provide clear and positive guidance to drivers approaching a TTC zone in frequently changing situations
- Ability to understand and apply safe traffic control practices, sometimes in stressful or emergency situations
- Ability to recognize dangerous traffic situations and warn workers in sufficient time to avoid injury

For daytime and nighttime activity, flaggers shall wear high-visibility safety apparel that meets Performance Class 2 or 3 requirements of the ANSI/ISEA 107-2004 publication titled *American National Standard for High-Visibility Apparel and Headwear*. The apparel background (outer) material shall be fluorescent orange-red, fluorescent yellow-green, or a combination of the two as defined in the ANSI standard. The retroreflective material shall be orange, yellow, white, silver, yellow-green, or a fluorescent version of these colors, and shall be visible at a minimum distance of 1,000 feet. The retroreflective safety apparel shall be designed to clearly identify the wearer as a person.

For nighttime activity, high-visibility safety apparel that meets the Performance Class 3 requirements of the ANSI/ISEA 107-2004 publication should be considered for flagger wear.

Flaggers are provided at work sites to stop traffic intermittently as necessitated by work progress. They also maintain continuous traffic past a work site at reduced speeds to help protect the work crew. For both of these functions, the flagger is always clearly visible to approaching traffic for a distance sufficient to permit proper response by the motorist to the flagging instructions and to permit traffic to reduce speed before entering the work site. In positioning flaggers, consideration is given to maintaining color contrast between the work area background and the flagger's protective garments.

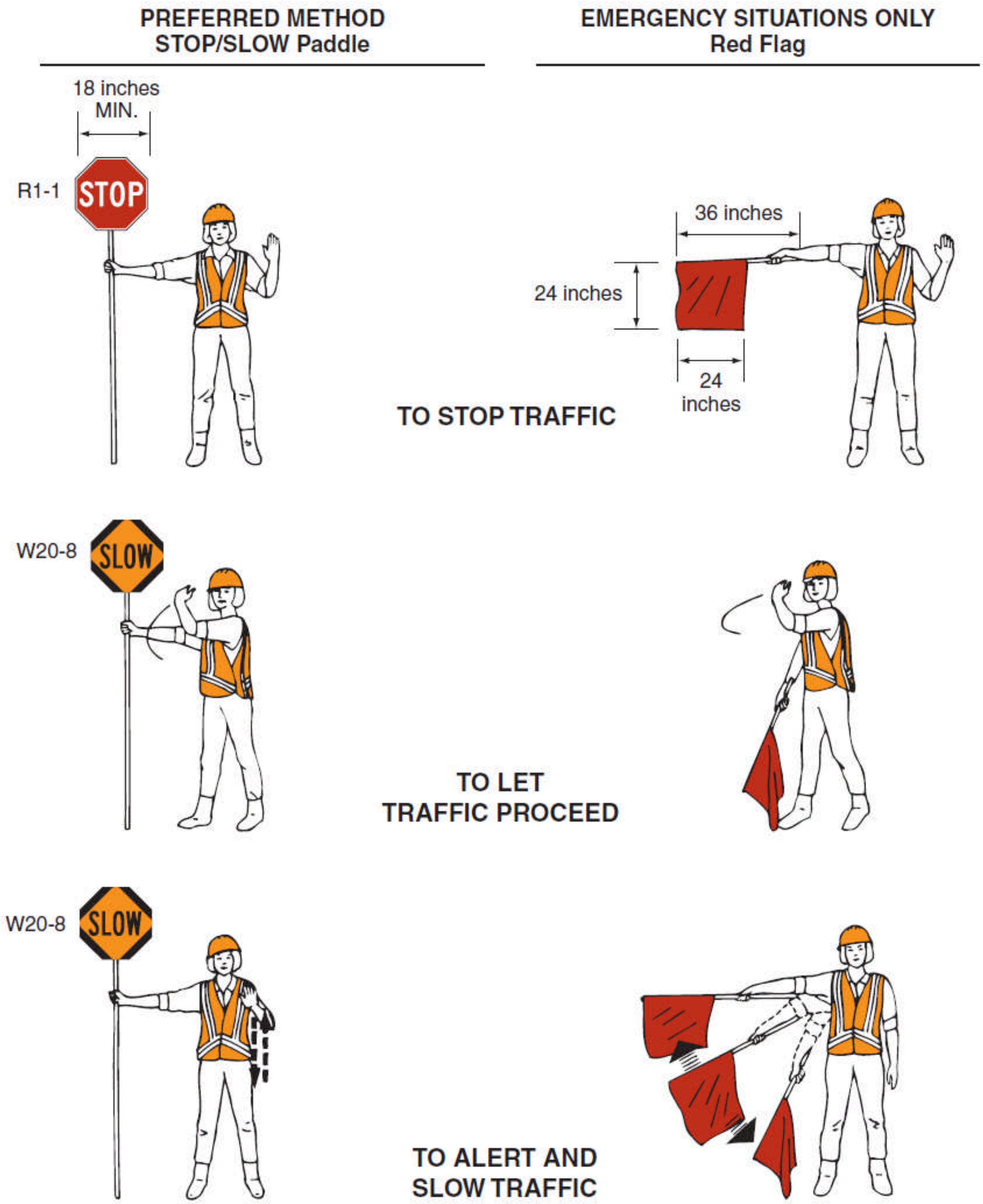

Figure 2.3.15 Use of Hand Signaling Devices by Flagger (from *Manual on Uniform Traffic Control Devices (MUTCD)*)

Use the following methods of signaling with sign paddles (see Figure 2.3.15):

- To stop traffic, the flagger faces the motorists and aims the STOP paddle face toward the traffic in a stationary position with the arm extended horizontally away from the body. The free arm is held with the palm of the hand above shoulder level toward approaching traffic.

- To direct traffic to proceed, the flagger faces the motorists with the SLOW paddle face aimed toward the traffic in a stationary position with the arm extended horizontally away from the body. The flagger motions with the free hand for traffic to proceed.
- To alert or slow traffic, the flagger faces the motorists with the SLOW paddle face aimed toward the motorists in a stationary position with the arm extended horizontally away from the body.

Use the following methods of signaling with a flag (see Figure 2.3.15):

- To stop traffic, the flagger faces the motorists and extends the flag staff horizontally across the traffic lane in a stationary position so that the full area of the flag is visibly hanging below the staff. The free arm may be held with the palm of the hand above shoulder level toward approaching traffic.
- To direct stopped traffic to proceed, the flagger faces the motorists with the flag and arm lowered from the view of the drivers, and motions with the free hand for road users to proceed. Flags are not to be used to signal road users to proceed.
- To alert or slow traffic, the flagger faces the motorists and slowly waves the flag in a sweeping motion of the extended arm from shoulder level to straight down without raising the arm above a horizontal position. The flagger keeps the free hand down.

For flagging traffic at night, lights approved by the appropriate highway authority or reflectorized sign paddles or reflectorized flags are used.

Whenever practicable, the flagger advises the motorist of the reason for the delay and the approximate period that traffic is halted. Flaggers and operators of machinery or trucks are made to understand that every reasonable effort is to be made to allow the driving public the right-of-way and prevent excessive delays.

Locate flagger stations far enough in advance of the work site so that approaching traffic have sufficient distance to reduce speed before entering the project. This distance is related to the approach speed and physical conditions at the site (see Figure 2.3.16). In urban areas, where speeds are low and streets are closely spaced, the distance is decreased.

Speed*	Distance
20 mph	115 feet
25 mph	155 feet
30 mph	200 feet
35 mph	250 feet
40 mph	305 feet
45 mph	360 feet
50 mph	425 feet
55 mph	495 feet
60 mph	570 feet
65 mph	645 feet
70 mph	730 feet
75 mph	820 feet

* Posted speed, off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed

Figure 2.3.16 Stopping Sight Distance as a Function of Speed (from *Manual on Uniform Traffic Control Devices (MUTCD)*)

The flaggers stand either on the shoulder adjacent to the traffic being controlled or in the barricaded lane (see Figure 2.3.17). At a spot obstruction, a position may have to be taken on the shoulder opposite the barricaded section to operate effectively. Under no circumstances is a flagger to stand in the lane being used by moving traffic. The flagger always is clearly visible to approaching traffic. For this reason, the flagger has to stand alone, never permitting a group of workers to congregate around the flagger station. The flagger is stationed sufficiently in advance of the work force to warn them of approaching danger, such as out-of-control vehicles.

Figure 2.3.17 Flagger with Stop/Slow Paddle

Adequately protect flagger stations and precede them by proper advance warning signs. At night, adequately illuminate flagger stations.

At short lane closures where adequate sight distance is available for the safe handling of traffic, the use of one flagger may be sufficient.

One-lane, Two-way Traffic Control

Where traffic in both directions use a single lane for a limited distance, make provisions for alternate one-way movement to pass traffic through the constricted work zone. At a spot obstruction, such as a short bridge, the movement may be self-regulating. However, where the one-lane section is of any length, there needs to be some means of coordinating movements at each end so that vehicles are not simultaneously moving in opposite directions in the work zone and so that delays are not excessive at either end. Chose control points at each end of the route so as to permit easy passing of opposing lines of vehicles.

Alternate one-lane, two-way temporary traffic control may be facilitated by the following means:

- Flagger control
- Flag transfer
- Pilot car
- Temporary traffic signals
- Stop or yield control

Flagger control is usually used for bridge inspection, where the one-lane section is short enough so that each end is visible from the other end. Traffic may be controlled by means of a flagger at each end of the section. Designate one of the two as the chief flagger to coordinate movement. They are able to communicate with each other verbally or by means of signals. These signals are not such as to be mistaken for flagging signals.

Where the end of a one-lane, two-way section is not visible from the other end, the flaggers may maintain contact by means of radio or cell telephones. So that a flagger may know when to allow traffic to proceed into the section, the last vehicle from the opposite direction can be identified by description or license.

Shadow Vehicles

Shadow Vehicles with truck mounted attenuators (TMAs) are used to prevent vehicles from entering the work zone if the motorist drifts into the lane closure. Each agency has its own specific requirements, but a shadow vehicle is generally employed any time a shoulder or travel lane is occupied by workers or equipment. Shadow vehicles are equipped with appropriate lights and warning signs which may be used for stationary operations for additional protection of occupants and vehicles within the work zone.

- The requirements for the truck itself vary, but high visibility with flashing lights, a striped panel, or an arrow board on the rear of a vehicle of a specified minimum weight is generally required.
- Some agencies recommend the use of truck or trailer mounted attenuators (see Figure 2.3.18). This protects the motorist, as well as the inspectors.

Figure 2.3.18 Shadow Vehicle with Attenuator

Police Assistance

On some inspection projects, police assistance may be helpful and even required. The presence of a patrol car aids in slowing and controlling the motorists. At a signalized intersection near a job site, a police officer may be required to ensure traffic flows properly and smoothly.

Specialized Traffic Crews

Some states have specialized traffic crews for high traffic roads. They are used due to their specialized training, allowing for a safer work environment.

2.3.6 Public Safety

Since the fundamental goal of bridge inspection is to enhance public safety, it makes little sense to endanger that same public by inadequate traffic control measures. Temporary traffic control does take time, money, and effort. It is, however, a necessary part of the business of bridge inspection.

In the broadest sense, the motorist is the customer of everyone in the transportation industry. Like everyone else, bridge inspectors need to treat customers well by inconveniencing them as little as possible and protecting their safety. This means providing well thought out, clear, and effective traffic control measures.

Also consider pedestrians. If a walkway is to be closed, be sure it is properly signed and barricaded. Indicate an alternate route for the pedestrian, if necessary through or preferably around the work zone.

Training

Each person whose actions affect inspection, maintenance and construction zone safety (from the upper-level management personnel to construction and maintenance field personnel) need training appropriate to the job decisions each individual is required to make. Only those individuals who are qualified by means of adequate training in safe traffic control practices and have a basic understanding of the principles established by applicable guidelines and regulations supervise the selection, placement, and maintenance of temporary traffic control devices in bridge safety inspection, maintenance, and construction areas.

Responsibility

Legally and morally, it is the inspector's responsibility to follow the regulations and guidelines of the agency having jurisdiction.

The primary goal of good traffic control is safety – safety of the workers, motorists, and pedestrians. If there is an accident, the secondary goal is to be able to defend yourself and your employer. Accidents bring lawsuits. Lawsuits bring inquiries about who is responsible. Temporary traffic control is one thing that is investigated. Anything not done in accordance with published standards, regulations, and directives could bring blame upon whoever violated them. Being blamed for an accident is expensive and damaging.

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Chapter 2

Safety Fundamentals
for Bridge Inspectors

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Topic 2.4 Inspection Equipment

2.4.1 Equipment Necessity

Several factors play a role in what type of equipment is needed for an inspection. Bridge location and type are two of the main factors in determining equipment needs. If the bridge is located over water, certain pieces of equipment such as life jackets and boats are necessary to have. Also, if the bridge is made of timber, then specific pieces of equipment like timber boring tools and ice picks are needed, whereas they are not necessary on a steel or concrete bridge. Another factor influencing equipment needs is the type of inspection. It is therefore important to review every facet about the bridge before beginning an inspection. A few minutes spent reviewing the bridge files and making a list of the necessary equipment can save hours of wasted inspection time in the field if the inspectors do not have the required equipment.

2.4.2 Standard Tools

In order for the inspector to perform an accurate and comprehensive inspection, the proper tools are to be used. Standard tools that an inspector uses at the bridge site can be grouped into seven basic categories:

- Tools for cleaning (see Figure 2.4.1)
- Tools for inspection (see Figure 2.4.2)
- Tools for visual aid (see Figure 2.4.3)
- Tools for measuring (see Figure 2.4.4)
- Tools for documentation
- Tools for access
- Miscellaneous equipment

Figure 2.4.1 Tools for Cleaning

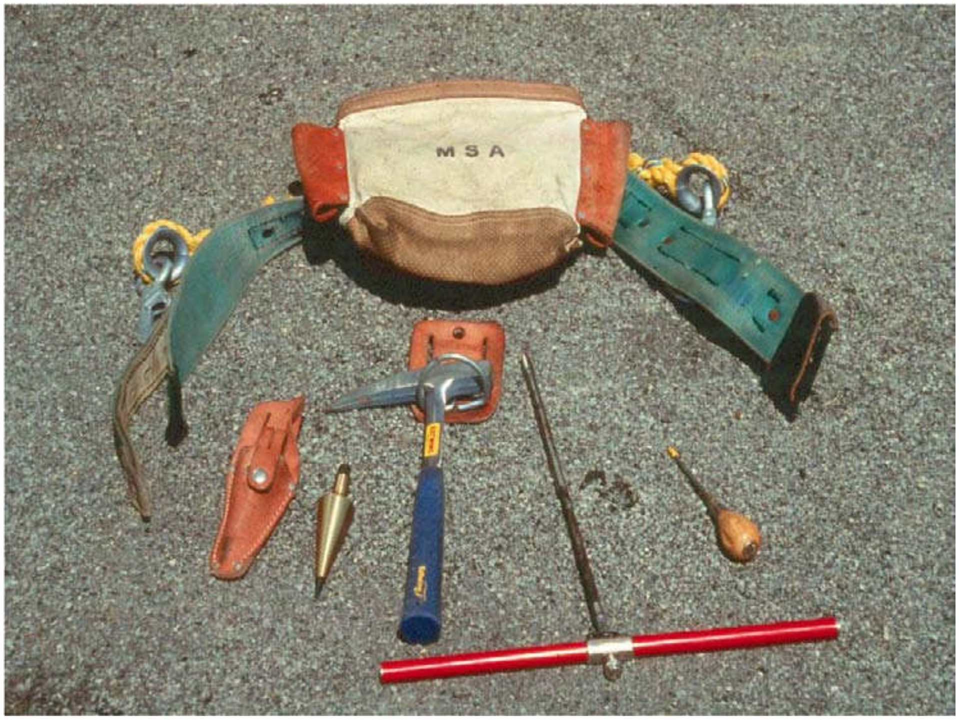

Figure 2.4.2 Tools for Inspection

Figure 2.4.3 Tools for Visual Aid

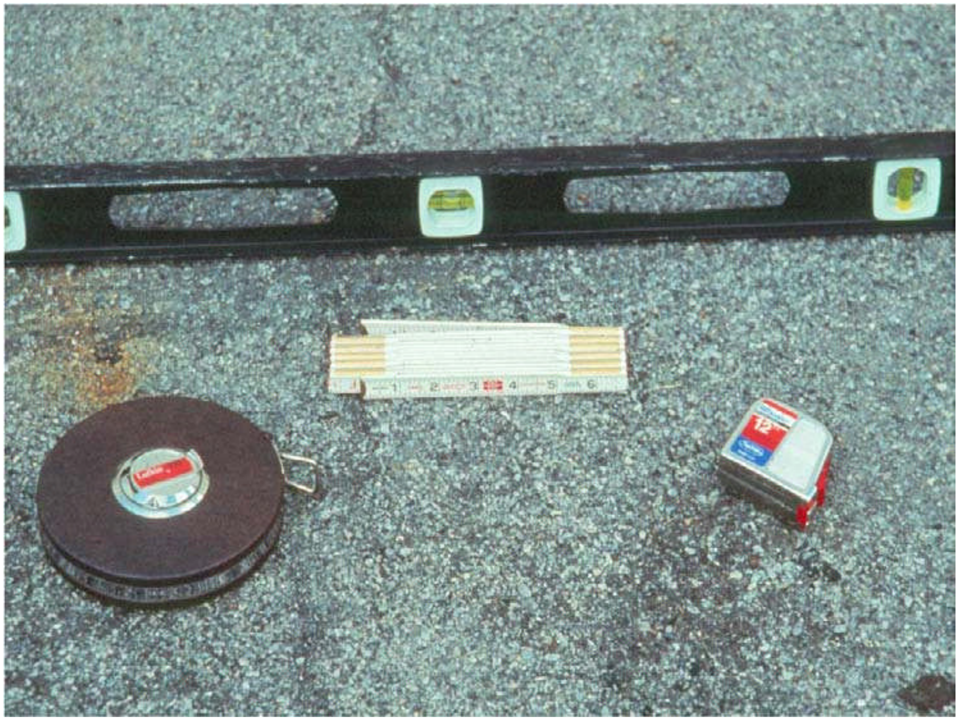

Figure 2.4.4 Tools for Measuring

Tools for Cleaning

Tools for cleaning include:

- Wisk broom - used for removing loose dirt and debris
- Wire brush - used for removing loose paint and corrosion from steel members
- Scrapers - used for removing corrosion or growth from member surfaces
- Flat bladed screwdriver - used for general cleaning and probing
- Shovel - used for removing dirt and debris from bearing areas

Tools for Inspection

Tools for inspection include:

- Pocket knife - used for general duty
- Ice pick - used for surface examination of timber members
- Hand brace and bits - used for boring suspect areas of timber members
- Timber boring tools - used for internal examination of timber members
- Chipping hammer with leather holder (16 ounce geologist's pick) - used for loosening dirt and rust scale, sounding concrete, and checking for sheared or loose fasteners
- Plumb bob - used to measure vertical alignment of a superstructure or substructure member
- Tool belt with tool pouch - used for convenient holding and access of small tools
- Chain drag - used to identify areas of delamination on concrete decks
- Range pole / probe - used for probing for scour holes

Tools for Visual Aid

Tools for visual aid include:

- Binoculars - used to preview areas prior to inspection activity and for examination at distances
- Flashlight - used for illuminating dark areas
- Lighted magnifying glass (e.g., five power and 10 power) - used for close examination of cracks and areas prone to cracking
- Inspection mirrors - used for inspection of inaccessible areas (e.g., underside of deck joints)
- Dye penetrant - used for identifying cracks and their lengths

Tools for Measuring

Tools for measuring include:

- Pocket tape (six foot rule) - used to measure deficiencies and member and joint dimensions
- 25 foot and 100 foot tape - used for measuring component dimensions
- Calipers - used for measuring the thickness of a member beyond an exposed edge
- Optical crack gauge - used for precise measurements of crack widths
- Paint film gauge - used for checking paint thickness
- Tiltmeter and protractor - used for determining tilting substructures and for measuring the angle of bearing tilt
- Thermometer - used for measuring ambient air temperature and superstructure temperature
- Four foot carpenter's level - used for measuring deck cross-slopes, approach pavement settlement and substructure alignment
- D-Meter (ultrasonic thickness gauge) - used for accurate measurements of steel thickness
- Electronic Distance Meter (EDM) - used for accurate measurements of span lengths and clearances when access is a problem
- Line level and string line

Tools for Documentation

Tools for documentation include:

- Inspection forms, clipboard, and pencil - used for record keeping for most bridges
- Note books - used for additional record keeping for complex structures
- Straight edge - used for drawing readable sketches
- Digital camera - used to provide digital images of deficiencies which can be downloaded and e-mailed for instant assessment
- Chalk, kiel, paint sticks, or markers - used for member and defect identification for improved organization and photo documentation
- Center punch - used for applying reference marks to steel members for movement documentation (e.g., bearing tilt and joint openings)
- "P-K" nails - Parker Kalon masonry survey nails used for establishing a reference point necessary for movement documentation of substructures and large cracks

Tools for Access

Some common tools for access include:

- Ladders - used for substructures and various areas of the superstructure
- Boat - used for soundings and inspection; safety for over water work
- Rope - used to aid in climbing
- Waders - used for shallow streams

Tools for access are described in further detail in Topic 2.5.2.

Miscellaneous Equipment

Miscellaneous equipment includes:

- "C"-clamps - used to provide a "third hand" when taking difficult measurements
- Penetrating oil - aids removal of fasteners, lock nuts, and pin caps when necessary
- Insect repellent - reduces attack by mosquitoes, ticks, and chiggers
- Wasp and hornet killer - used to eliminate nests to permit inspection
- First-aid kit - used for small cuts, snake bites, and bee stings
- Dust masks or respirators - used to protect against inhalation in dusty condition or work around pigeon droppings
- Coveralls - used to protect clothing and skin against sharp edges while inspecting
- Life jacket - used for safety over water
- Cell phone - used to call in emergencies
- Toilet paper - used for other "emergencies" (better safe than sorry)

2.4.3 Special Equipment

For the routine inspection of a common bridge, special equipment is usually not necessary. However, with some structures, special inspection activities require special tools. These special activities are often subcontracted by the agency responsible for the bridge. These inspectors are familiar with the special equipment and its application.

Survey Equipment

Special circumstances may require the use of a transit, a level, an incremental rod, or other survey equipment. This equipment can be used to establish a component's exact location relative to other components, as well as an established reference point.

Non-destructive Evaluation Equipment

Non-destructive evaluation (NDE) is the in-place examination of a material for structural integrity without damaging the material. NDE equipment allows the inspector to "see" inside a bridge member and assess deficiencies that may not be visible with the naked eye. Generally, a trained technician is necessary to conduct NDE and interpret their results. For a more detailed description of NDE, refer to Topics 15.1.2, 15.2.2, and 15.3.2.

Underwater Inspection Equipment

Underwater inspection is the examination of substructure units and the channel below the water line. When the waterway is shallow, underwater inspection can be performed above water with a simple probe. Probing can be performed using a range pole, piece of reinforcing steel, a survey rod, a folding rule, or even a tree limb.

When the waterway is deep, an underwater inspection is performed by trained divers. This requires special diving equipment that includes a working platform, fathometer, air supply systems, radio communication, and sounding equipment. Refer to Topic 13.3 for a more detailed description of underwater inspection equipment.

Other Special Equipment

An inspection may require special equipment to prepare the bridge prior to the inspection. Such special equipment includes:

- Air-water jet equipment - used to clean surfaces of dirt and debris
- Sand or shot blasting equipment - used to clean steel surfaces to bare metal
- Burning, drilling, and grinding equipment

2.4.4 Recent Developments in Equipment

In addition to the standard and special equipment listed previously, there are new equipment and technology available to aid in bridge inspection. The developments in various types of advanced testing methods are described in Topics 15.1, 15.2 and 15.3. The following information represents some of the advances in inspection tools and data collection.

Rotary Percussion

Rotary percussion is a method whereby a uniform tapping is produced by rolling a gear-toothed wheel on a concrete member to detect the presence of concrete deficiencies. This allows for the inspection of overhead and vertical surfaces to be done quickly, and is similar to using a chain drag for the inspection of horizontal surfaces. Advantages of rotary percussion testing tools include the ability to detect near-surface delaminations, quickness of testing, low equipment cost, relatively low level of user's skill required, and low sensitivity to the surroundings.

Figure 2.4.5 Rotary Percussion

Scour Measurement

There is a specialized device used to measure the depth of scour during flood flows. It consists of a depth finder mounted on a water ski. The use of a water ski allows for depth readings to be taken in extremely fast flowing water and also allows for excellent maneuverability of the depth finder into locations under a bridge.

Scour Monitoring

Side Scan Sonar

Side scan sonar is a specialized application of basic sonar theory. Although common for oceanographic and hydrographic survey work, side scan sonar has not been widely utilized for portable scour monitoring. Side scan sonar transmits a specially shaped acoustic beam to either side of the support craft, which allows for one of the most accurate systems for imaging large areas of channel bottom. A disadvantage to this method is that most side scan systems do not provide depth information.

Multi-beam Sonar

Multi-beam systems provide similar fan-shaped coverage to side scan systems, but output depths instead of images. Multi-beam sonar is typically attached to the surface vessel rather than being towed.

Scanning Sonar

Scanning sonar operates by rotating the transducer assembly, emitting a beam while the assembly (or "head") moves in an arc. Scanning sonar is performed by moving the transducer assembly, which allows it to be used from a fixed, stationary position.

Web-based Scour Monitoring

Scour monitoring software allows transportation engineers to predict, identify, prepare for, and record potentially destructive flooding events through a secure internet connection. This type of system identifies the occurrence of a flood event and collects and processes relevant bridge information, several sources of real-time hydrological data and any bridge scour monitoring device data. Transportation officials are able to efficiently dispatch emergency personnel, bridge safety inspectors, and maintenance workers before, during, and after a flood event affects a state's bridge inventory.

Portable Depth Sounders with Transducers

Portable depth sounders with transducers have been used to monitor real time scour at substructure units during major flood events. The deck elevations and scour depths of concern are indicated on the Scour Action Plan. If the scour reaches the critical depth specified, the bridge is closed.

Scour Monitoring Collar

The Magnetic Sliding Collar (MSC) is a scour monitoring device. The magnetic sliding collar device consists of a stainless steel pipe driven into the channel bottom with a sliding collar that drops down the pipe as the scour progresses. The location of the collar is detected by the magnetic field created by magnets on the collar. Installations conducted in cooperation with state highway agencies demonstrated that this simple, low-cost instrument is adaptable to various field situations, and can be installed with the equipment and technical skills normally available at the district level of a state highway agency.

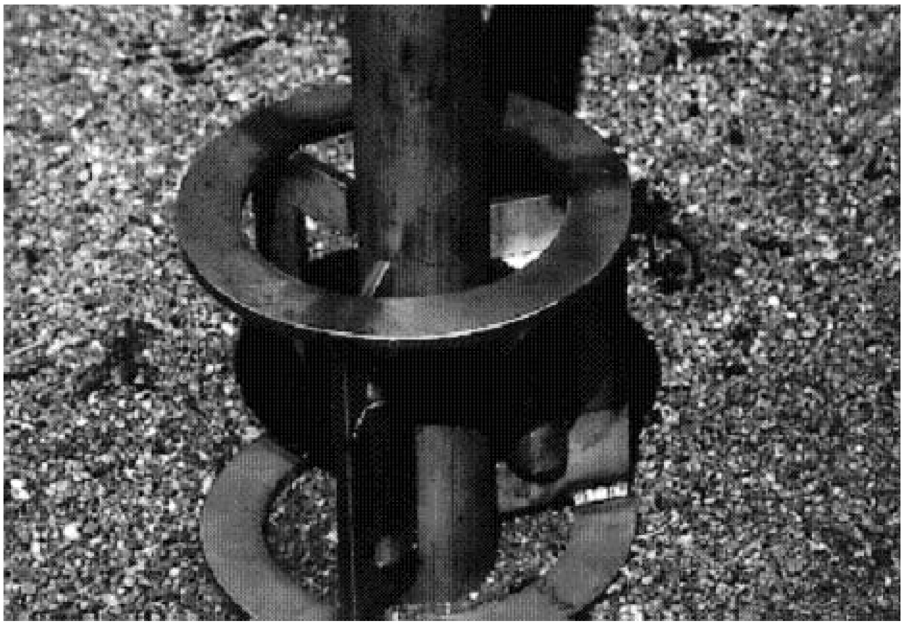

Figure 2.4.6 Scour Monitoring Collar

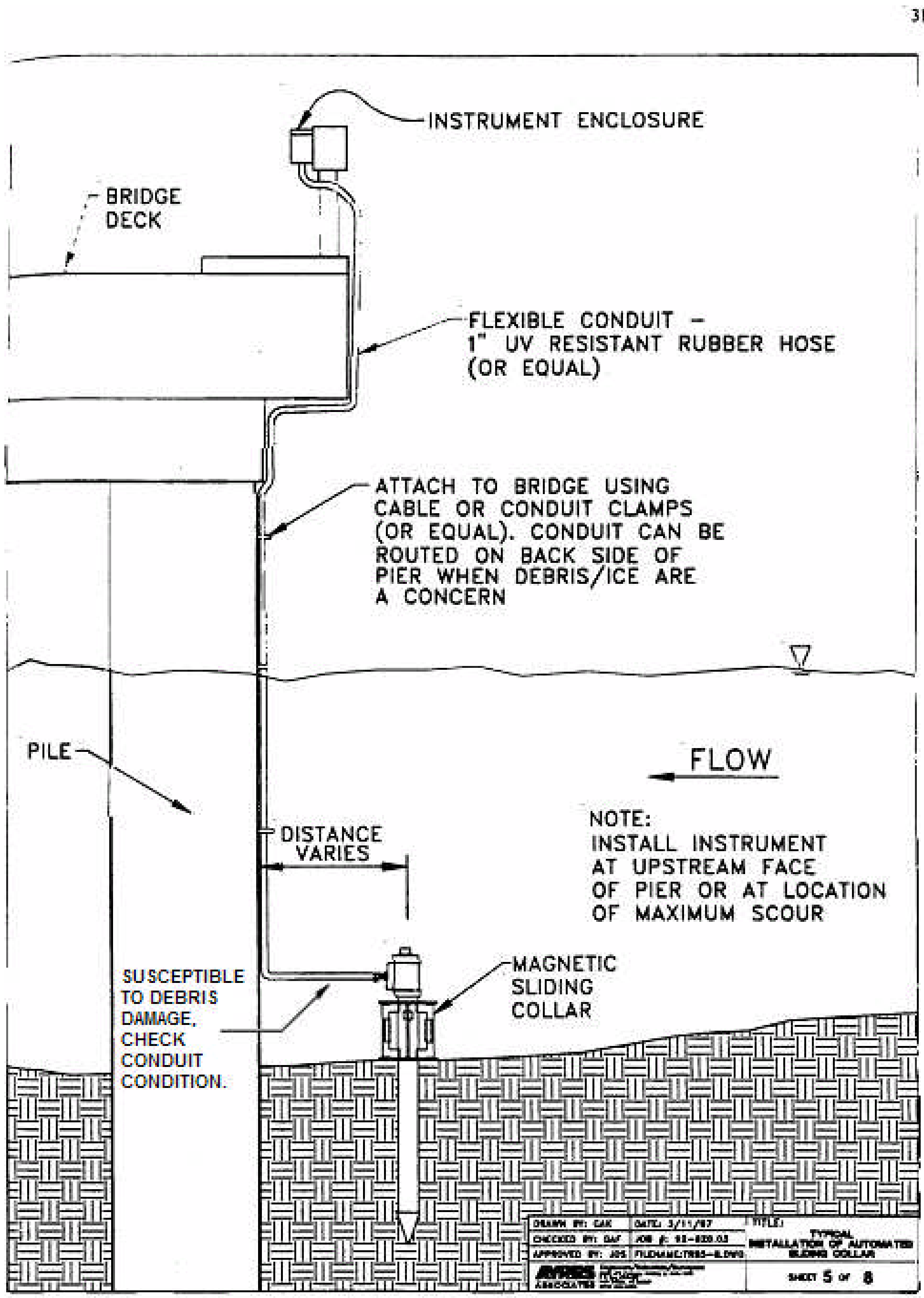

Figure 2.4.7 Scour Monitoring Collar Schematic

Remote Camera

The basic components of a computer-based image system include: an imaging sensor, most commonly a solid-state camera; the image acquisition boards, which convert optical images into an array of digital information, representing the brightness values of the surface; and dedicated processor. The computer-based imaging system can provide two main types of information: spatial measurements and surface analysis. Spatial information encompasses two-dimensional or three-dimensional analysis, measurements and recognition. The surface analysis provides information regarding the color or gray-scale attributes of the target. For example, imaging systems are able to distinguish a flaw from the rest of the surface, and determine size, shape, location and even smallest color attributes of the deficiency. The field of view can be processed in a fraction of a second and can be on the order of 200 to 500 times the size of the smallest feature of interest.

This system works well in a clean environment, however if the item/member is very dirty or has debris surrounding it, cleaning may need to be performed prior to using a remote camera.

Figure 2.4.8 Remote Camera

High Speed Underclearance Measurement System

The high speed underclearance measurement system can mount on any vehicle with a trailer hitch receiver. The system measures the underclearance of a bridge at normal highway speeds. Along with the underclearance data, the GPS location is gathered. Software is used for the data acquisition, display and analysis. The bridge beam height is read to the nearest tenth of a foot. The GPS information can be pasted into a map program to obtain the structure location for future reference.

Figure 2.4.9 High Speed Underclearance Measurement System

Robots

Robotic devices for many applications are being developed by university researchers. High level and underwater bridge inspection are among these applicatons.

One example is the serpentine robot being developed that possesses multiple joints that give it a superior ability to flex, reach, and approach every point on the bridge. This robot is under development.

Other developments in robotic devices are presented in more detail in Topic 15.3.

Laser Scanning

Laser scanning technology can create accurate and complete 3D as-built models quickly and safely. These digital models are automatically combined with CAD design models to allow generation of “as-built” drawings for existing structures. This method can replace tedious field measurements for rehabilitation projects.

Data Recording

The majority of bridge inspectors use pencil and paper to record deficiencies on a bridge. They usually take a copy of the last inspection notes or report and "mark-up" changes since the last inspection. The inspectors input the current findings into the bridge owner's software and the inspection is updated.

Many State agencies are using Electronic Data Collection for bridge inspection.

Hardware

Data recording hardware can include regular office computers, notebook computers or tablet PCs (see Figure 2.4.10) Some versions of these devices have been made to be more rugged and even “wearable” for use in the field.

Software

Specialized software packages can provide a comprehensive set of solutions to manage, inspect, maintain and repair bridges. They allow the user to maintain a comprehensive asset inventory database, collect inspection data from electronic devices, keep history of inspection and maintenance records, assign inspection and maintenance requirements to each structural component, automatically generate inspection reports, and offer decision support.

AASHTO Pontis suports databases on bridge inspection and management. Many bridge owners use AASHTO Pontis based software and have developed programs to address their specific needs.

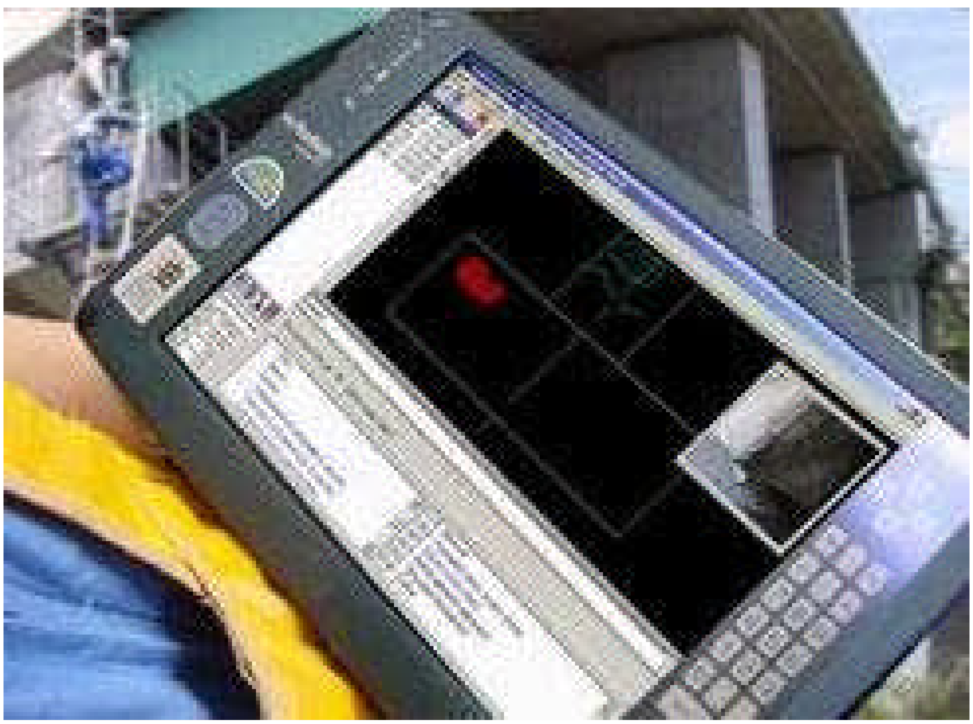

Figure 2.4.10 Tablet PC Used to Collect Inspection Data

2.4.5 Primary Safety Concerns

Proper inspection equipment plays a key role in maintaining the safety of the traveling public and the inspectors. Inspectors who do not have the right equipment, may attempt to use an alternate piece of equipment that is not really designed for the job. Using whatever equipment is at hand, in an attempt to save time and money, can prove dangerous for the inspection team as well as the public. The best way to avoid these circumstances is to ensure the inspectors have the proper equipment for the job and that the equipment is serviced or replaced periodically. This responsibility lies not only with the inspector or team leader but also their employer. It is important that the employer make every effort to properly equip their inspection teams. Also, the inspector needs to be familiar with every piece of equipment and how to use and operate it properly and safely.

Safety fundamentals for bridge inspectors is presented in detail in Topic 2.2.

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