Guidelines for Inspecting Complex Components of Bridges

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on Highways

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Abbreviations

Table 1 Abbreviations and Acronyms

Abbreviation	Term
AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BME	Bridge Management Element
CFR	Code of Federal Regulations
CMP	Corrugated Metal Plate
CoRe	Commonly Recognized
FCM	Fracture Critical Member
FHWA	Federal Highway Administration
HEC-18	Hydraulic Engineering Circular No. 18
HMA	Hot-Mix Asphalt
IOM	Independent Oversight Model
MR&R	Maintenance, Repair and Replacement
NBE	National Bridge Element
NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
NDT	Non-destructive Testing
NHS	National Highway System
OSHA	Occupational Safety and Health Administration
POA	Plan of Action
PPCB	Pretensioned/Prestressed Concrete Beam
PPE	Personal Protective Equipment
PPRJ	Pavement Pressure Relief Joint
QA	Quality Assurance
QC	Quality Control
RMS	Records Management System
SI&A	Structure Inventory and Appraisal
UBIV	Under Bridge Inspection Vehicle

Definitions

Complex Bridge – Movable, suspension, cable stayed, and other bridges with unusual characteristics.

Critical Finding – A structural or safety related deficiency that requires immediate follow-up inspection or action.

Fatigue – The tendency of a member to fail at a stress level below yield stress when subjected to cyclical loadings.

Fracture Critical Member – A steel member in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse.

Quality Assurance – 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.

Quality Control – Procedures that are intended to maintain the quality of a bridge inspection and load rating at or above a specified level.

Structurally Deficient Bridge – A bridge in which significant load-carrying elements are found to be in poor condition due to deterioration, or a bridge in which the adequacy of the waterway opening provided by the bridge is determined to be extremely insufficient to the point of causing intolerable traffic interruptions.

Team Leader – An individual in charge of an inspection team responsible for planning, preparing, and performing field inspection of the bridge.

Triaxial Constraint – A 3-dimensional stress state reducing the ductility of a material. Under triaxial constraint, the apparent fracture toughness of the material is reduced, and brittle fracture can occur under service conditions where ductile behavior is normally expected.

EXECUTIVE SUMMARY

The objective of this research is to develop guidelines for complex bridge inspection to support State DOTs in preparing their own complex bridge inspection procedures that will comply with Metric 19 of FHWA's 23 Metrics. The proposed guidelines are intended to be incorporated into the Section 4 of the AASHTO Manual for Bridge Evaluation or be presented as a stand-alone supplement to the AASHTO Manual for Bridge Evaluation.

This final report is organized to describe current practices (domestic and international), perceived effectiveness, synthesis of research data, and to provide inspection of complex components of bridges guidance to state DOTs. The report has two separate stand-alone sections.

Section I describes the Research phase of the project and contains six chapters.

Chapter 1 provides background information including definitions of complex bridge inspections described in the National Bridge Inspection Standards and the AASHTO Manual for Bridge Evaluation.

Chapter 2 describes the purpose and scope of the guidelines.

Chapter 3 highlights the findings from the literature reviews of both domestic and international scans.

Chapter 4 summarizes the main results of the Agency Survey to include qualifications required for inspecting complex components of bridges, inspection procedures, non-destructive testing methods, existing issues with complex bridge inspections, and areas where improvements could be made to current inspection procedures.

Chapter 5 lists definitions, and references and guides from both domestic and international sources.

Chapter 6 summarizes the conclusions of the research and introduces the guidelines.

Section II presents the Guidelines for Inspecting Complex Components of Bridges comprising three chapters.

Chapter 1 describes inspection personnel qualifications, experience and training for inspecting complex components of bridges.

Chapter 2 identifies complex components of bridges and describes specialized inspection procedures for complex components of bridges.

Chapter 3 includes examples of written inspection procedures, including recommended inspection preparations and inspection procedures, and two detailed examples of complex bridge component inspection procedures for a suspension bridge and for a cable-stayed bridge.

Each section of the final report can be viewed as a stand-alone document.

SECTION I - RESEARCH

1 BACKGROUND

The purpose of this stand-alone Report I – Research, is to present the findings from the preliminary project tasks of literature reviews (domestic and international) and surveying owner Agencies.

1.1 Standards and Manuals

The National Bridge Inspection Standards (NBIS) define complex bridges as movable, suspension, cable stayed, and other bridges with unusual characteristics. The AASHTO Manual for Bridge Evaluation (MBE), Section 4.9 Special Structures, provides guidance on bridge inspection requirements for special structure types such as movable bridges, suspension bridges, cable stayed bridges. These are some examples of structure types considered to be complex bridges. By definition, complex bridges are structure types with unusual characteristics. Complex bridges are usually subject to specialized inspection procedures, additional inspector training and experience may be required to inspect complex bridges. Under the NBIS regulations, states are required to identify complex structures, develop the inspection procedures, and inspector training and experience requirements for these structures. Complex bridges are inspected according to those procedures. Complex bridge inspection requirements, procedures, and inspector qualifications are usually contained in the bridge inspection file for the specific bridge, supplemented with procedures in Bridge Inspection Manuals published by the owner or in their state regulations. Due to the limited guidance in the MBE and NBIS, owners have developed their own complex bridge inspection program requirements to fill this need and meet the NBIS requirements. This results in wide variability among the procedures with respect to the level of detail, inspection rigor, and training requirements.

1.2 Complex Bridge Definition

A complex bridge is a bridge that because of its intricacy may require a significantly greater inspection effort than could be accomplished on a normal routine inspection or may have a complex component. These inspections may require greater engineering knowledge and/or expertise to accurately and fully determine the condition of the various bridge elements. They also may require specialized equipment or climbing to access all parts of the bridge. For example, a bridge may be fairly conventional but have external post-tensioning with intricate details, which would be complex components that may require special knowledge to properly inspect.

2 PURPOSE AND SCOPE OF THE GUIDELINES

2.1 Purpose

The purpose is to develop guidelines for complex bridge inspections. The NBIS require all complex bridge inspections to follow procedures specific to the complex needs of each bridge. The proposed guidelines with commentary are intended as either a stand-alone supplement to the AASHTO Manual for Bridge Evaluation or as an addition to Section 4.

2.2 Scope

The scope will focus exclusively on inspecting complex components of bridges, not categorized as fracture critical, movable or underwater inspections. Fracture critical bridge inspection is specifically spelled out in the current NBIS, and Course No. FHWA-NHI-130078 "Fracture Critical Inspection Techniques for Steel Bridges" provides targeted training for inspecting fracture critical bridges. Underwater bridge inspection is also discussed in the current NBIS, and Course No. FHWA-NHI-130091 "Underwater Bridge Inspection" provides specific criteria for underwater inspection of bridges. Movable bridge inspection is mentioned in the current NBIS, and the AASHTO Movable Bridge Inspection, Evaluation and Maintenance Manual provides specific criteria for movable bridge inspection (NCHRP Project 14-32 "Proposed Revisions to the AASHTO Movable Bridge Inspection, Evaluation, and Maintenance Manual" is underway to develop the Second Edition).

3 LITERATURE REVIEWS

3.1 Domestic Scan

Specific domestic documents reviewed are listed below in 5.2.

- *Table 40 – U.S. Complex Bridges* of NCHRP Synthesis 375 provides a list of structures identified by respondent DOTs as complex or needing special inspection methods:
    - Suspension 19/32 = 59%
    - Cable-Stayed 17/32 = 53%
    - Movable Bridge 14/32 = 44%
    - Tied-Arch 13/32 = 41%
    - Eyebar Bridge 8/32 = 25%
    - Box Girder with External Post-Tensioning 8/32 = 25%
    - Single Concrete Box Girder 7/32 = 22%
    - Two-Girder 6/32 = 19%
    - Single Steel Box Girder 6/32 = 19%
    - Bridges with Pins and Hangers 6/32 = 19%
- *Table F6 – Routine Inspection of Structure Types and Details* of NCHRP Synthesis 375 notes structure types or components requiring special inspections or with special features:
    - State in SE
        - Special A—Segmental concrete
        - Special B—Cable stayed
        - Special C—Suspension and movable bridges
        - Special J—Long-span metal culverts and structural plate culverts
    - State in NW
        - Special feature—High-strength steel
        - Special feature—Pins/hangers, redundant structures
        - Special feature—Floating bridge (water tightness of pontoons)
        - Special feature—Segmental bridge
        - Special feature—Suspension bridge
        - Special feature—Cable-stayed bridge
        - Floating bridge—Equipment (Electrical and mechanical systems)

3.2 International Scan

Specific international documents reviewed are listed below in 5.2.

- Bridge Inspector Training and Certification in France (standardized approach methodology) from FHWA-PL-08-016:
  - Training is provided in six modules, the first five designed for bridge inspectors and the sixth required for project manager certification.
    - Modules 1 through 5 are as follows:
      - Module 1: A 6-day course on basic knowledge (strength of materials, reinforced concrete bridges, common steel bridges, common prestressed concrete bridges, masonry bridges, culverts, common retaining walls)
      - Module 2: A 1-day course on large prestressed concrete bridges
      - Module 3: A 3-day course on uncommon retaining walls
      - Module 4: A 2-day course on large steel bridges and cable bridges
      - Module 5: A 3-day course on tunnels and underground structures
    - Module 6 is a 3-day project manager's course that includes the following:
      - Methodology of detailed inspection
      - Investigation techniques
      - Monitoring and surveillance techniques
      - Repair and strengthening techniques
      - Actions to be proposed after an inspection

This "cafeteria-style" offering of training in specific modules may prove useful for the U.S. From the French offerings, a 3-day module on large P/S concrete, steel and cable bridges would comprise the "Inspecting Complex Components of Bridges" training course.

4 SURVEY RESULTS

NCHRP Project 20-07(337) sponsored a Project-Specific Agency Survey, the results of which are highlighted below as Agency Responses and Best Practices. Surveys were sent to 65 State/Agency Bridge Engineer representatives listed in the Directory on AASHTO's website under SCOBS. 36 completed surveys were returned (55%) from the following: Alabama DOT, Arizona DOT, California DOT, Colorado DOT, Delaware DOT, Florida DOT, Georgia DOT, Hawaii DOT, Idaho Transportation Department, Illinois DOT, Indiana DOT, Iowa DOT, Kansas DOT, Maryland State Highway Administration, Massachusetts DOT, Michigan DOT, Minnesota DOT, Missouri DOT, Nebraska Department of Roads, Nevada DOT, New Jersey DOT, New Mexico DOT, New York State DOT, New York State Bridge Authority, North Carolina DOT, North Dakota DOT, Ohio DOT, Oklahoma DOT, Pennsylvania DOT, Pennsylvania Turnpike Commission, South Dakota DOT, Tennessee DOT, Texas DOT, U.S. Army Corps of Engineers, Vermont Agency of Transportation, Washington DOT

4.1 Agency identified qualifications required for inspecting complex components of bridges:

- Use our more experienced inspectors
- Require licensed professional engineers for all complex bridge inspections
- NHI two-week inspection course, FC inspection course & scour-critical inspection course
- NHI bridge inspection refresher course
- NHI heat straightening course
- Experience in complex bridges
- Precertification documentation showing familiarity with the type of complex bridge to be inspected, understanding of how the bridge functions, and where possible defects might occur
- OSHA Confined Space Training

4.2 Agency identified inspection procedures:

- Suspension Bridge
- Cable stayed Bridge
- Concrete Box Girder with External Post-Tensioning
- Single Concrete Box Girder
- Pin and Hanger Assemblies
- Steel Orthotropic Decks
- Steel Bents
- Integral Steel Pier Caps

4.3 Agency identified non-destructive testing (NDT) methods:

- Actively Using:
    - Visual Testing (VI – Visual Inspection)
    - Dye Penetrant Testing (PT)
    - Magnetic Particle Testing (MT)
    - Ultrasonic Testing (UT)
    - Ground Penetrating Radar (GPR) to locate internal ducts [then destructive borescopes are used to evaluate grout voids.]
- Experimenting/Investigating:
    - Phased Array Ultrasonic Testing (PAUT)
    - Acoustic Emission Testing (AET)
    - Acoustic Resonance Testing (ART)
    - Infrared Testing (IRT)
    - Taut Cable Vibration
    - Load Testing

4.4 Agency identified existing issues with complex bridge inspections:

- The designer of innovative or complex bridges, or of bridges that incorporate innovative or unusual elements or details, shall identify those bridge elements or details that warrant specialized inspection attention. A Special Emphasis Inspection Procedure shall be assembled.

- Traffic control and access to all bridge components are the major issues in the complex bridge inspection program.
- Coordination with ongoing activities (construction, city events, etc.)
- Gaining access to areas that trains/subways run in.
- Issues with the post-tensioned concrete boxes and grout voids in some ducts.
- Issues with main suspension bridge cables and suspender ropes.

4.5 Agency identified areas for improvements to be made to current inspection procedures:

- The complex/major bridge inspection program functions as well as it can, given the size and intricacies of the structures involved. With the increasing traffic volumes on the nation's highways and lane restriction times in urbanized areas, it is difficult to implement the appropriate traffic control within the time constraints provided and perform the inspections in a timely fashion. Inspection times are increasing due to limited access times to some structures. Some inspections in highly urbanized areas are only allowed to proceed at night limiting the usefulness of visual inspection techniques. It seems, in many instances, that the safety of the structure is taking a "back seat" to the mobility of the traveling public. This perception of unduly inconveniencing the traveling public to perform inspection activities needs to change.
- Standardizing documented inspection policy and procedures for complex bridges.
- More training and identifying what other agencies are doing for complex bridges.
- Input of inspection data to bridge inventory and timeliness of report writing
- There are no real practical and economical methods for performing interior wire inspection for Suspension and Cable Stayed Bridges.

5 DEFINITIONS, REFERENCES AND GUIDES

This chapter provides a list of definitions associated with the research, as well as a compilation of references and guides that were reviewed during the course of the research.

5.1 Definitions

The following list of definitions is provided for the reader's benefit:

- Complex Bridge – Movable, suspension, cable stayed, and other bridges with unusual characteristics.
- Critical Finding – A structural or safety related deficiency that requires immediate follow-up inspection or action.
- Fatigue – The tendency of a member to fail at a stress level below yield stress when subjected to cyclical loadings.
- Fracture Critical Member – A steel member in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse.
- Quality Assurance – 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.
- Quality Control – Procedures that are intended to maintain the quality of a bridge inspection and load rating at or above a specified level.

- Structurally Deficient Bridge – A bridge in which significant load-carrying elements are found to be in poor condition due to deterioration, or a bridge in which the adequacy of the waterway opening provided by the bridge is determined to be extremely insufficient to the point of causing intolerable traffic interruptions.
- Team Leader – An individual in charge of an inspection team responsible for planning, preparing, and performing field inspection of the bridge.
- Triaxial Constraint – A 3-dimensional stress state reducing the ductility of a material. Under triaxial constraint, the apparent fracture toughness of the material is reduced, and brittle fracture can occur under service conditions where ductile behavior is normally expected.

5.2 References and Guides

The following compilation of references and guides was developed from the literature reviews, domestic and international, respectively.

Domestic:

- National Bridge Inspection Standards (NBIS) 23 CFR 650 Subpart C
- FHWA/NHI Bridge Inspector's Reference Manual (BIRM)
- AASHTO Manual for Bridge Evaluation (MBE), 2nd Edition, with 2011 Interim Revisions
- AASHTO Manual for Bridge Element Inspections (MBEI), First Edition, 2013 (Note: Information contained in this manual supersedes AASHTO Guide to Commonly Recognized Structural Elements, 1st Edition and AASHTO Guide Manual for Bridge Element Inspection, 1st Edition)
- FHWA-IF-11-045, "Primer for the Inspection and Strength Evaluation of Suspension Bridge Cables," Wash. DC, May 2012.
- FHWA-NHI-130096, "Cable-Stayed Bridge Seminar". (Major topics covered include: bridge configurations, construction methodology, component details, analysis, aerodynamics, design methodology, construction engineering, and maintenance and inspection. Participants will receive a copy of FHWA Design Guidelines for the Arch and Cable-Supported Signature Bridges.)
- FHWA-IF-12-027, "Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges," Wash. DC, February 2012.
- FHWA-NHI-12-042, "Safety Inspection of In-Service Bridges (Vol. 1)," 2012.
- FHWA-NHI-12-043, "Safety Inspection of In-Service Bridges (Vol. 2)," 2012.
- NCHRP Synthesis 375, "Bridge Inspection Practices," Transportation Research Board, Wash. DC, 2008.
- NCHRP 12-82, "Developing Reliability-Based Bridge Inspection Practices," Transportation Research Board, Wash. DC, (Phase I – 2011; Phase II – 2014).
- FHWA-IP-86-26, "Inspection of Fracture Critical Bridge Members," 1986.
- AASHTO Movable Bridge Inspection, Evaluation and Maintenance Manual, 1998.
- FDOT New Directions for Florida Post-Tensioned Bridges, Volume 4 of 5: Condition Inspection and Maintenance of Florida Post-Tensioned Bridges, 2002.
- Washington State Bridge Inspection Manual, M 36-64.03, November 2012.

- Indiana Department of Transportation Bridge Inspection Manual, Dated thru December 2013.
- Iowa Department of Transportation Bridge Inspection Manual, October 2013.

International:

- FHWA-PL-08-016, "Bridge Evaluation Quality Assurance in Europe," Wash. DC, March 2008.
- *Bridge Inspection and Maintenance System Inspection Manual* (Version 3.1), Alberta Infrastructure and Transportation, Edmonton, AB, Canada, March 2008.
- *Bridge Inspection and Maintenance System - Level 2 Inspection Manual* (Version 1.1), Alberta Infrastructure and Transportation, Edmonton, AB, Canada, March 2007.
- *Ontario Structure Inspection Manual (OSIM)*, Ontario Ministry of Transportation, Toronto, ON, Canada, 2000.
- *Design Manual for Roads and Bridges*, Highways Agency, London, United Kingdom, 2006.
- *Handbook for Bridge Inspections*, Norwegian Public Roads Administration, Oslo, 2001.
- Special Bridge Inspection Manual for Cable Stayed Bridge, Japan International Cooperation Agency (JICA) with the Department of Public Works and Highways (DPWH), September 2014.

6 CONCLUSION

This research document has presented background information including definitions of complex bridge inspections described in the National Bridge Inspection Standards and the AASHTO Manual for Bridge Evaluation. The research highlights the findings from the literature reviews of both domestic and international scans, and summarizes the main results of the Agency Survey to include qualifications required for inspecting complex components of bridges, inspection procedures, non-destructive testing methods, existing issues with complex bridge inspections, and areas where improvements could be made to current inspection procedures.

It is envisioned that the information provided will be utilized by bridge owners as a foundation for developing inspection procedures for complex components of bridges that meet the needs of their particular programs. The guidelines that were subsequently developed provide the framework and examples to assist bridge owners in this endeavor.

SECTION II - GUIDELINES FOR INSPECTING COMPLEX COMPONENTS OF BRIDGES

1 INSPECTION PERSONNEL QUALIFICATIONS, EXPERIENCE AND TRAINING FOR INSPECTING COMPLEX COMPONENTS OF BRIDGES

1.1 Federal Requirements

23 CFR 650 Subpart C National Bridge Inspection Standards (NBIS)—Last major re-write dated December 14, 2004. Most recently updated on August 31, 2009 to incorporate by reference the AASHTO Manual for Bridge Evaluation in the NBIS and revise the definition thereof.

For reference, the following sections of the NBIS specifically mention “Complex Bridge(s)”:

> **§ 650.305 Definitions.**
>
> Complex bridge. Movable, suspension, cable stayed, and other bridges with unusual characteristics.
>
> **§ 650.313 Inspection procedures.**
>
> (f) Complex bridges. Identify specialized inspection procedures, and additional inspector training and experience required to inspect complex bridges. Inspect complex bridges according to those procedures.

1.1.1 Program Manager

§ 650.309(a) lists the minimum requirements to serve as Program Manager.

1.1.2 Team Leader

§ 650.309(b) lists the minimum requirements to serve as Team Leader.

1.2 Non-Regulatory Inspection Practices for Complex Components of Bridges

The minimum requirement is to establish specialized inspection needs, level of effort and additional inspector training and/or experience. These procedures are applied to the unique features of complex bridges that would not normally be covered in a routine inspection.

1.2.1 Inspection Personnel Qualifications

Federal Requirements of 23 CFR 650.309 set the minimum requirements to serve as Program Manager and Team Leader as referenced above.

1.2.2 Inspection Personnel Experience

Establish special experience requirements as the complexity may require previous experience inspecting the specific complex components.

1.2.3 Inspection Personnel Training

Establish special training requirements as the complexity of the specific components may require specialized training for the inspector.

1.3 Movable Bridge Mechanical & Electrical Systems Inspection

The requirements of Section 1.2 apply as the systems meet the definition of a complex bridge.

1.4 Training Courses

Courses are available or may be developed to improve inspection of complex components of bridges.

1.4.1 Currently Developed Courses:

Federal Requirements of 23 CFR 650.309 set the minimum requirements to serve as Program Manager and Team Leader as referenced above.

- FHWA-NHI-130055 Safety Inspection of In-Service Bridges
- FHWA-NHI-130053 Bridge Inspection Refresher Training
- FHWA-NHI-130078 Fracture Critical Inspection Techniques for Steel Bridges
- FHWA-NHI-130091 Underwater Bridge Inspection
- FHWA-NHI-130096 "Cable-Stayed Bridge Seminar"

1.4.2 Suggested Courses for Development:

Establish special experience requirements as the complexity may require previous experience inspecting the specific complex components.

- An FHWA-NHI course on Movable Bridge Inspection based on NCHRP Project 14-32 "Proposed Revisions to the AASHTO Movable Bridge Inspection, Evaluation, and Maintenance Manual"
- An FHWA-NHI course on Inspection of Complex Components of Bridges based on NCHRP Project 20-07(337) "Proposed AASHTO Guidelines for Inspecting Complex Components of Bridges"

2 IDENTIFICATION AND SPECIALIZED INSPECTION PROCEDURES FOR COMPLEX COMPONENTS OF BRIDGES

2.1 Complex Components

The National Bridge Inspection Standards (NBIS) define complex bridges as movable, suspension, cable stayed, and other bridges with unusual characteristics. The AASHTO Manual for Bridge Evaluation (MBE), Section 4.2.6 Complex Bridge Inspections, provides guidance on bridge inspection requirements for complex bridge types such as movable bridges, suspension bridges, and cable stayed bridges. These are some examples noted in Article 4.1.5.9 (MBE) of structure types considered to be complex bridges. Under the NBIS regulations, states are required to identify complex structures, develop the inspection procedures, and inspector training and experience requirements for these structures. Complex components of bridges are inspected according to those procedures. Complex bridge inspection requirements, procedures, and inspector qualifications are usually contained in the bridge inspection file for the specific bridge, supplemented with procedures in Bridge Inspection Manuals published by the owner or in their state regulations.

Bridges may be comprised of complex features or have structure types with unusual characteristics that require a specific complex inspection plan. These same bridges have defined procedures for routine inspections, and may also have specific defined procedures related to fracture critical and/or underwater inspections. A complex inspection plan is intended to complement these existing procedures, it is not intended to replace them.

This section provides information to assist the program manager and team leader in identifying complex components of bridges, preparing written procedures, planning and performing effective inspections of complex components and completing the required inspection report. The information presented here is meant as a summary of the main points of the complex component inspection. Chapter 3 includes a representative summary example of recommended inspection preparations and inspection procedures, and example written procedures for selected bridges with complex components, which are provided as a guide. A "Complex Components of Bridges Inspection Report Form" is also included with these guidelines in the Appendix for use in the field or as a template to develop bridge-specific forms.

2.2 Program Management

Each agency Program Manager should identify the bridges within its jurisdiction which contain complex components, as well as determine scope and frequency of inspections. The agency can then identify, through documentation, the particular complex components within each bridge. For the member to be considered complex, it would have unusual characteristics subject to:

- Specialized inspection procedures.
- Additional inspector training and experience.

As noted in the Washington State Bridge Inspection Manual, bridges with complex components may include structures such as movable bridges, suspension bridges, cable-stayed bridges, floating bridges, and ferry terminals. Also included are bridges that were built using techniques such as segmentally constructed post-tensioned concrete boxes. Bridges with pin and hanger connections may also be considered complex component bridges. Written procedures should be developed and included in the bridge file for all Complex Components inspections. Procedures should include:

- Type, detail, and frequency of inspection required.
- The location of members to be inspected.
- Special equipment required.

Complex Component bridge types normally have detailed maintenance and inspection manuals developed specifically for each bridge. This bridge-specific documentation provides information regarding unique details of design, construction and operation, which will facilitate an effective and efficient inspection of the complex components of the bridge.

2.3 Bridge Types

"Complex bridges" are structure types with unusual characteristics. NCHRP Synthesis 375: Bridge Inspection Practices (2008), a synthesis of information on formal inspection practices obtained from 28 returned questionnaires that were sent to departments of transportation (DOTs), identified the following structures and inspection types as complex or as needing special methods in descending order of responses:

- Suspension (FHWA-IF-11-045)
- Cable-Stayed (FHWA-NHI-130096)

- Movable Bridge (AASHTO Movable Bridge Inspection, Evaluation and Maintenance Manual)
- Tied-Arch (FHWA-IP-86-26)
- Eyebar Bridge (FHWA-IP-86-26)
- Box Girder with External Post-Tensioning, (FDOT New Directions for Florida PT Bridges)
- Single Concrete Box Girder – Segmentally Constructed
- Two-Girder (FHWA-IP-86-26)
- Single Steel Box Girder (FHWA-IP-86-26)
- Bridges with Pins and Hangers (FHWA-IP-86-26)

Several of the structures identified in NCHRP Synthesis 375 as complex are also classified as fracture critical. Inspection procedures, specific to the appropriate fracture critical member (FCM), should be developed in conjunction with the Fracture Critical Plan maintained in the bridge file. Applicable access methods, inspection tools and equipment, as well as non-destructive testing (NDT), should be used to inspect the structure. Some agencies may prefer to segregate their inventories of FCM and complex components, whereas others may maintain a combined inventory of both FCM and complex component inspections. In either scenario, the specific members/components are identified and special inspection procedures are developed and maintained in the bridge file.

Representative figures are provided for suspension bridges (3.1.2) and cable-stayed bridges (3.1.3), which illustrate these bridge types and note the location of the complex components.

Although not all-inclusive, some examples of complex components of bridges may include the following:

2.3.1 Suspension Bridges

Suspension bridges typically consist of a pair of main cables hanging between and passing over two towers, and anchored in massive counterweight foundations at both ends of the side spans. Suspender cables hang from the main cables and support a pair of stiffening trusses or girders that run the length of the suspended spans. The stiffening trusses or girders support floor beams, stringers, and a roadway deck. Orthotropic steel decks may be used in place of the stringers and roadway deck. See the BIRM, MBEI and the MBE for general guidance on performing inspections of suspension bridges.

- Suspension Bridge Components (AASHTO NBE #147 and #148)
  - Main Suspension Cable – inspect the main suspension cables for indications of corroded wires. Inspect the protective covering or coating, especially at low points of cables, areas adjacent to the cable bands and saddles over towers.
  - Tower Saddle – inspect the tower saddle for missing or loose bolts, damaged sleeves, bellows or flashing, and corrosion or cracks in the casting. Check for proper connection to top of tower, and possible slippage of the main cable.
  - Cable Bent Saddle – inspect the cable bent saddle for missing or loose bolts, damaged sleeves, bellows or flashing, and corrosion or cracks in the

casting. Check for proper connection to top of supporting member, and possible slippage of the main cable.

- Cable Bands – inspect for missing or loose bolts, rust stains or dripping water, indicative of internal corrosion, or broken suspender saddles. Check for the presence of cracks in the band itself as well as corrosion or deterioration of the band.
- Suspender Cables and Connections – inspect for corrosion or deterioration, broken wires, and kinks or slack. Check for abrasion or wear at sockets, clamps and spreaders. Note excessive vibrations.
- Sockets – inspect for corrosion, cracks, deterioration and possible movement, or abrasion at connection to bridge superstructure.
- Anchorages – inspect the anchorage system at the ends of the main suspension cables. The splay saddle, bridge wires, strand shoes or sockets, anchor bars, and chain gallery need to be inspected. The conditions of the following bridge components should be reported:
  - Strands inside Anchorages, inspect for corrosion or broken wires, and swelling or bulges at the strand shoes.
  - Anchorage Walls and Roof (Chain Gallery), inspect for signs of water intrusion.
  - Eyebars and Strand Wires, inspect for signs of condensation.
  - Points of contact between Eyebars and Concrete Mass, inspect for corrosion.
  - Eyebars and Anchorage Strands, inspect for paint anomalies.

2.3.2 Cable-Stayed Bridges

Cable-stayed bridges are very distinct structures with many unique details that require special inspection. There are two major classes of cable-stayed bridges: harp and fan. The roadway deck is supported by inclined cables (or stays) that extend directly into anchors or saddles in one or two towers (or pylons). In a harp arrangement, the cables are nearly parallel with the height of their attachment to the tower proportional to the distance from the tower to their mounting on the deck. In a fan arrangement, the cables all connect to or pass over the top of the towers. One cantilevered component on one side of the tower is balanced by another cantilevered component on the opposite side of the tower. The deck may be anchored to the ground to resist seismic forces and any unbalance in the cantilevered spans. See the BIRM, MBEI and the MBE for general guidance on performing inspections on cable-stayed bridges.

- Cable-Stayed Bridge Components (AASHTO NBE #147)
  - Stay Cable – inspect cable “protective covering” enclosure for cracks or impact damage.
  - Pylon/Tower Anchorage – inspect for water tightness, drainage and corrosion protection.
  - Girder/Deck Anchorage – inspect for water tightness, drainage and corrosion protection.
  - Pylon/Tower – inspect the exterior and interior for signs of deterioration or damage.
  - Dampening System – inspect the overall soundness of the system for effectiveness.

2.3.3 Movable Bridges

There are generally three basic types of movable bridges: vertical lift (tower- or span-driven), bascule (single- or double-leafed drawbridges), and swing (pivot) spans. All of these structures are operated by either electrical/mechanical drive systems or hydraulic systems. See the BIRM, MBEI, MBE and AASHTO Movable Bridge Inspection, Evaluation and Maintenance Manual for general guidance on performing inspections on movable bridges.

- Movable Bridge Mechanical & Electrical Inspections (AASHTO ADE 800 Series)
    - The specialized mechanical and electrical systems required to operate bascule, swing and vertical lift bridges should be inspected as detailed in the reference above. Inspection procedures, specific to the movable bridge component, should be developed in conjunction with the Movable Bridge Plan maintained in the bridge file. Applicable access methods, inspection tools and testing equipment, as well as non-destructive testing (NDT), should be used to operate and inspect the structure.

2.3.4 Segmental Bridges

Segmental bridges are unique due to their construction. A segmental bridge is either a single trapezoidal box girder or comprised of multiple box girders that are formed from segments post-tensioned together. This type of construction takes advantage of the standardization of the manufacturing process, either using cast-in-place concrete or precast concrete. See the BIRM, MBEI and the MBE for general guidance on performing inspections of concrete segmental bridges.

- Concrete Box Girder with External Post-Tensioning (AASHTO NBE #104)
    - External Post-Tensioning – inspect the grouted ducts in externally post-tensioned members of pre-cast segmental type bridges. Use combination of destructive and non-destructive testing procedures, as necessary or if ducts or tendons show signs of defects.
- Single Concrete Box Girder (AASHTO NBE #104)
    - Internal Prestressing – inspect for cracking around the bearings and cast-in-place diaphragms.

2.3.5 Pin and Hanger Connections

A pin and hanger assembly is a system used to connect suspended spans to cantilevered spans. The hanger is connected to a girder by a pin on one or both ends. In two-girder and three-girder systems, the pin and hanger connection is fracture critical. Even when used in a multi-girder system where the bridge has a high degree of redundancy, the connection should still be inspected as closely as any fracture critical element, due to documented problems. See the BIRM, MBEI and the MBE for general guidance on performing inspections of pin and hanger assemblies.

- Pin and Hanger Assemblies (AASHTO NBE #161)
    - Pins – evaluate using visual inspection and Ultrasonic Testing as necessary.
    - Hangers – evaluate using visual inspection, Dye Penetrant, Magnetic Particle, or Ultrasonic Testing as necessary.

2.3.6 Orthotropic Decks

Due to the dead load weight savings, several suspension bridges have been rehabilitated with steel orthotropic decks replacing heavier concrete bridge decks. In addition, many bridge types were originally constructed with steel orthotropic decks. See the BIRM, MBEI, MBE and FHWA-IF-12-027 Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges for general guidance on performing inspections of steel orthotropic decks.

- Steel Orthotropic Decks (AASHTO NBE #30)
  Due to the large number of welded connection details, a sampling of welds of representative orthotropic details (number/location to be determined as part of an overall inspection program) should be inspected every 24 months. These predetermined details are then monitored over time to determine whether the detail is exhibiting any fatigue cracking.
  - Rib-to-Deck (RD) Weld – inspect for cracks in longitudinal rib-to-deck weld.
  - Rib-to-Floorbeam (RF) Connection at the Base of the Trapezoidal Rib – rib is continuous, passing through floorbeam.
  - Rib-to-Floorbeam (RF) Connection at the Cut-out Transition – rib is continuous with smooth transition cut-out.
  - Rib-to-Deck Weld at the Floorbeam (RDF) – inspect for cracks in tri-axial configuration.
  - Deck Plate Cracking – inspect for evidence of overlay deterioration.

2.3.7 Floating Bridges

Floating bridges support the bridge deck and its dynamic loads on concrete pontoons that are bolted together longitudinally and are held in position by steel cables connected to anchors on the bottom of the waterway. Some of the bridges may be reinforced with prestressing steel.

2.3.8 Ferry Terminal Transfer Bridges

Ferry terminals typically have a dock or holding area built over the water and a transfer span to carry the vehicular traffic onto the ferry deck. The holding area can be constructed of treated timber, concrete, or steel components. The transfer spans generally are steel trusses or girders (I-shaped or box) with one end supported on the fixed pier and a free end which can be raised or lowered onto the boat to accommodate tidal changes.

2.4 Prepare Written Procedures

Once the complex components within a bridge have been identified, the agency or consultant prepares a detailed plan to accomplish the complex component inspection. These written inspection procedures are recorded in each bridge file. Complex component inspections can be expensive; therefore, the inspection plan should be developed considering the following:

2.4.1 Scheduling

If possible, schedule a complex component inspection during colder temperatures (cracks will be more visible), at lower water levels (if the complex component is underwater at high water), during daylight hours, and during lower traffic volume (traffic control may be required).

2.4.2 Equipment

The team leader needs up-close access to each complex component member; therefore, some type of access equipment may be needed. Ladders, rigging, scaffolding, bucket trucks, man-lifts, UBIVs or industrial rope access may be required for a given situation. The choice of equipment will depend on the cost of rental, the time needed to perform the inspection using that equipment, and equipment availability. If a UBIV is used, determine, before its use, whether it could overload the bridge, operate on the bridge grade/super elevation, reach over fencing and scope to the full-width of structure, and/or damage the deck with outriggers. Use of a UBIV, bucket truck or man-lift typically requires traffic control, whether operating on structure or from below the structure.

2.4.3 Workforce

Efficient use of inspection manpower minimizes on-site time while ensuring all required components are inspected. Each inspector should be assigned clearly defined duties and scheduled working hours established.

2.4.4 Tools

Complex component inspections typically use the same tools as any routine inspection. For example, a chipping hammer, scrapper, wire brush, magnifying glass, and a flashlight should be available. In addition, nondestructive testing (dye penetrant kit, magnetic particle kit or ultrasonic testing device) may be needed, depending upon the component material and surface indications.

2.4.5 Inspection Procedures

The complex component inspection plan should identify the inspection frequency and method, based upon the information gathered during the inspection preparation. This information should include the bridge's history (construction, rehabilitation and maintenance), the criticality of the complex components, calculated remaining fatigue life (if applicable), current visual indications, material properties, consequences and likelihood of rapid failure, etc.

If several types of inspection are performed (routine, fracture-critical, complex component), identify when, where and how they are to be used. For example, a pinned truss bridge may require each of the pins to be examined visually during each inspection, supplemented by ultrasonic testing of 1/3 of the pins during each inspection. Therefore, all of the pins would be inspected ultrasonically in a 72-month period, if the inspection frequency was 24 months.

2.5 Perform the Complex Component Inspection

The purpose of the complex component inspection is to assess the structural condition of each bridge component identified as complex. When inspecting these members, the inspection should be conducted carefully and thoroughly to ensure the same degree of care and attention is given to the last area inspected as the first. Previously, the general areas within a bridge where complex components will be located were presented. The following describe the particular features to note.

2.5.1 Access

The team leader must initially gain access to the complex component area. The team leader should be within arm's reach of the surface being inspected and should work with a light source of at least 50 to 100 lumens. The best viewing angle is at approximately 120°. The team leader will look for surface deteriorations based upon material type, including surface cracks. The BIRM discusses inspection procedures and the types of problems that may be found.

2.5.2 Areas to be Checked

The following areas or members should be checked:

- Areas vulnerable to corrosion (under and adjacent to deck joints, on surfaces where water and debris collect, in places where dissimilar materials meet).
- Areas where there is a change in the bridge cross section, where stress is concentrated (stress riser), or which display out-of-plane bending.
- Web stiffeners (especially at the ends).
- Coped sections and/or re-entrant corners.
- Eyebars.
- Shear connectors.
- Pin and hanger assemblies.
- Punched holes.
- Rivet and bolt heads.
- Tack welds and field welds (especially at weld ends or returns).

2.5.3 Evaluate Findings

If any cracks, blemishes, or other irregularities are found, the team leader will need to evaluate these further, which may include the use of a magnifying glass. A dye penetrant kit or a magnetic particle kit can be used to establish the limits of a surface crack in a steel member. In addition to a visual inspection, magnetic or ultrasonic testing devices may be required to detect subsurface flaws in steel members. The agency may determine which devices will be the most cost effective and reliable for the given situation.

2.5.4 Document Findings

The team leader will finally record the location and size of any cracks found. Mark and date the crack ends in permanent marker, keel or lumber crayon for follow-up monitoring of the structure. It will be helpful to take a photograph of such cracks to provide visual documentation. This information and the photographs are to be included in the Complex Component Inspection Report.

2.6 Prepare the Complex Component Inspection Report

At the conclusion of the complex component inspection, a Complex Component Inspection Report should be prepared to provide detailed documentation of the inspection findings. The report should provide both qualitative and quantitative information concerning the complex component. This information is important to provide insight about the condition of the member, to substantiate a continual history of the bridge, and to substantiate the thoroughness of the inspection effort in the event of litigation arising from a bridge failure.

The inspection report should:

- Identify what parts of the bridge were inspected and the location of each complex component. (This can be shown on a photograph or sketch of the bridge.)
- Describe the procedures followed to inspect the complex component.
- Describe the condition of the complex component.

- Provide the following details about any defects found:
    - What the defect is, its overall size (Length x Width x Depth), its severity.
    - Where the defect is located (a sketch may be used to illustrate its location relative to the ends of the member, and its position in the cross section of the member).
    - Summarize the inspection findings (addressing how individual defects affect the member's overall condition).
    - Make any appropriate recommendations (i.e., repair the complex component, recalculate load ratings, channelize traffic to reduce live load effects, install temporary shoring, or close the bridge).

3 EXAMPLES

3.1 Written Inspection Procedures

A representative summary example of recommended inspection preparations and inspection procedures from the Indiana Department of Transportation Bridge Inspection Manual is provided in 3.1.1. This is followed by the more detailed examples of complex bridge component inspection procedures associated with two of the most complex bridge types:

- Suspension Bridge in 3.1.2 [derived from the 2014 routine and fracture-critical bridge inspection and condition report for the St Johns Bridge (ODOT Br. No. 06497) carrying OR Highway 30 Bypass over the Willamette River in Portland, OR].
- Cable-Stayed Bridge in 3.1.3 [derived from the Special Bridge Inspection Manual for Cable Stayed Bridge, Japan International Cooperation Agency (JICA) with the Department of Public Works and Highways (DPWH)].

3.1.1 Recommended Inspection Preparations and Inspection Procedures

(From Indiana Department of Transportation Bridge Inspection Manual)

INSPECTION PREPARATIONS

Good preparation will increase the quality of the field inspection. To develop an effective and efficient plan, the inspection team should research the bridge history, develop an inspection sequence, identify personnel requirements, and estimate a time frame for the inspection. They must ensure that all needed tools and safety devices are available. The team should format field notes, secure needed permits, anticipate traffic control and weather conditions, and plan for any material testing and bridge access. The team must determine if other measures are required to ensure the productive use of time in the field.

Formulate an Inspection Plan

From the information gathered during the inspection preparation, a field inspection plan needs to be compiled prior to the inspection. A pre-inspection visit to the site may be required to develop or finalize this plan. A good plan should include most of the following:

- The type of inspection(s) to be completed
- A brief historical fact statement about the bridge type and condition
- Confirmation that the bridge has been properly cleaned for the type of inspection planned
- Copies of essential plans
- A mapped route to the site
- Keys for any locked access points
- Identification of tension members and fatigue-prone details, failure-prone details, and fracture critical members or member components
- Identification of access equipment and arrangements for it to be on-site
- Identification of inspection personnel and arrangements for them to be on-site
- Identification of inspection tools, safety equipment, and arrangements for these to be on-site
- Identification of required nondestructive testing (NDT) equipment and arrangements for it to be on-site
- Identification of traffic control requirements and arrangements for on-site implementation
- Press releases, if necessary
- Inspection time estimate
- Coordination with the owner and other agencies as required

On larger or more complex bridges, it may be necessary to create individual sections for each of the required areas of the inspection plan.

Special Considerations

The Inspection Team Leader has many additional items to consider when planning an inspection including set-up time, the overall condition of the bridge, and the weather.

Set-up time can be significant and needs to be considered when planning an inspection.

It takes longer to document and inspect a bridge or component that is deteriorated because extra sketches, photographs, and measurements are required. Inspectors should use old inspection reports to estimate the time required for the inspection and reporting.

Unexpected weather conditions can adversely affect inspection work.

INSPECTION PROCEDURES

Inspection procedures are used to implement the inspection plan. It is critical that the Inspection Team Leader guide the inspection process to assure that each inspection is done safely and to the desired level of quality.

Uniform inspection techniques and recording are required for efficiency and completeness. No element of the bridge should be overlooked. The time spent on each element should be in proportion to the importance of the element. The inspector should systematically record all observations that affect the bridge at the time of the inspection or that may cause concern in the future.

Historical Review and Critical Member Plan Review

The construction history, rehabilitation and maintenance history, and previous inspection records should be reviewed at the bridge site prior to performing an inspection. The bridge orientation should be reviewed to determine the location of critical members. The location of panel points in relation to bridge orientation should be confirmed.

The critical members identified in the inspection plan should be reviewed prior to performing the inspection. Look for details known to cause specific problems or deterioration. Note any maintenance, repairs, or rehabilitation made to the bridge since the last inspection and determine how this has affected the condition of the bridge.

Traffic Control

Traffic control requirements should be reviewed prior to performing an inspection to assure safety of the inspection team and the traveling public. The inspection team should review safety considerations and the traffic control requirements with the people setting up and operating the traffic control if they are not part of the inspection team. All traffic control requirements, including railroad traffic control, should be documented.

Inspection Tools

A review of the bridge and its condition should be performed to determine what tools may be required to perform a thorough visual or hands-on inspection and any required NDT.

Field Inspection

It is paramount that an inspection is thorough and complete. The condition of each member or component needs to be determined, including any deficiencies such as section loss, cracks, impact damage, and material flaws. To ensure a complete inspection, check off members on the plan as they are inspected.

For Special and Fracture Critical Inspections, inspectors should perform a hands-on inspection of all pertinent members and components.

NDT is required for certain details and may be required to further analyze defects.

Data

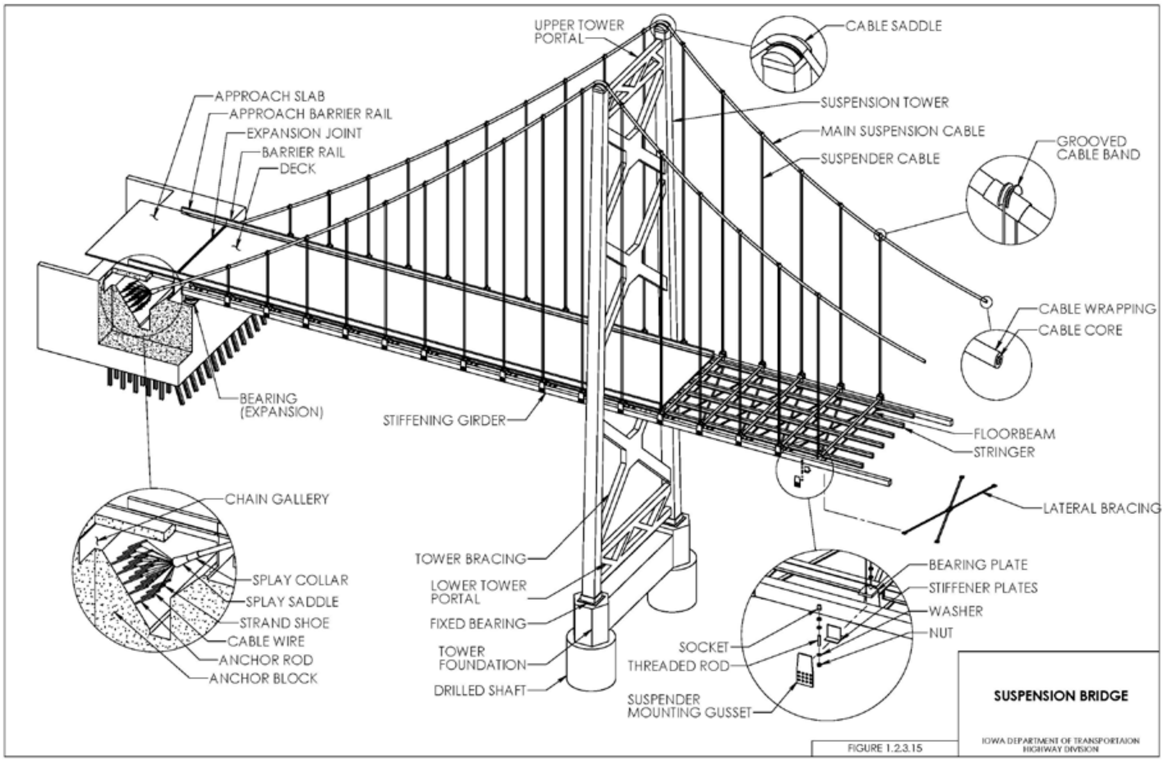
The team should discuss its findings before leaving the bridge site. The inspection data should be collected in its entirety at the bridge site. All notes need to be easy to understand and appropriate pictures should be labeled and dated. Follow good quality control practices to eliminate any errors or omissions.

Inspectors should document any defect(s) and list the recommended remedial actions. Items requiring immediate attention should be reported to the bridge owner. Upon identifying a potential critical finding, immediately report the deficiency to the appropriate agency officials. Problems that require prompt action to maintain public safety need to be mitigated before leaving the bridge site.

Re-rating, Load Posting, or Closure

The inspection team may recommend the re-rating, load posting, or closure of a bridge based on the findings of the inspection.

3.1.2 Inspection Procedures for Complex Bridge Components of Suspension Bridges



(Figure from Iowa Department of Transportation Bridge Inspection Manual)

BRIDGE INSPECTION PROCEDURES FOR A SUSPENSION BRIDGE

This example is derived from the 2014 routine and fracture-critical bridge inspection and condition report for the St Johns Bridge (ODOT Br. No. 06497) carrying OR Highway 30 Bypass over the Willamette River in Portland, OR.

This suspension bridge has an overall length of 3608’ and consists of inverted Warren-style deck truss approaches and a 2060’ main span unit. The superstructure is supported by reinforced concrete abutments, concrete encased steel towers, and structural steel towers in the main span. The structure provides two lanes of vehicular traffic in each direction and pedestrian sidewalks on either edge of deck. At the time of construction, the bridge set records for the longest suspension span and highest navigational clearance in the United States.

Inspection services included close-up, hands-on inspection of 100% of the superstructure’s fracture critical members. Fracture critical members on this structure include the main cables, suspender cables, selected members in the stiffening trusses, main span floor system, and the deck trusses in the approach spans. Special attention was devoted to examining fatigue–prone details, structural connections and gusset plates, as well as areas with previously identified deficiencies. Routine inspection of the substructure, safety facilities, and steel tower components was also performed.

Inspection by means of industrial rope access was performed in accordance with the Society of Professional Rope Access Technicians (SPRAT), a member-based organization that serves the rope-access industry by developing and maintaining standards and administering an independent certification program. Rope access bridge inspectors are certified to SPRAT Level I (Worker), Level II (Technician) and Level III (Supervisor). Industrial rope access was used to inspect the main cables and suspender cables. The main span floor system and stiffening trusses were inspected using two 60’ under bridge inspection cranes. The deck truss approaches were inspected using a 50’ under bridge inspection crane and the two 60’ under bridge inspection cranes. Access to the tower interiors and each anchorage vault was obtained using confined space entry techniques. Inspection of the East Anchorage Vault included the use of a scissor lift winched into the vault through use of a small stairway. Traffic control was provided as required. All inspections of approach and main span floor systems and trusses were done at night.

Bridge Details and History

Prior to the inspection, the inspector should review all available information relative to:

1. Type of bridge
2. Maintenance history
3. As-Built Drawings
4. Previous inspection reports
5. Photographs

Copies of the above-listed information for the bridge should be properly managed and stored by the owner. The inspector should take pertinent information into the field, such as previous inspection reports with photographs included.

Resource Requirements
In order to perform a proper and efficient inspection, appropriate equipment and manpower should be readily available. A list of recommended equipment is included in the following Table and should be carefully considered prior to inspection. It may also be necessary to arrange specialized equipment on a case-by-case basis. These might include scaffolding, rigging, industrial rope access techniques, under bridge inspection vehicle, boats, testing equipment, etc.

Table

Equipment for Visual Inspection (Condition Inspection)

1. Safety Vest
2. Safety Shoes
3. Shirt with long sleeves and Pants
4. Hard Hat with chinstrap
5. Gloves
6. Hand Mirror for viewing behind bearings, etc.
7. Flashlight
8. Geologist's Hammer
9. Measuring Tape
10. Crayon, Keel, Felt-tip Marker and/or Chalk for marking
11. Digital Camera with zoom and date feature
12. Inspection Forms
13. Sketch Drawing Forms
14. Copy of previous report
15. First-Aid Kit
16. 4-Gas Meter
17. Shovel and Broom
18. Wire Brush
19. Crack Comparator Gauge
20. Extension Ladder
21. Boat or Barge
22. Under Bridge Inspection Vehicle (UBIV) – 50' and 60' reach
23. Rope Access Inspector's Kit – suspension harness with equipment
24. Climbing Helmet with Headlamp
25. Climbing Gloves

Inspection and Sketch Drawings Forms

The inspection of a suspension bridge is unique to the specific structure, due to the complex design characteristics compared to conventional bridges.

Prior to conducting the inspection, the Inspection and Sketch Drawing Forms will be prepared in advance.

The initial data shown shall be checked for correctness during the bridge inspection, and corrections made or missing information added as necessary.

CONDITION INSPECTION

Purpose

The purpose of the Condition Inspection is to record defects and rate the condition of the suspension bridge as a basis for identifying its current maintenance needs, forecasting its future preservation measures and estimating its future funding requirements. Also, the result of Condition Inspection should be used to monitor the deterioration of defects over time.

Scope of the Inspection

The Condition Inspection includes:

- Reviewing the existing inventory data of the bridge structure for accuracy.
- Visually inspecting the bridge components and recording their defects to assess their condition using a standard condition rating system.
- Sketch drawings to monitor the progress and deterioration of defects
- Reporting the condition of each bridge component.
- Providing a general condition rating for the structure as a whole.
- A photographic record of defects.

During a Condition Inspection, the inspector should record all details of defects for assessing the bridge condition using a standard condition rating system and also for monitoring the progress and deterioration of defects. Therefore, each component of the bridge shall be inspected within arm's reach distance from the surface of the components.

All surfaces of the components shall be exposed in good natural or artificial light during the inspection, sufficient to observe fine cracks and other defects on the surfaces. Bearings at the abutments and piers shall be inspected at eye level. The interior of both anchorage vaults and the towers shall also be inspected closely. A visual inspection is performed to cover all parts of the bridge above the ground and water level.

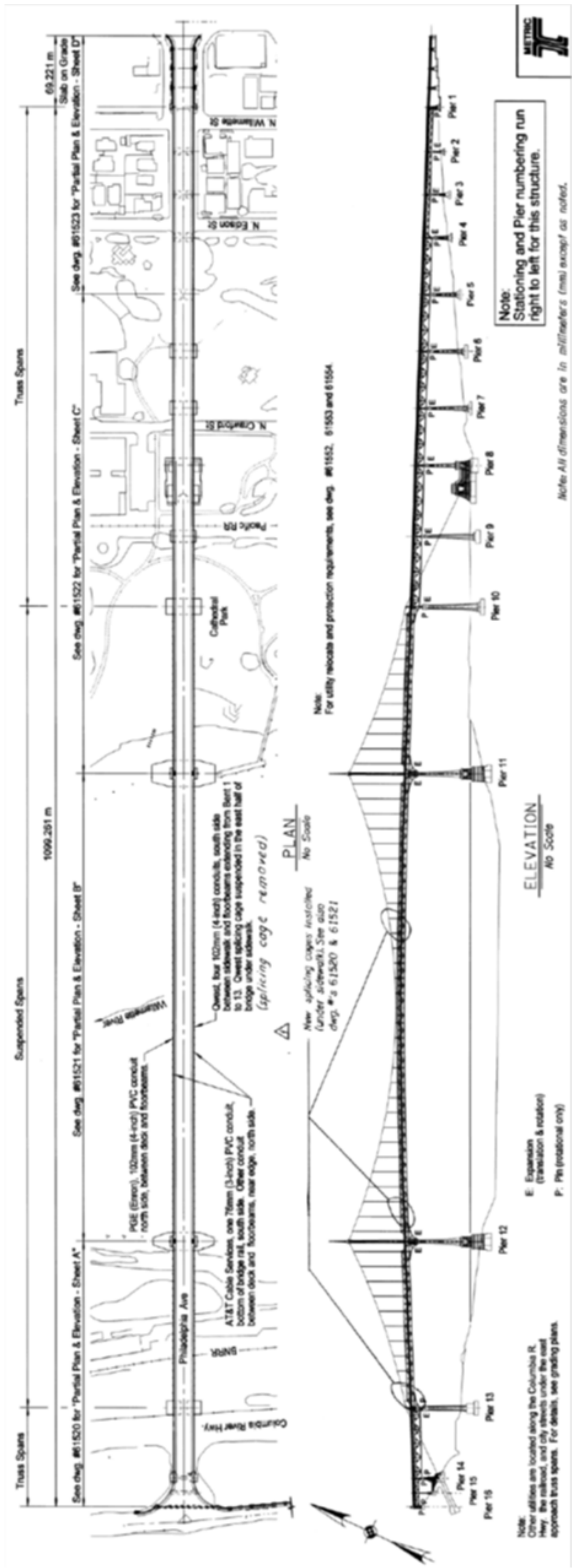
Sketch drawings compiled during the Condition Inspection are very important for analyzing the bridge condition and for the monitoring the deterioration of defects. Inspectors should sketch carefully the details of defects. Sketch drawings of defects should include the location, measurements and severity of defects as much as possible. When inspectors cannot possibly measure the defects, they can roughly estimate measurement through their engineering judgment.

Condition Inspection Form

The inspection findings of the suspension bridge are shown in the following Figures.

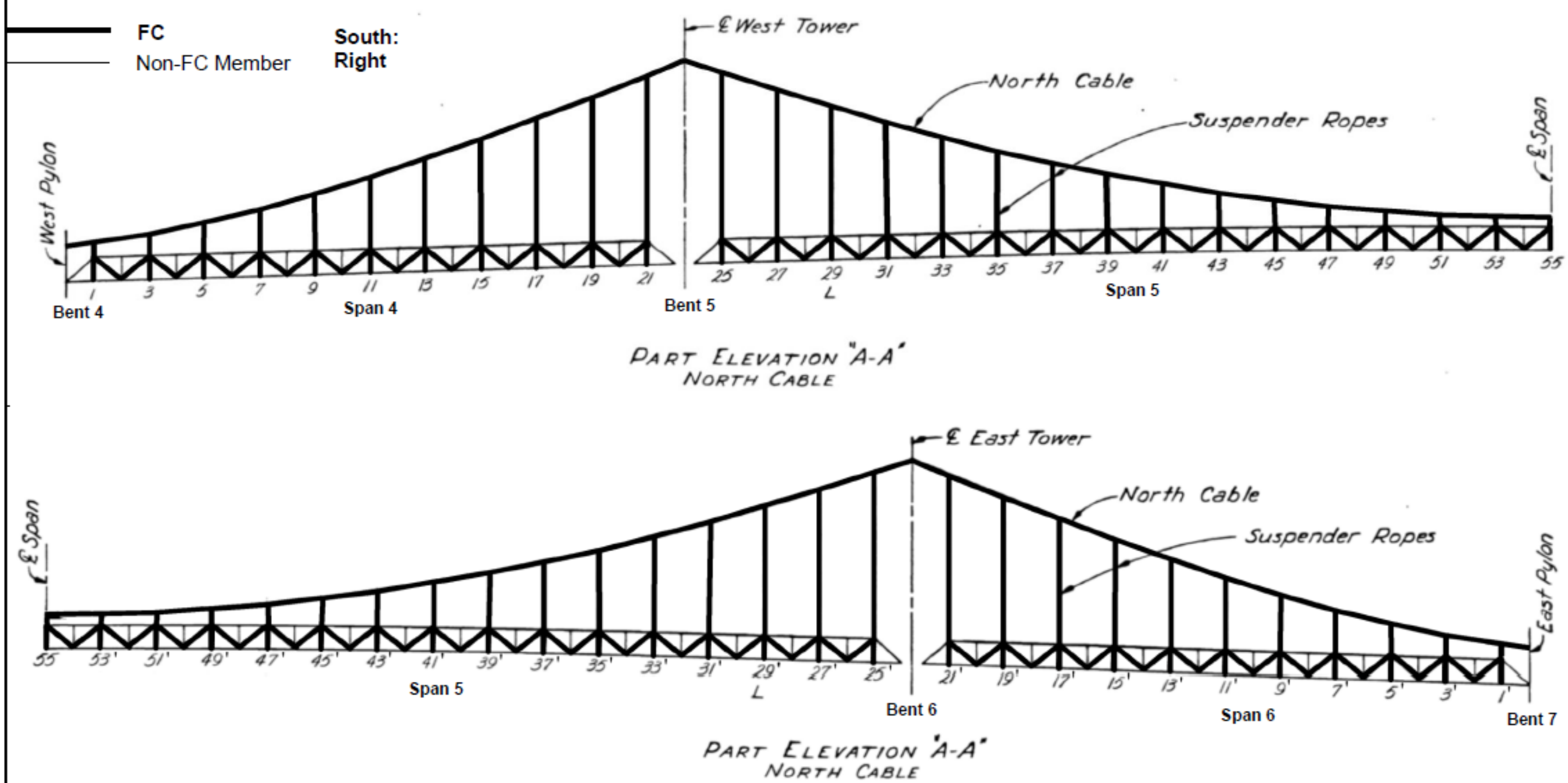
Suspension bridges are complex structures. Before conducting the inspection, proper numbering of elements and components on the forms should be considered to avoid misinterpretation of its location. During the inspection, each component shall be numbered/marked for easy identification. Numbering and marking of attributes are also shown in the Figures.

PLAN AND ELEVATION



OREGON DEPARTMENT OF TRANSPORTATION
FRACTURE CRITICAL INSPECTION REPORT
(Executive Summary)

Bridge Name: Willamette River (St Johns Bridge)					**Owner:** State	**Bridge No.** 06497	
District:	2B				**Year Built:** 1931	**Highway:** 123	
CO.: Multnomah					**Frequency:** 2 years	**MP:** 0.91	
FC Structure Type: Steel Stiffening Through Truss					**Date of Inspection**		
FC Member Type: Truss Diagonals and Verticals Below Suspenders					**Inspector's Name**		
Fracture Critical Bridge Inspection Procedures: The appropriate FC Bridge Inspection Procedures, as contained in the ODOT Bridge Inspection Manual, Section 11 categorized by type of steel superstructure & member.					**Inspector's Name**		



FC MAIN SPAN TRUSS (SAMPLE ENTRIES)

SPAN	BENT	MEMBER		LENGTH	TYPE OF MEMBER	FC Detail / Category	Detail Location	INSPECTION RESULTS, REMARKS, OR RECOMMENDATIONS	SKETCH
Right Side Truss									
4	South	Diagonal	U1L2	25'-0"	2 - C10 x 20"	Visual	None		
4	South	Vertical	U1L1	18'-0"	4 - 6" x 3 1/2" x 7/16" Angles	Visual	None		
5	South	Diagonal	U25L26	25'-0"	2 - C10 x 20"	Visual	None		
5	South	Verticals	U25L25	18'-0"	4 - 6" x 3 1/2" x 7/16" Angles	Visual	None		
6	South	Diagonals	U21'L20'	25'-0"	2 - C10 x 20"	Visual	None		
6	South	Verticals	U21'L21'	18'-0"	4 - 6" x 3 1/2" x 7/16" Angles	Visual	None		
Right Side Truss									
4	North	Diagonal	U1L2	25'-0"	2 - C10 x 20"	Visual	None		
4	North	Vertical	U1L1	18'-0"	4 - 6" x 3 1/2" x 7/16" Angles	Visual	None		
5	North	Diagonal	U25L26	25'-0"	2 - C10 x 20"	Visual	None		
5	North	Verticals	U25L25	18'-0"	4 - 6" x 3 1/2" x 7/16" Angles	Visual	None		
6	North	Diagonals	U21'L20'	25'-0"	2 - C10 x 20"	Visual	None		
6	North	Verticals	U21'L21'	18'-0"	4 - 6" x 3 1/2" x 7/16" Angles	Visual	None		

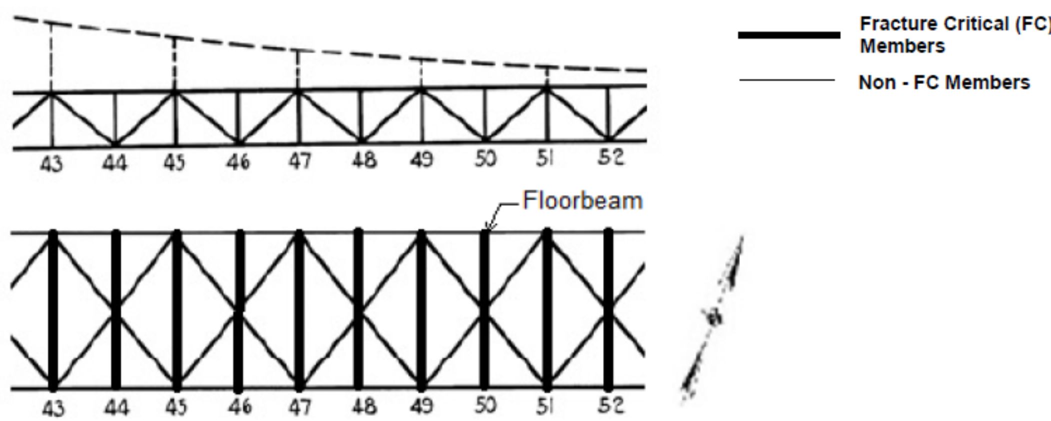
NOTES:

1. The inspection of the FC members was performed at night with two teams using two 60' UBIVs. Traffic control is required.

FC MAIN SPAN FLOOR SYSTEM

OREGON DEPARTMENT OF TRANSPORTATION
FRACTURE CRITICAL INSPECTION REPORT

Bridge Name: Willamette River (St Johns Bridge)	**Owner:** State	**Bridge No.** 06497
District: 2B	**Year Built:** 1931	**Highway:** 123
CO.: Multnomah	**Frequency:** 2 years	**MP:** 0.91
FC Structure Type: Steel Stiffening Through Truss Floor System	**Date of Inspection**	
FC Member Type: Floorbeams	**Inspector's Name**	
Fracture Critical Bridge Inspection Procedures: The appropriate FC Bridge Inspection Procedures, as contained in the ODOT Bridge Inspection Manual, Section 11 are categorized by the type of steel superstructure and member type.	**Inspector's Name**	



TYPICAL FLOOR SYSTEM PLAN

(NOTE: Bents and floorbeams are numbered from West to East with increasing MP.)

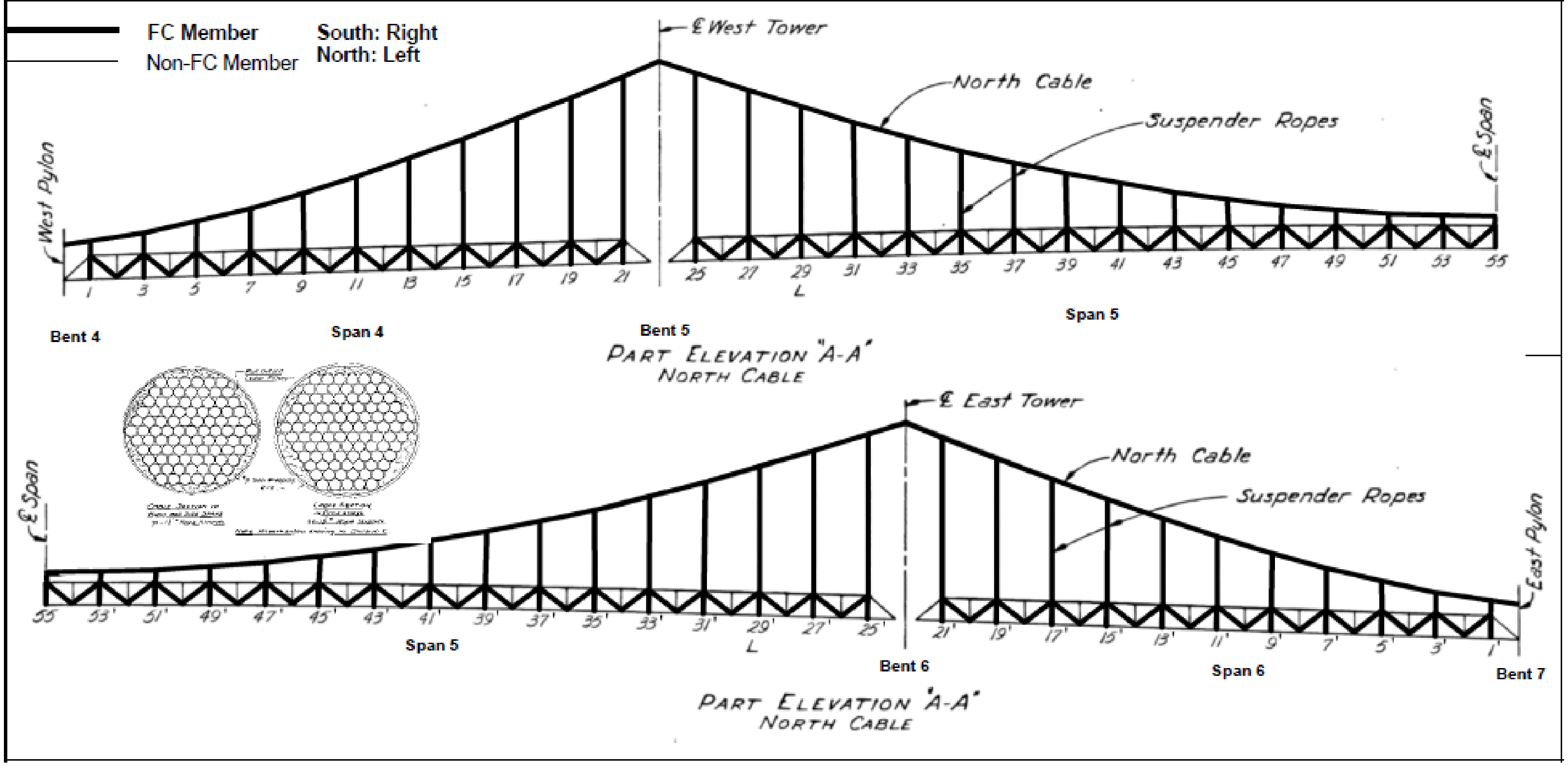
FC MAIN SPAN FLOOR SYSTEM (SAMPLE ENTRIES)

SPAN	MEMBER	LENGTH	TYPE OF MEMBER	FPD		INSPECTION RESULTS, REMARKS, OR RECOMMENDATIONS	PHOTO/ SKETCH?
				Cat.	Location		
Span 4							
4	Floorbeam 0	50'-08"	Steel built-up riveted members.	Visual	None		
Span 5							
5	Floorbeam 24	50'-08"	Steel built-up riveted members.	Visual	None		
Span 6							
6	Floorbeam 22'	50'-08"	Steel built-up riveted members.	Visual	None		

NOTES:
1. The inspection of the FC members was performed at night with two teams using two 60' UBIVs. Traffic control is required.

OREGON DEPARTMENT OF TRANSPORTATION
FRACTURE CRITICAL INSPECTION REPORT
(Executive Summary)

Bridge Name: Willamette River (St Johns Bridge)					**Owner:** State	**Bridge No.** 06497	
District:	2B				**Year Built:** 1931	**Highway:** 123	
CO.: Multnomah					**Frequency:** 2 years	**MP:** 0.91	
FC Structure Type: Main Cables and Suspender Cables					**Date of Inspection**		
FC Member Type: Cables					**Inspector's Name**		
Fracture Critical Bridge Inspection Procedures: The appropriate FC Bridge Inspection Procedures, as contained in the ODOT Bridge Inspection Manual, Section 11 are categorized by the type of steel superstructure and member type.					**Inspector's Name**		



FC MAIN SPAN CABLES (SAMPLE ENTRIES)

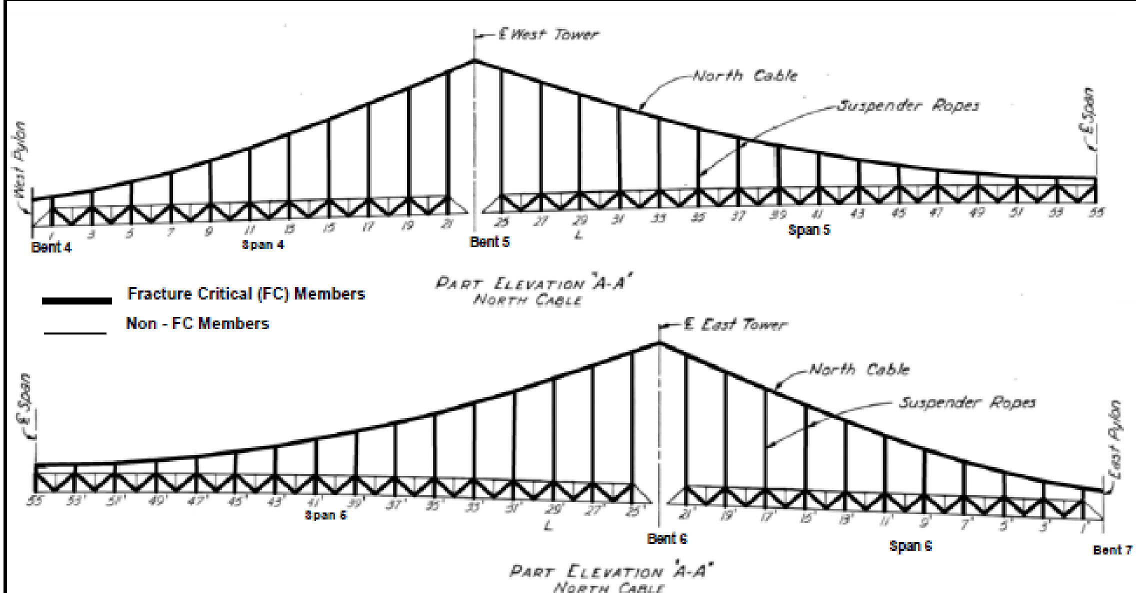
SPAN	BENT	MEMBER	TYPE OF MEMBER	FC Detail / Category	Detail Location	INSPECTION RESULTS, REMARKS, OR RECOMMENDATIONS	SKETCH/ PHOTO
			West Anchorage				
4	South		Main Cable				
5	South		Main Cable				
6	South		Main Cable				
		Bent 9 (East Anchor House Pier 8 Per Plans)					
		Bent 9 (East Anchor House Pier 8 Per Plans)					
			West Anchorage				
4	North		Main Cable				
5	North		Main Cable				
6	North		Main Cable				
		Bent 9 (East Anchor House Pier 8 Per Plans)					
North Cables							
4	North		Suspender 1				
5	North		Suspender 25				
6	North		Suspender 21'				
South Cables							
4	South		Suspender 1				
5	South		Suspender 25				
6	South		Suspender 21'				
South Side							
4	L1	Stiffener Truss End Tie down pins & link	Seismic Dampeners				
5	L53	Stiffener Truss End Tie down pins & link	Seismic Dampeners				
6	L3'	Stiffener Truss End Tie down pins & link	Seismic Dampeners				
	L1'	Stiffener Truss End Tie down pins & link	Seismic Dampeners				
North Side							
4	L1	Stiffener Truss End Tie down pins & link	Seismic Dampeners				
5	L53	Stiffener Truss End Tie down pins & link	Seismic Dampeners				
6	L3'	Stiffener Truss End Tie down pins & link	Seismic Dampeners				
	L1'	Stiffener Truss End Tie down pins & link	Seismic Dampeners				

NOTES:
1. The inspection of the FC members was performed with three teams using industrial rope access techniques.

FP MAIN SPAN TRUSS

OREGON DEPARTMENT OF TRANSPORTATION
FATIGUE PRONE & INTERSECTING WELD DETAIL INSPECTION REPORT
(Executive Summary)

Bridge Name:	Willamette River (St John's Bridge)	**Owner:**	State	**Bridge No.:** 06497
District 2B	**County:** Multnomah	**Year Built:**	1931	**Highway:** 123
FC Structure Type:	Steel Stiffening Through Truss	**Frequency:**	24 months	**MP:** 0.91
FC Member Type:	Truss Diagonals and Verticals below Suspenders	**Date of Inspection:**		
Agency Inspected By:		**Inspector Name:**		



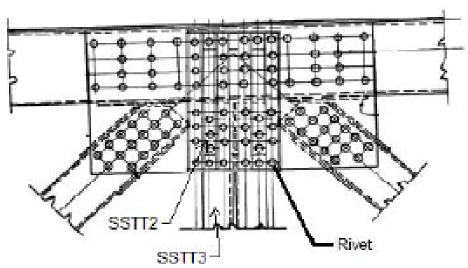
(NOTE: Bents and panel points are numbered from West to East with increasing MP.)

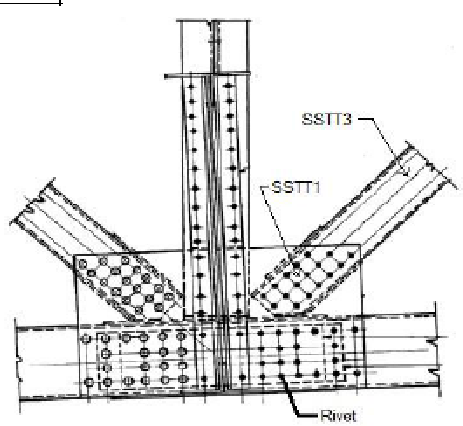
NOTE: Fatigue Prone details for the truss diagonals and verticals below the suspender cables are documented in the Fracture Critical Inspection Report

Inspection date:

Steel Stiffening Through Truss Typical Fatigue Prone Details

Detail	Category	Description
SSTT1	D	Riveted connection of tension diagonals to top and bottom chord.
SSTT2	D	Riveted connection of tension vertical below the suspender cables to top chord.
SSTT3	A	Base metal (painted) of tension diagonals and verticals.



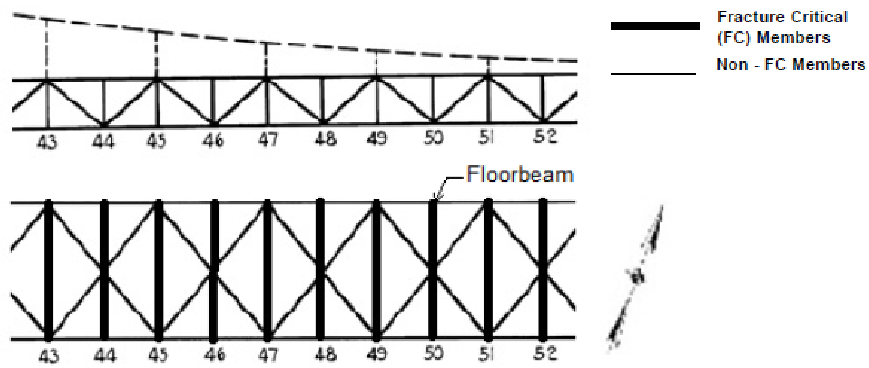


FP MAIN SPAN TRUSS (SAMPLE ENTRIES)

SPAN	MEMBER			LENGTH/ WIDTH	TYPE OF MEMBER	FPD	INSP. MTHD.	INSPECTION RESULTS, REMARKS, OR RECOMMENDATIONS	SKETCH/ PHOTO
Span 4									
Span 4	Right	Diagonal	U1L2	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
			L20U21	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
		Vertical	U1L1	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
			U21L21	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
Span 4	Left	Diagonal	U1L2	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
			L20U21	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
		Vertical	U1L1	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
			U21L21	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
Span 5									
Span 5	Right	Diagonal	U25L26	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
			L26'U25'	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
		Vertical	U25L25	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
			U27'L27'	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
Span 5	Left	Diagonal	U25L26	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
			L26'U25'	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
		Vertical	U25L25	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
			U27'L27'	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
Span 6									
Span 6	Right	Diagonal	U21'L20'	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
			L2'U1'	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
		Vertical	U21'L21'	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
			U1'L1'	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
Span 6	Left	Diagonal	U21'L20'	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
			L2'U1'	25'-0"	Steel built-up riveted members.	SSTT1, SSTT3	VT	See typical FPD sketch above	Typ FPD
		Vertical	U21'L21'	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD
			U1'L1'	18'-0"	Steel built-up riveted members.	SSTT2-3	VT	See typical FPD sketch above	Typ FPD

OREGON DEPARTMENT OF TRANSPORTATION
FATIGUE PRONE & INTERSECTING WELD DETAIL INSPECTION REPORT
(Executive Summary)

Bridge Name:	Willamette River (St John's Bridge)	**Owner:**	State	**Bridge No.:** 06497
District 2B	**County:** Multnomah	**Year Built:**	1931	**Highway:** 123
FC Structure Type:	Steel Stiffening Through Truss Floor System	**Frequency:**	24 months	**MP:** 0.91
FC Member Type:	Floorbeams	**Date of Inspection:**		
Agency Inspected By:		**Inspector Name:**		



TYPICAL FLOOR SYSTEM PLAN

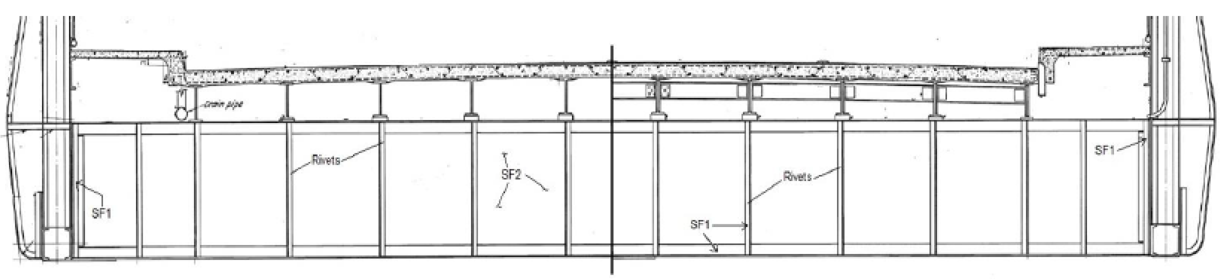
(NOTE: Bents and floorbeams are numbered from West to East with increasing MP.)

NOTE: Fatigue Prone details for the floorbeams are documented in the Fracture Critical Inspection Report

Inspection date:

Steel Floorbeam Typical Fatigue Prone Details

Detail	Category	Description
SF1	D	Riveted connection of transverse (bearing) stiffeners, top flange angles, bottom flange angles, and connection to the stiffening truss.
SF2	A	Base metal (painted) of floorbeams.



Section At Odd Numbered Panel Points   Section At Even Numbered Panel Points

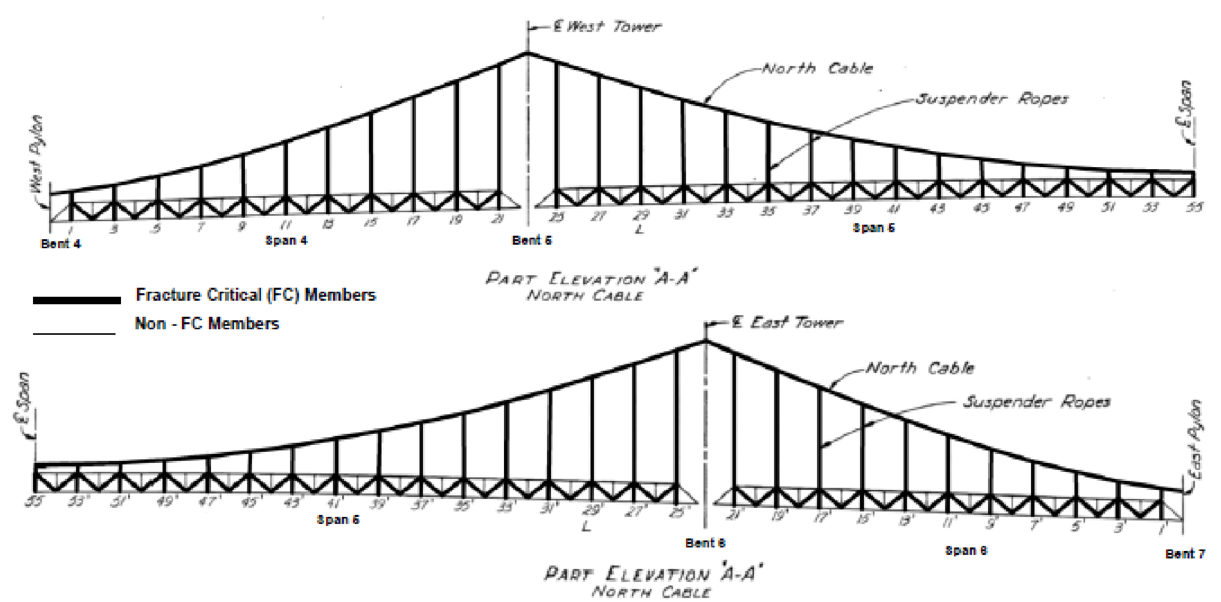
FP MAIN SPAN FLOOR SYSTEM (SAMPLE ENTRIES)

SPAN	MEMBER	LENGTH/ WIDTH	TYPE OF MEMBER	FPD	INSP. MTHD.	INSPECTION RESULTS, REMARKS, OR RECOMMENDATIONS	SKETCH/ PHOTO
Span 4							
Span 4	Floorbeam 0	50'-08"	Steel built-up riveted members.	SF1-2	VT	See typical FPD sketch above.	Typ FPD
	Floorbeam 22	50'-08"	Steel built-up riveted members.	SF1-2	VT	See typical FPD sketch above.	Typ FPD
Span 5							
Span 5	Floorbeam 24	50'-08"	Steel built-up riveted members.	SF1-2	VT	See typical FPD sketch above.	Typ FPD
	Floorbeam 24'	50'-08"	Steel built-up riveted members.	SF1-2	VT	See typical FPD sketch above.	Typ FPD
Span 6							
Span 6	Floorbeam 22'	50'-08"	Steel built-up riveted members.	SF1-2	VT	See typical FPD sketch above.	Typ FPD
	Floorbeam 0'	50'-08"	Steel built-up riveted members.	SF1-2	VT	See typical FPD sketch above.	Typ FPD

FP MAIN SPAN CABLES

OREGON DEPARTMENT OF TRANSPORTATION
FATIGUE PRONE & INTERSECTING WELD DETAIL INSPECTION REPORT
(Executive Summary)

Bridge Name:	Willamette River (St John's Bridge)	**Owner:**	State	**Bridge No.:** 06497
District: 2B	**County:** Multnomah	**Year Built:**	1931	**Highway:** 123
FC Structure Type:	Main Cables and Suspender Cables	**Frequency:**	24 months	**MP:** 0.91
FC Member Type:	Cables	**Date of Inspection:**		
Agency Inspected By:		**Inspector Name:**		



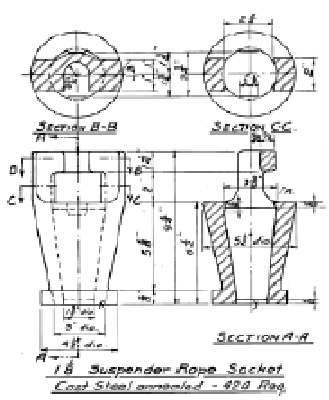
(NOTE: Bents and suspender cables are numbered from West to East with increasing MP.)

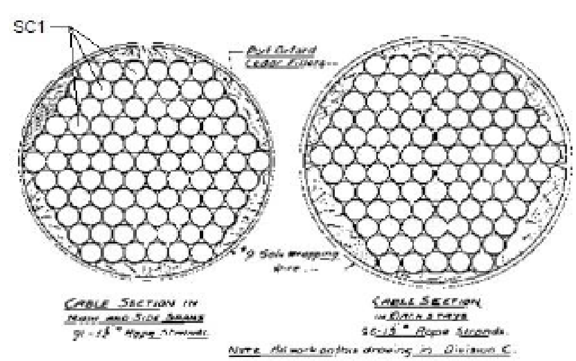
NOTE: Fatigue Prone details for the cables are documented in the Fracture Critical Inspection Report

Inspection date:

Steel Cable Typical Fatigue Prone Details

Detail	Category	Description
SC1	B	Cold-drawn base metal of steel wires in the two wrapped main cables and 212 painted 1 5/8" diameter suspender cables.





FP MAIN SPAN CABLES (SAMPLE ENTRIES)

SPAN	MEMBER		LENGTH/ WIDTH	TYPE OF MEMBER	FPD	INSP. MTHD.	INSPECTION RESULTS, REMARKS, OR RECOMMENDATIONS	SKETCH/ PHOTO
Main Cables								
4	Right	Main Cable		Wrapped steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
5	Right	Main Cable		Wrapped steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
6	Right	Main Cable		Wrapped steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
4	Left	Main Cable		Wrapped steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
5	Left	Main Cable		Wrapped steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
6	Left	Main Cable		Wrapped steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Suspender Cables								
Span 4								
Span 4	Right	Suspender 1		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 4	Right	Suspender 21		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 4	Left	Suspender 1		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 4	Left	Suspender 21		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 5								
Span 5	Right	Suspender 25		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 5	Right	Suspender 25'		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 5	Left	Suspender 25		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 5	Left	Suspender 25'		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 6								
Span 6	Right	Suspender 21'		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 6	Right	Suspender 1'		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 6	Left	Suspender 21'		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD
Span 6	Left	Suspender 1'		Painted steel wires.	SC1	VT	See typical FPD sketch above.	Typ FPD

MAIN SPAN GUSSET PLATES (SAMPLE ENTRIES)

Gusset Plate Condition Assessment Form

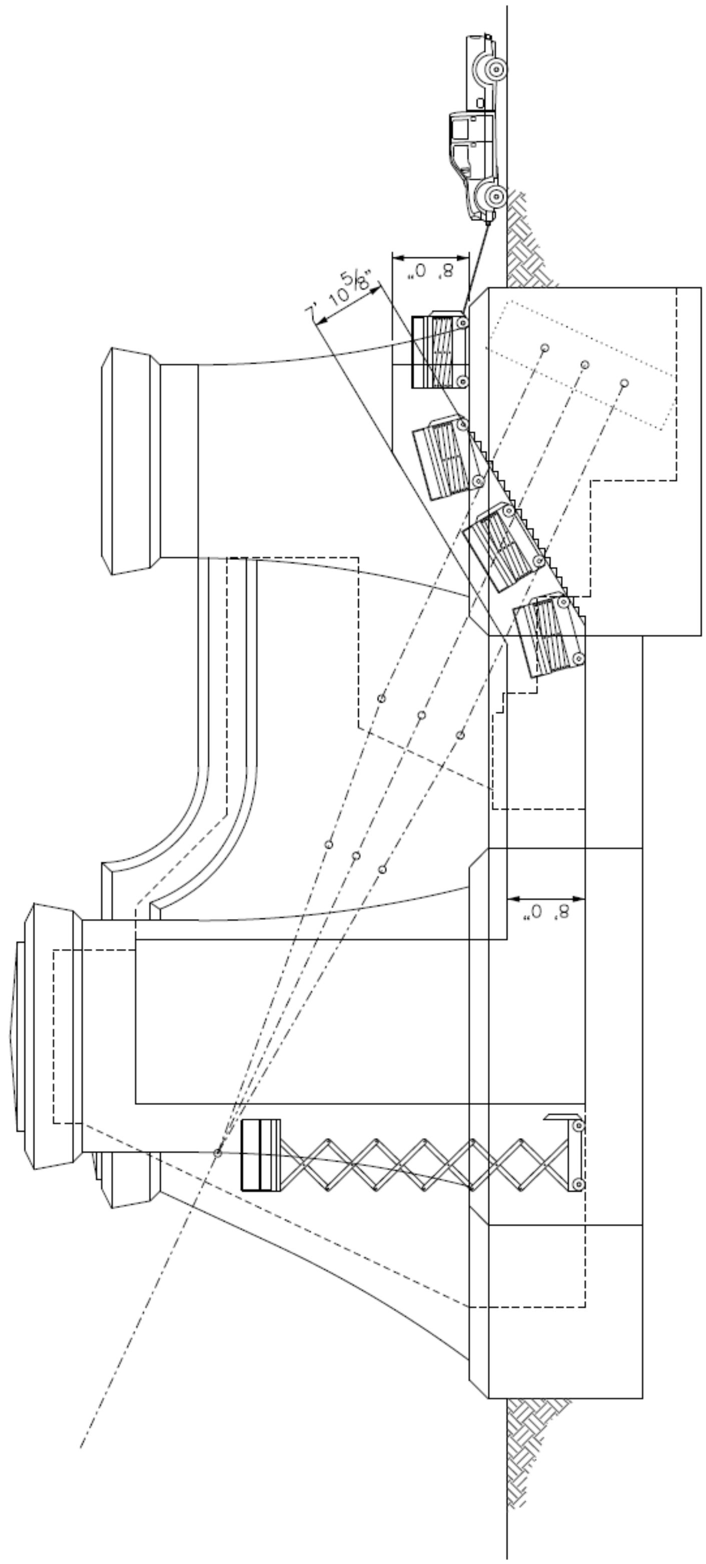
1.) Condition Assessment is visual
2.) Gusset Plate Areas of concern
- * Condition of the Gusset Plate immediately adjacent to each connecting member
- * Whether distortion is present on each unsupported edge of the plate
- * The number of missing fasteners associated with connecting members

Structure: Willamette River (St. Johns Bridge) Mile Point: 0.91 South : Right
Bridge ID: 06497 Frequency: 24 months North : Left
Inspectors: ______ Date: ______

Span	Truss	Panel Point	Gusset Plate Thickness, Amount of Distortion and Remarks	Distortion CS	Smart Flags			Number of Missing or Deteriorated Fasteners	
					Pack Rust CS	Section Loss CS	Steel Fatigue CS		
4	South	L0							WS
4	South	L22							
5	South	L24							MS
5	South	L24'							
6	South	L22'							ES
6	South	L0'							
4	South	U0							WS
4	South	U22							
5	South	U24							MS
5	South	U24'							
6	South	U22'							ES
6	South	U0'							
4	North	L0							WS
4	North	L22							
5	North	L24							MS
5	North	L24'							
6	North	L22'							ES
6	North	L0'							
4	North	U0							WS
4	North	U22							
5	North	U24							MS
5	North	U24'							
6	North	U22'							ES
6	North	U0'							

Note: If a gusset plate is found to contain deficiencies or defects that would have a direct impact on the capacity of either the panel point or the bridge, the bridge inspector is expected to invoke the critical finding notification procedures as specified in the Element Coding Guide.

EAST ANCHORAGE (PIER 8) ACCESS PROCEDURE



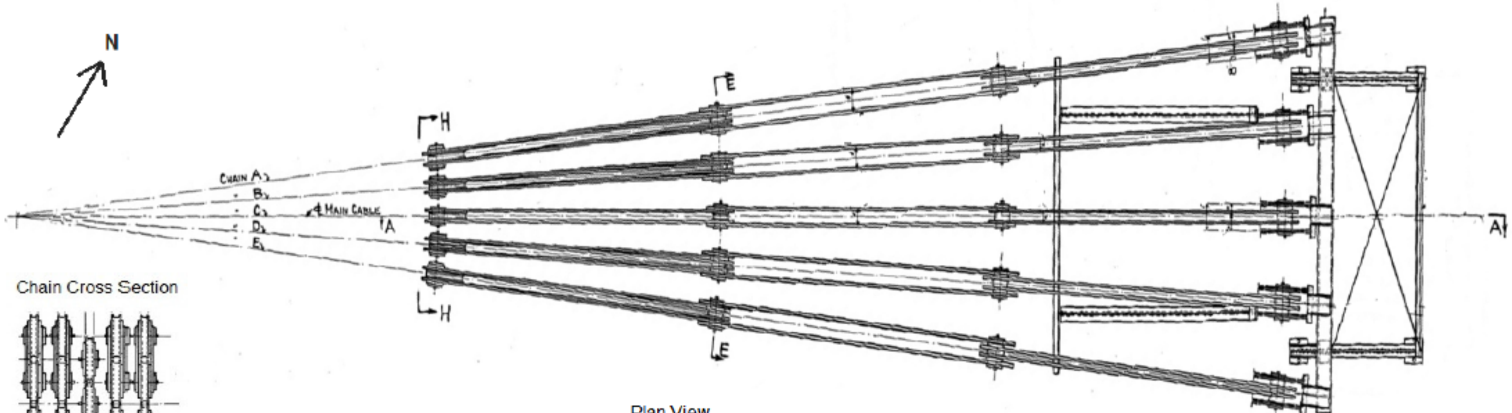
St. John's Bridge Inspection - Field Notes

Bridge #: 06497

Inspector: ____________________

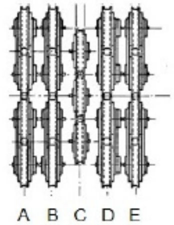
East Anchorage - North Cable - Plan View and Cross Section

Date: ____________________



Plan View

Chain Cross Section



Section H-H

Note	Description	%CS (1-2-3-4)	Photo

EAST ANCHORAGE – NORTH CABLE

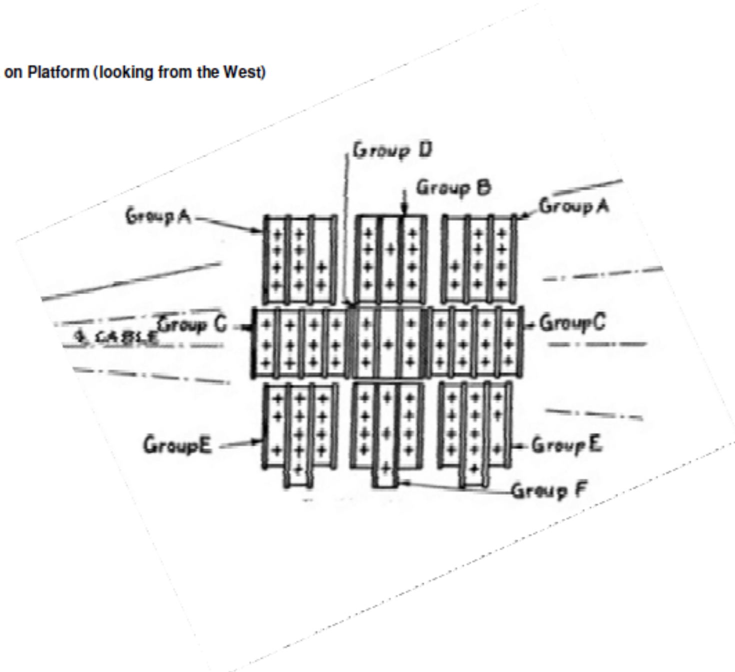
St. John's Bridge Inspection - Field Notes

Bridge #: 06497

Inspector: ____________

East Anchorage - North Cable - Strand Block on Platform (looking from the West)

Date: ____________



Note	Description	%CS (1-2-3-4)	Photo

EAST ANCHORAGE – NORTH CABLE

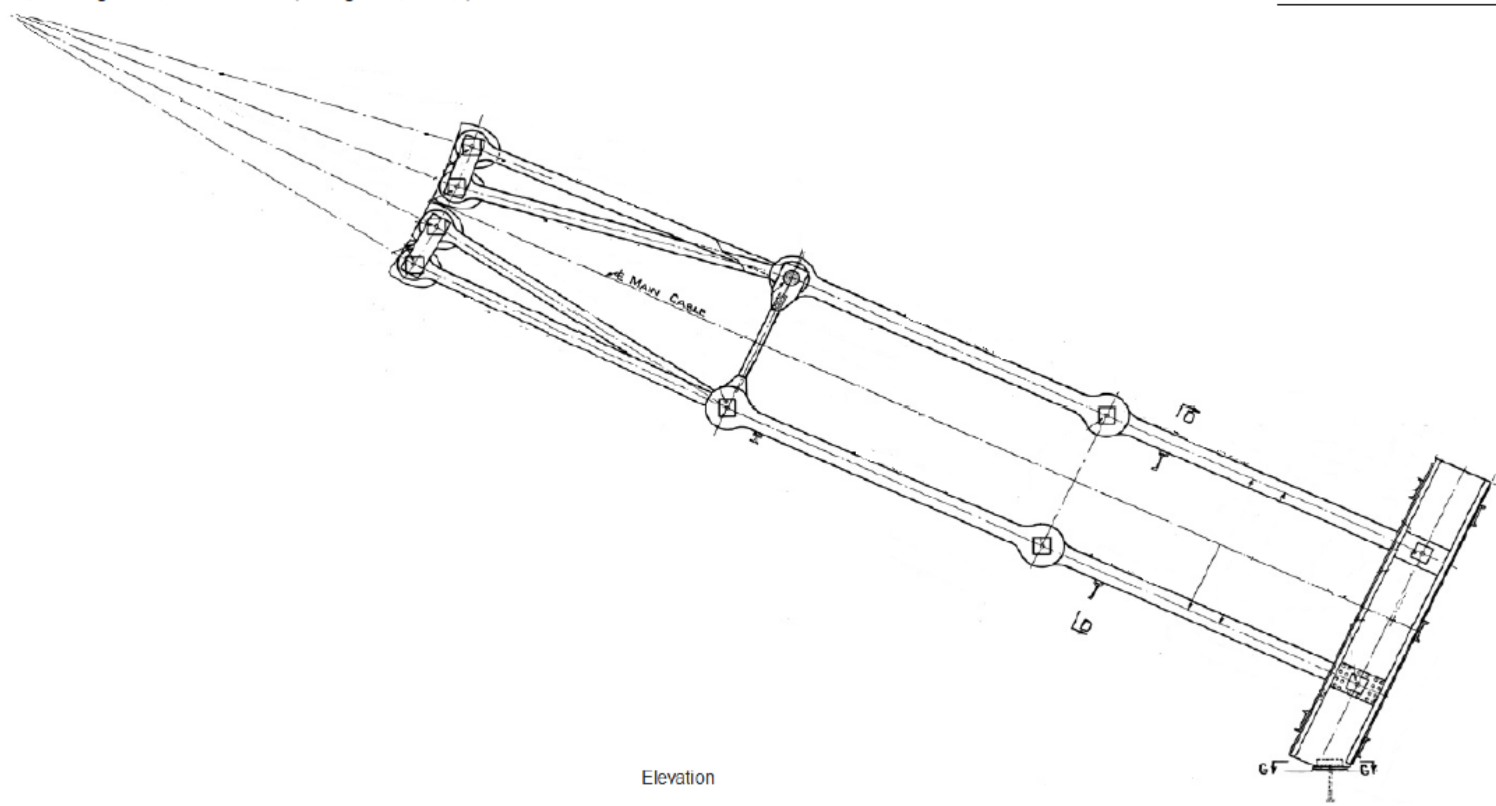
St. John's Bridge Inspection - Field Notes

Bridge #: 06497

Inspector: ____________

East Anchorage - North Cable - Chain A (looking from the North)

Date: ____________



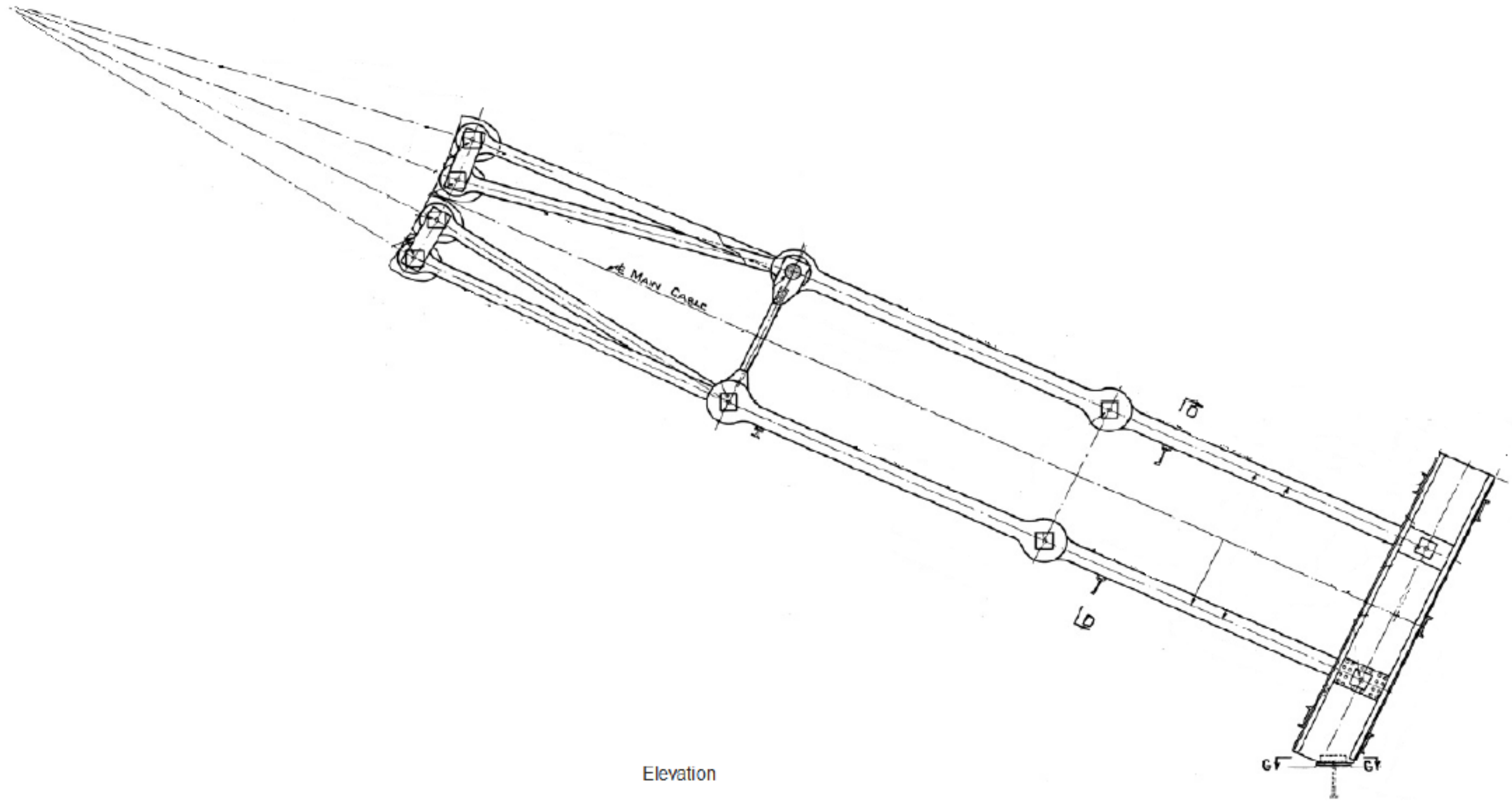
Elevation

Note	Description	%CS (1-2-3-4)	Photo

St. John's Bridge Inspection - Field Notes

Bridge #: 06497 **Inspector:** ____________

East Anchorage - North Cable - Chain B (looking from the North) **Date:** ____________



Elevation

Note	Description	%CS (1-2-3-4)	Photo

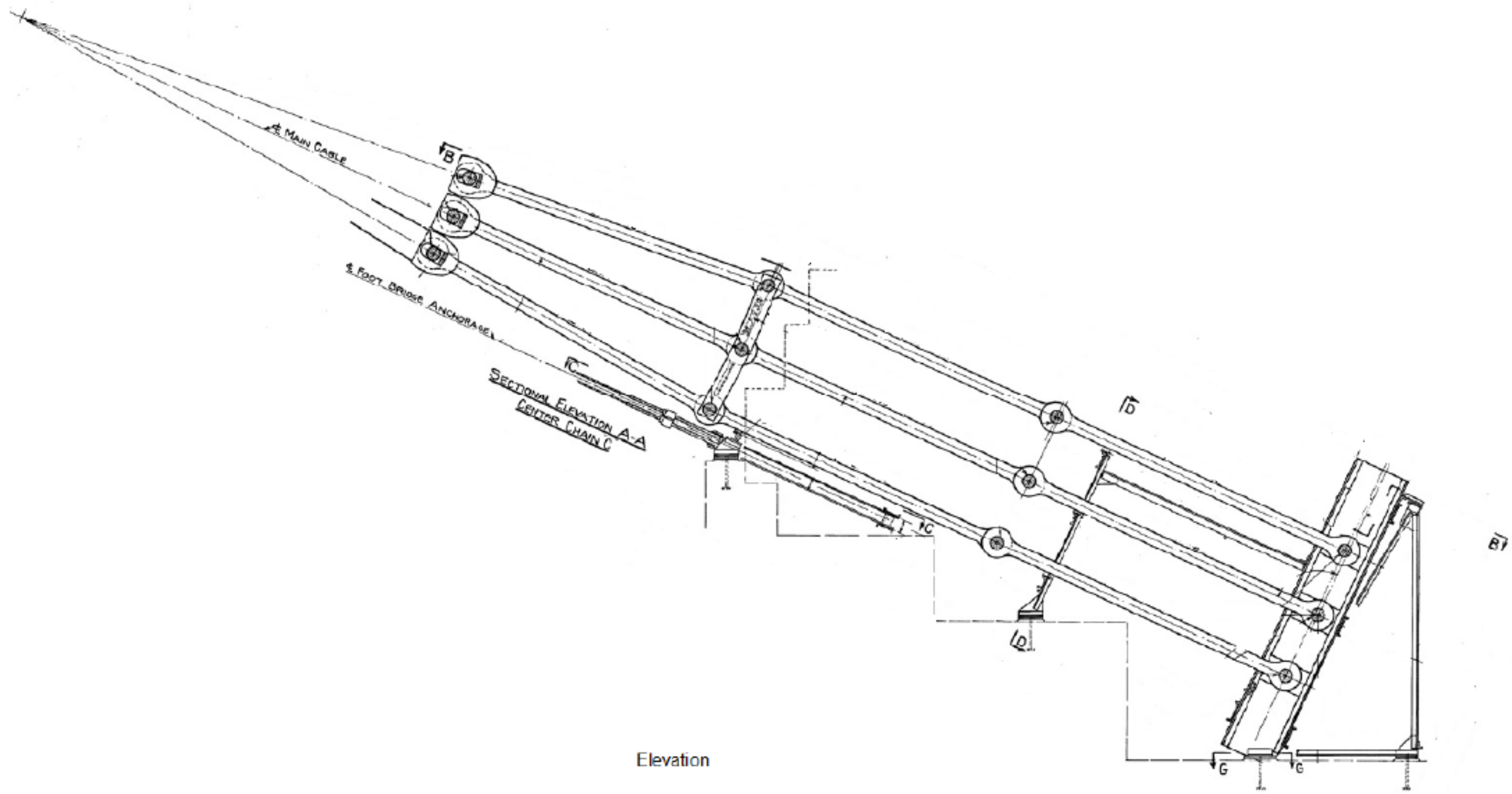
St. John's Bridge Inspection - Field Notes

Bridge #: 06497

Inspector: ______________

East Anchorage - North Cable - Chain C (looking from the North)

Date: ______________



Elevation

Note	Description	%CS (1-2-3-4)	Photo

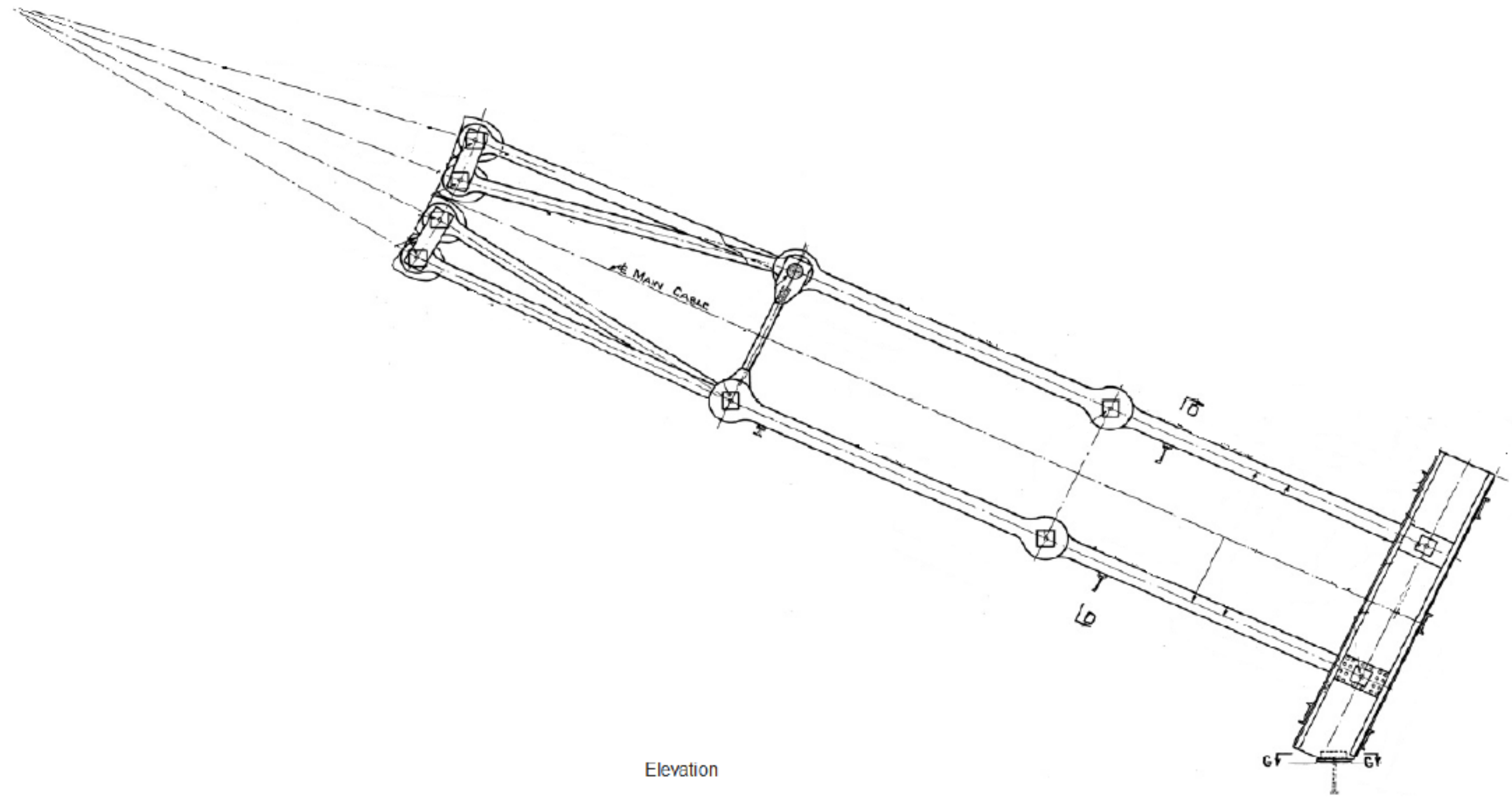
St. John's Bridge Inspection - Field Notes

Bridge #: 06497

Inspector: ______

East Anchorage - North Cable - Chain D (looking from the North)

Date: ______



Elevation

Note	Description	%CS (1-2-3-4)	Photo

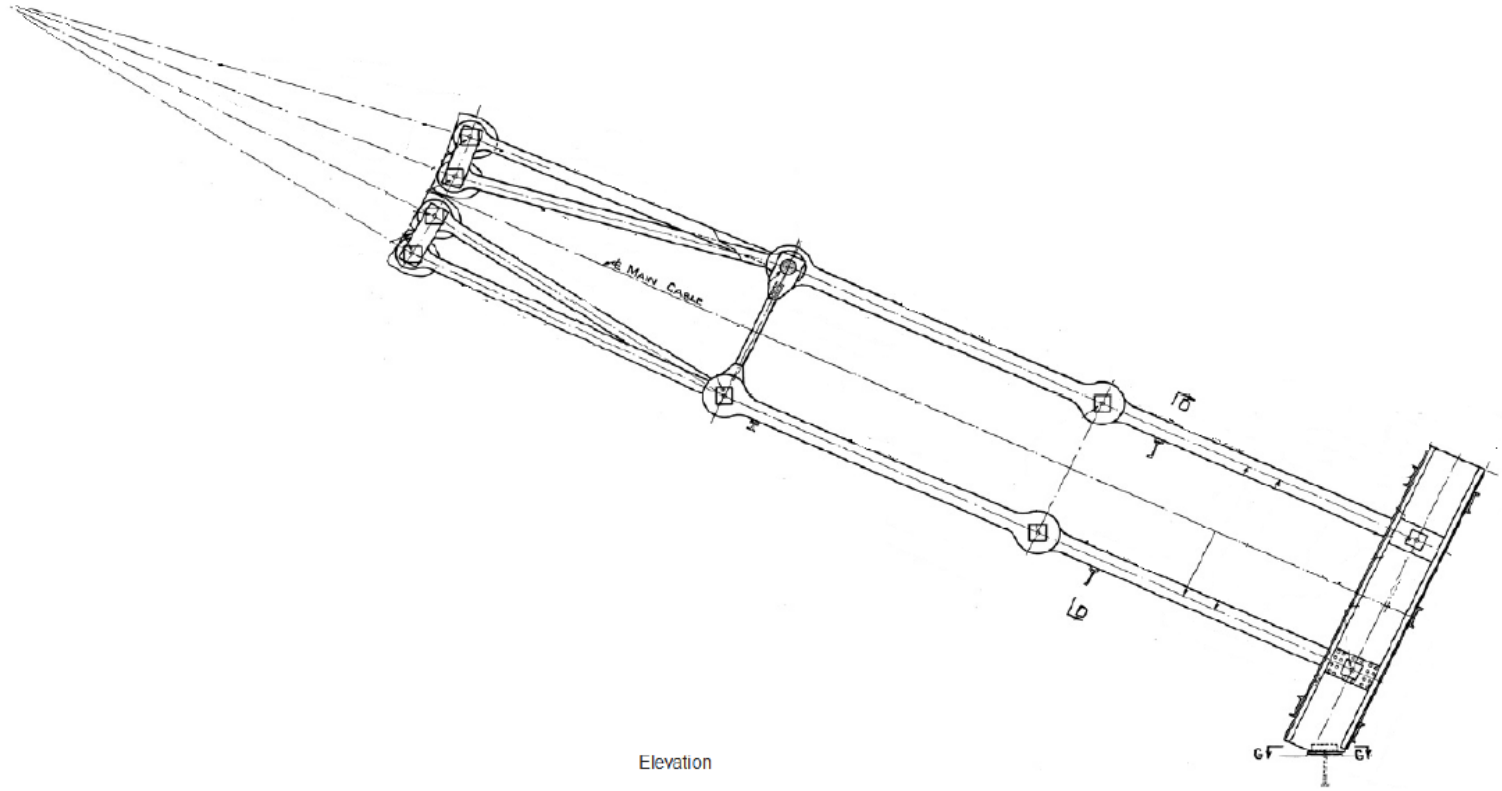
St. John's Bridge Inspection - Field Notes

Bridge #: 06497

Inspector: ____________________

East Anchorage - North Cable - Chain E (looking from the North)

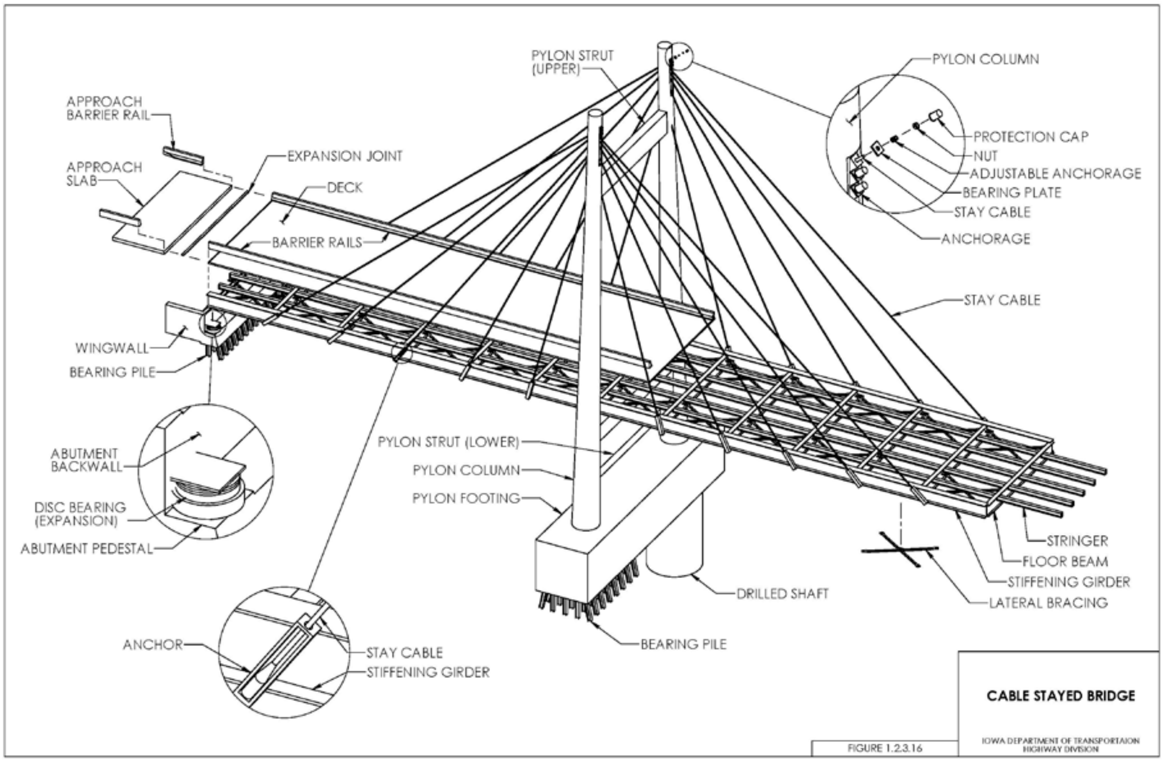
Date: ____________________



Elevation

Note	Description	%CS (1-2-3-4)	Photo

3.1.3 Inspection Procedures for Complex Bridge Components of Cable-Stayed Bridges



(Figure from Iowa Department of Transportation Bridge Inspection Manual)

BRIDGE INSPECTION MANUAL FOR CABLE STAYED BRIDGE (SPECIAL BRIDGE) SEPTEMBER 2014

This example is derived from the Special Bridge Inspection Manual for Cable Stayed Bridge, one of several manuals improved by the Japan International Cooperation Agency (JICA) with the Department of Public Works and Highways (DPWH) in the implementation of the Technical Cooperation Project for the Improvement of Quality Management for Highways and Bridge Construction and Maintenance, Phase II (2011-2014).

A cable stayed bridge is a complex structure with complicated design, inspection and maintenance characteristics. There may be unique methods of access, box shaped members or components that should be inspected both on the interior and exterior, including climbable towers, primary longitudinal members, etc. Before mobilizing the inspection team to the bridge site, the inspection route and coordinated schedule should be planned. Proper and consistent numbering of the elements is necessary to avoid misinterpreting the location of the defects.

When developing an effective inspection program, the following factors should be considered:

- Traffic restrictions
- Access difficulties (e.g., waterways, terrain, buildings, built-up areas, combined bridges)
- Safety of inspection personnel and the traveling public
- Specialized equipment or personnel such as divers that may be needed
- Water level restrictions (i.e., tidal fluctuations)

If the inspector is not familiar with the site and other external factors, a site visit is recommended.

Bridge Details and History

Prior to the inspection, the inspector should review all available information relative to:

1. Type of bridge
2. Maintenance history
3. As-Built Drawings
4. Previous inspection reports
5. Photographs

Copies of the above-listed information for the bridge should be properly managed and stored by the owner.

In particular, As-Built Drawings are important to understand the specific cable stayed bridge. Each bridge has its own unique features. There are no standard drawings for cable stayed bridges. Before scheduling the inspection, As-Built Drawings should be collected and electronic data should be uploaded for use during the field inspection.

Inspectors should review the As-Built Drawings to confirm the details on the structure and to formulate field note checkpoints sheets before the start of the bridge inspection.

In the absence of As-Built Drawings, it is recommended to collect bridge data from Contract Drawings or from documents of past rehabilitation work. In case there are no available bridge data, a site survey should be performed to collect basic bridge data and prepare general inventory drawings.
The information mentioned above shall be reviewed prior to the inspection, so that the Team Leader and inspection team members are all aware of critical areas, previously encountered problems or unusual features.

A copy of previous inspection reports with photographs included, and any other relevant information, should be brought to the bridge site for reference during the inspection.

Resource Requirements

In order to perform a proper and efficient inspection, appropriate equipment and manpower should be readily available. A list of recommended equipment is included in the following Table and should be carefully considered prior to the inspection. It may also be necessary to arrange specialized equipment on a case-by-case basis. These might include scaffolding, rigging, industrial rope access techniques, under bridge inspection vehicle, boats, testing equipment, etc.

Table

Equipment for Visual Inspection (Condition Inspection)

1. Safety Vest
2. Safety Shoes
3. Shirt with long sleeves and Pants
4. Hard Hat
5. Gloves
6. Hand Mirror for viewing behind bearings, etc.
7. Flashlight
8. Geologist's Hammer
9. Measuring Tape
10. Crayon, Keel, Felt-tip Marker and/or Chalk for marking
11. Digital Camera with zoom and date feature
12. Inspection Forms
13. Sketch Drawing Forms
14. Copy of previous report
15. First-Aid Kit
16. 4-Gas Meter
17. Shovel and Broom
18. Wire Brush
19. Crack Comparator Gauge
20. Extension Ladder
21. Boat or Barge
22. Under Bridge Inspection Vehicle (UBIV)
23. Rope Access Inspector's Kit – suspension harness with equipment
24. Climbing Helmet with Headlamp
25. Climbing Gloves

Inspection and Sketch Drawings Forms

The inspection of a cable stayed bridge is unique to the specific structure, due to the complex design characteristics compared to conventional bridges.

Prior to conducting the inspection, the Inspection and Sketch Drawing Forms will be prepared in advance. All available information relative to the bridge can be viewed and printed out from the database. Also data gathered will be uploaded in the database by inspectors and/or coordinators.

The initial data shown shall be checked for correctness during the bridge inspection, and corrections made or missing information added as necessary.

CONDITION INSPECTION

Purpose

The purpose of the Condition Inspection is to record defects and rate the condition of the cable stayed bridge as a basis for identifying its current maintenance needs, forecasting its future preservation measures and estimating its future funding requirements. Also, the result of Condition Inspection should be used to monitor the deterioration of defects over time.

Scope of the Inspection

The Condition Inspection includes:

- Reviewing the existing inventory data of the bridge structure for accuracy.
- Visually inspecting the bridge components and recording their defects to assess their condition using a standard condition rating system.
- Sketch drawings to monitor the progress and deterioration of defects
- Reporting the condition of each bridge component.
- Providing a general condition rating for the structure as a whole.
- Identifying bridges that require a Rehabilitation Inspection (those with an overall condition state of 3 or 4).
- A photographic record of defects.

During a Condition Inspection, the inspector should record all details of defects for assessing the bridge condition using a standard condition rating system and also for monitoring the progress and deterioration of defects. Therefore, each component of the bridge shall be inspected within arm’s reach distance from the surface of the components.

All surfaces of the components shall be exposed in good natural or artificial light during the inspection, sufficient to observe fine cracks and other defects on the surfaces. Bearings at the abutments and piers shall be inspected at eye level. The interior of both box girders and towers shall also be inspected closely. A visual inspection is performed to cover all parts of the bridge above the ground and water level.

Sketch drawings compiled during the Condition Inspection are very important for analyzing the bridge condition and for the monitoring the deterioration of defects. Inspectors should sketch carefully the details of defects. Sketch drawings of defects should include the location, measurements and severity of defects as much as possible. When inspectors cannot possibly measure the defects, they can roughly estimate measurement through their engineering judgment.

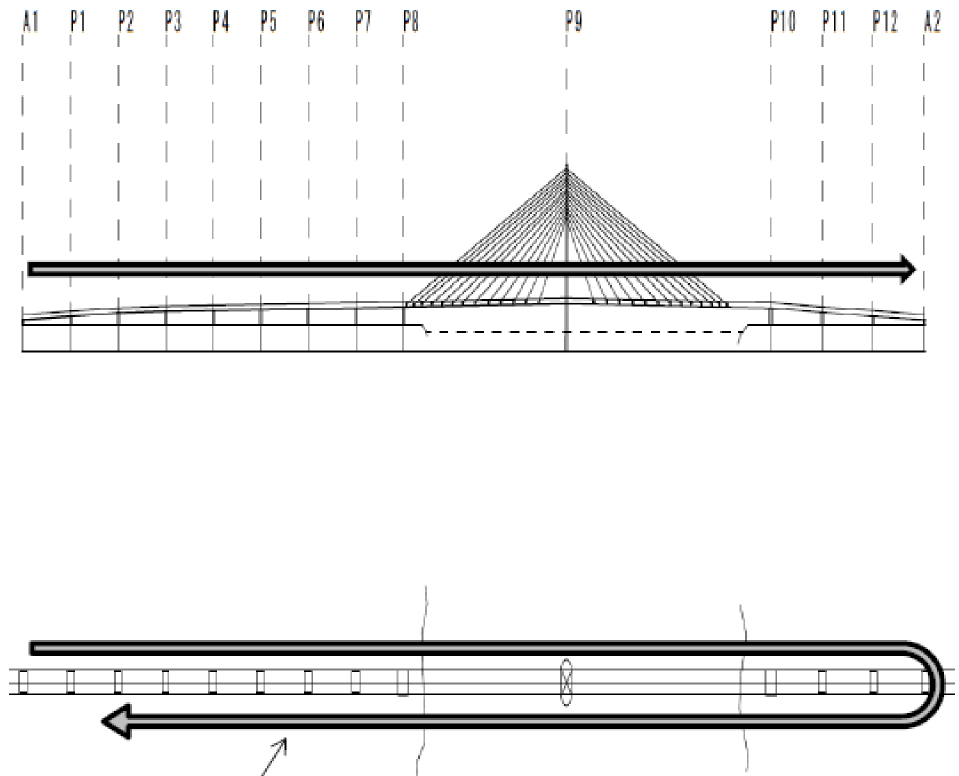
If a previous Rehabilitation Inspection Report is available, the findings of the report will be used in the next Condition Inspection to verify whether these findings remain valid.

Condition Inspection Form

The Bridge Condition Inspection Routes of the cable stayed bridge and the Checkpoints of the Condition Inspection are shown in the following Figures.

Cable stayed bridges are complex structures. Before conducting the inspection, proper numbering of elements and components on the forms should be considered to avoid misinterpretation of its location. During the inspection, each component shall be numbered/marked for easy identification. Numbering and marking of attributes are also shown in the Figures.

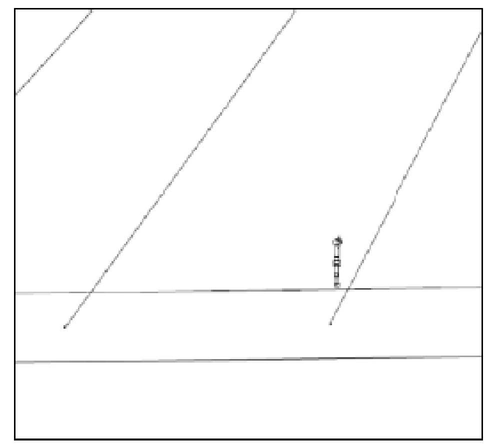
Inspection of Upper Deck



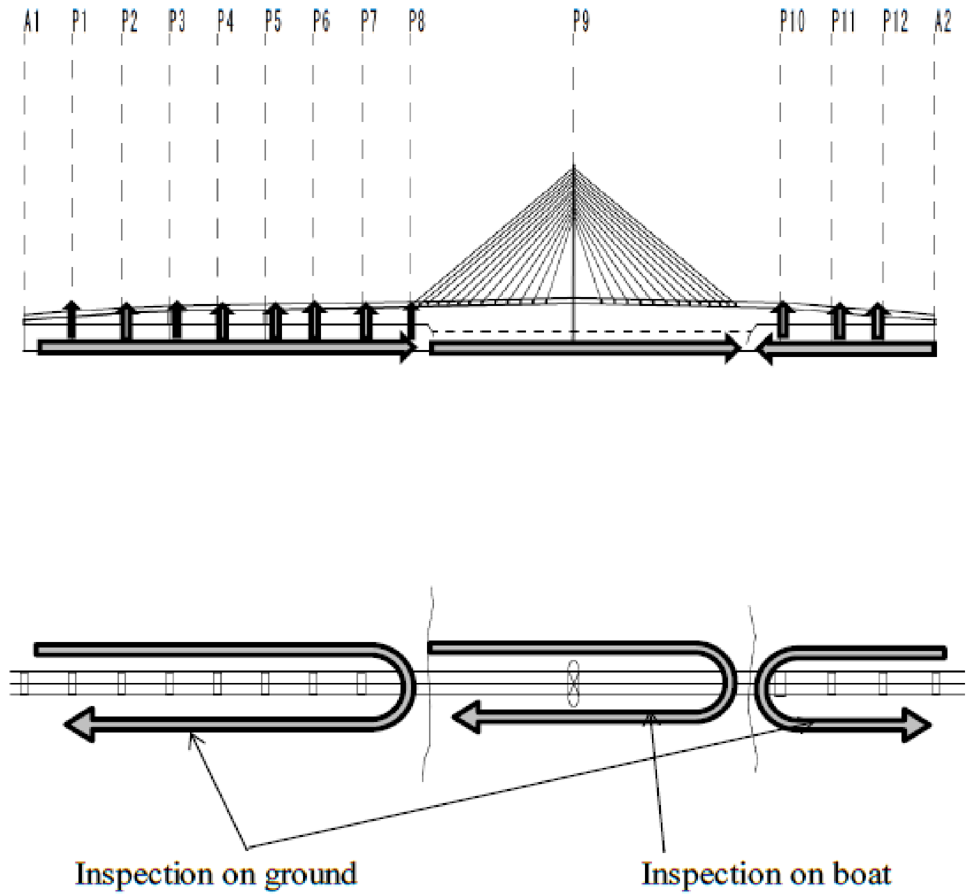
Inspection of Upper Deck

Main Members to be Inspected

- Cable
- Cable Cover, Socket, Anchorage
- Tower
- Railing
- Curb
- Stabilizer
- Pavement
- Drainage
- Expansion Joint

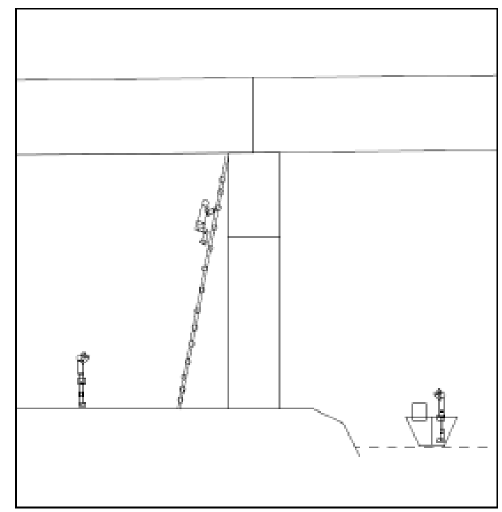


Inspection of Underside

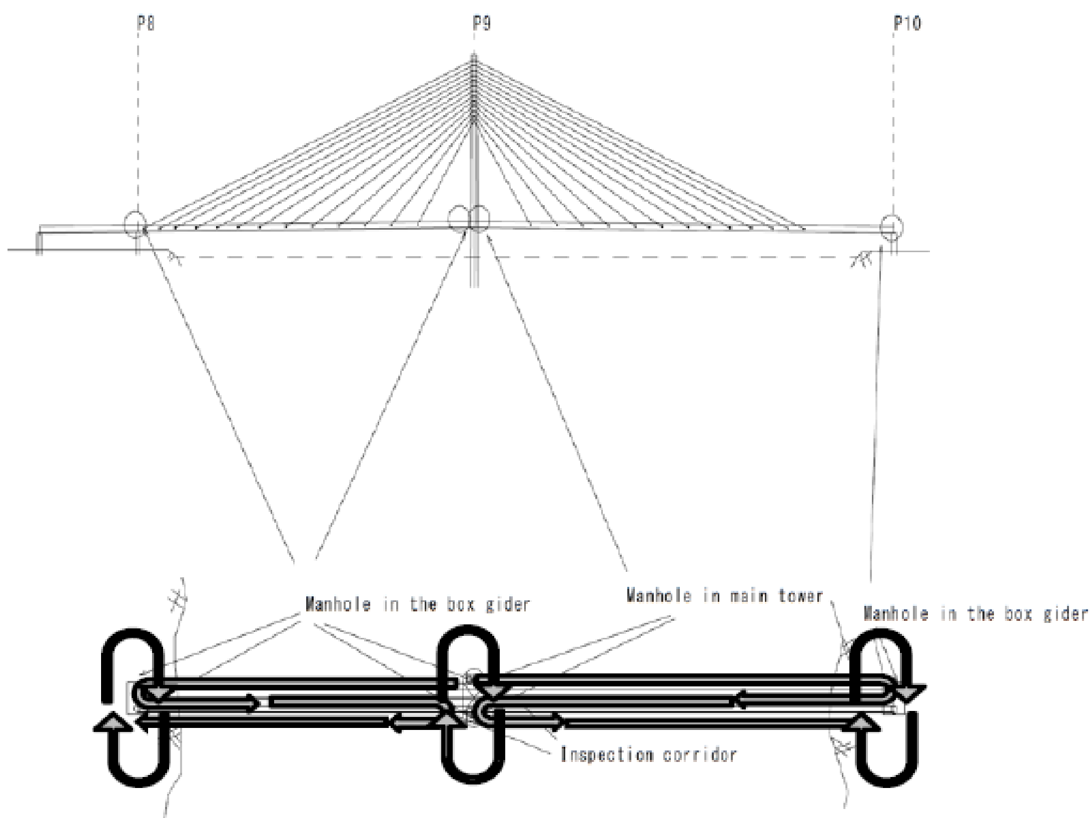


Main Members to be Inspected

- Girder
- Cross Section
- Pier (Side)
- Pier (Top)
- Bearing
- Connection
- Bolt



Inspection on Corridor and Inside Box Girder

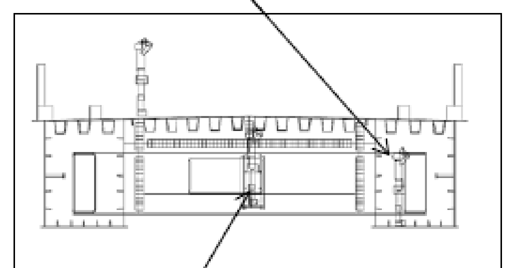


Inspection on corridor and inside the box girder
Inspection around the top of piers

Main Members to be Inspected

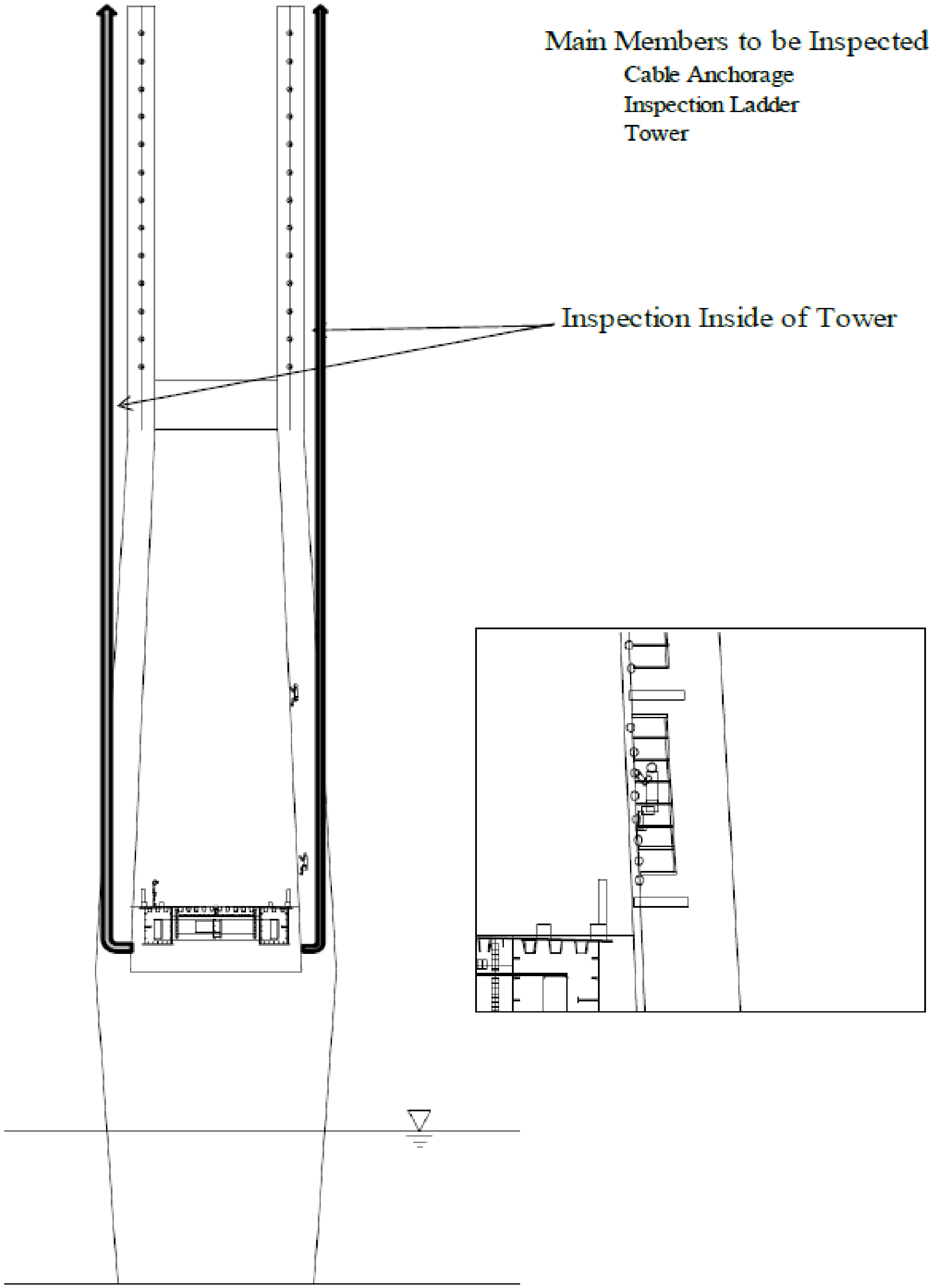
- Deck
- Rib (I, U and Transverse)
- Diaphragm
- Cross Beam
- Girder (Web, Flange)
- Connection
- Bolt
- Inspection Corridor
- Bearing (Pendulum)
- Bearing (Lateral)
- Bearing (Vertical)
- Bearing (Seismic Isolation)
- Restrainer

Inspection inside box girder

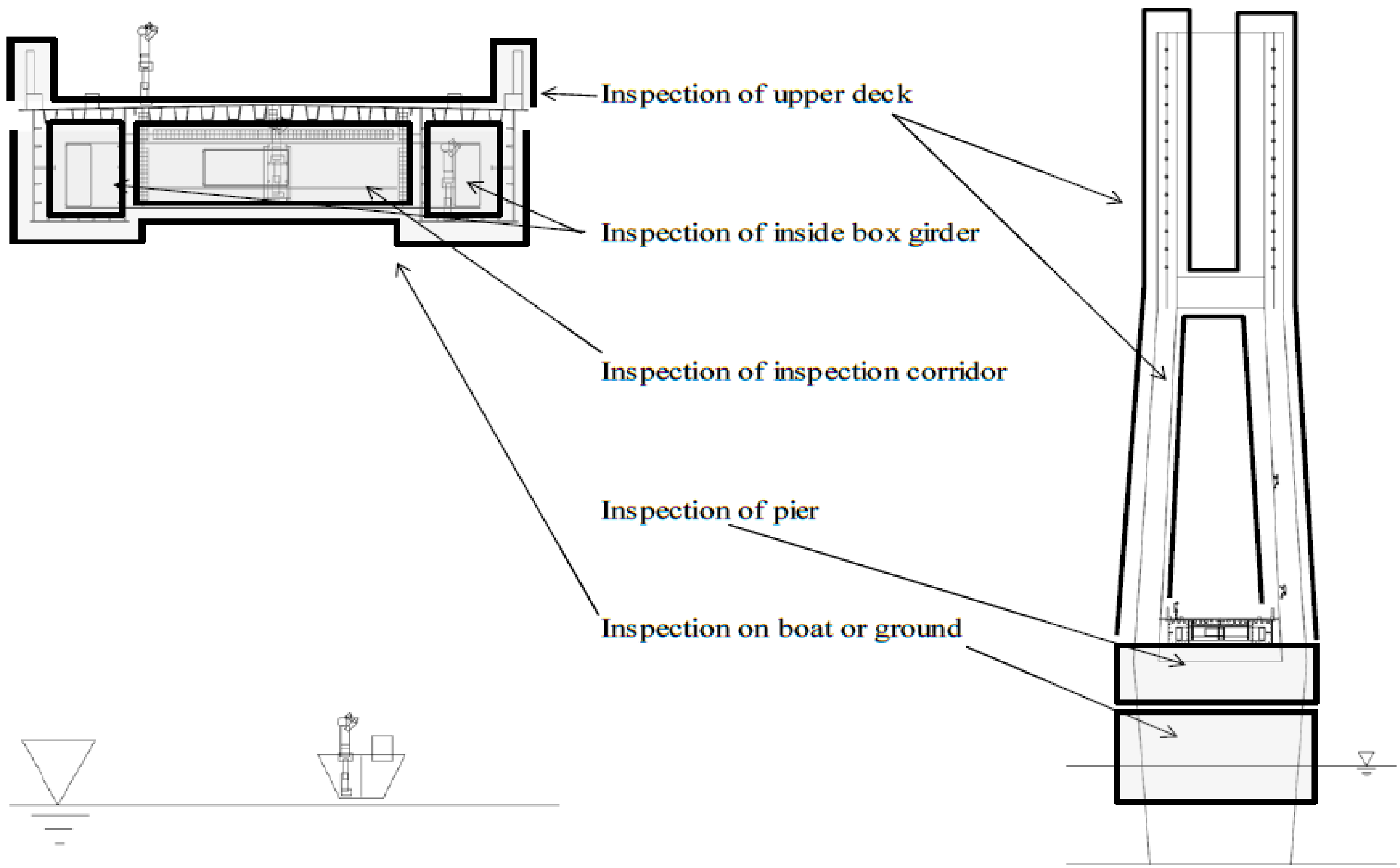


Inspection on corridor

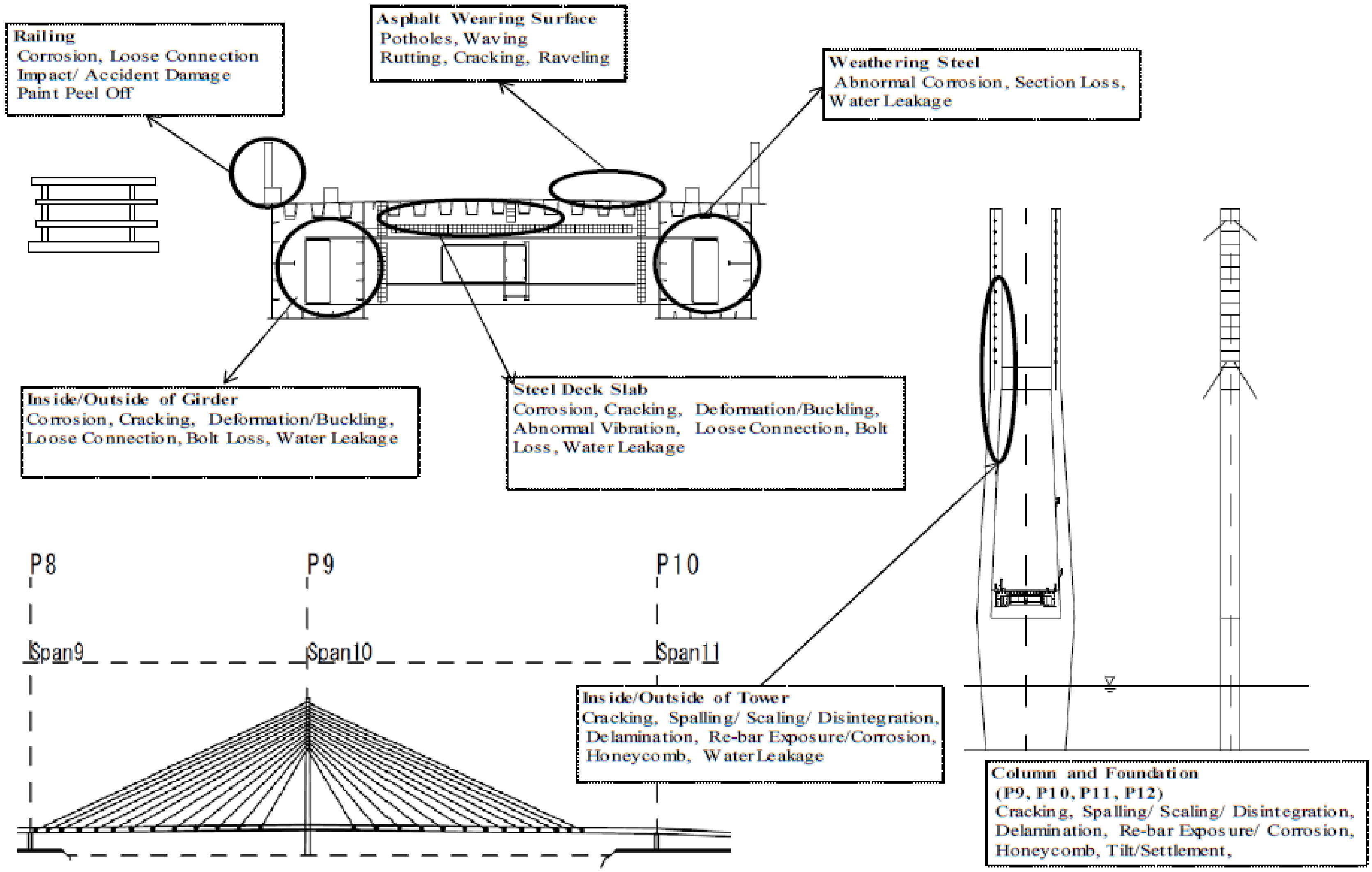
Inspection Inside of Tower



Inspection Area of Each Place

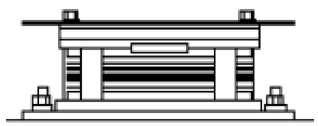


Main Span (Main Structure)



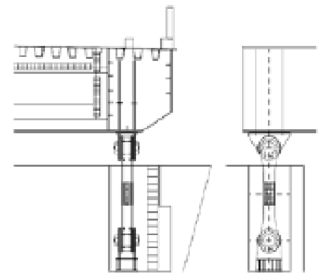
Main Span (Bearing)

Seismic Isolation Bearing (P8, 9, 10)

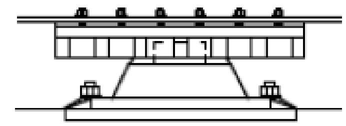


Rubber Type Bearing
Bulging, Abnormal Displacement, Bed (Support) Damage, Corrosion, Loose Connection, Paint Deterioration

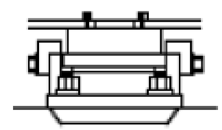
Pendulum Bearing (P8)



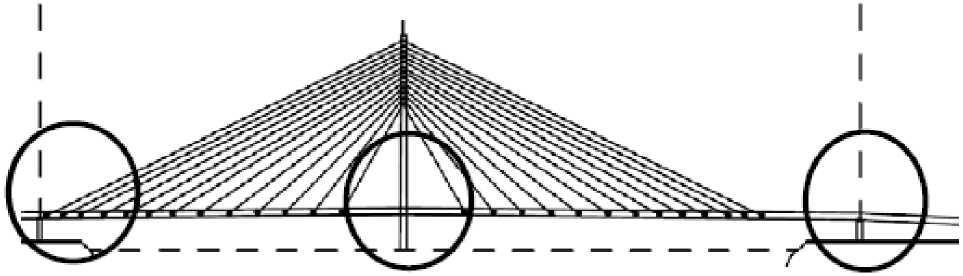
Steel Lateral Bearing (P8, 9, 10)



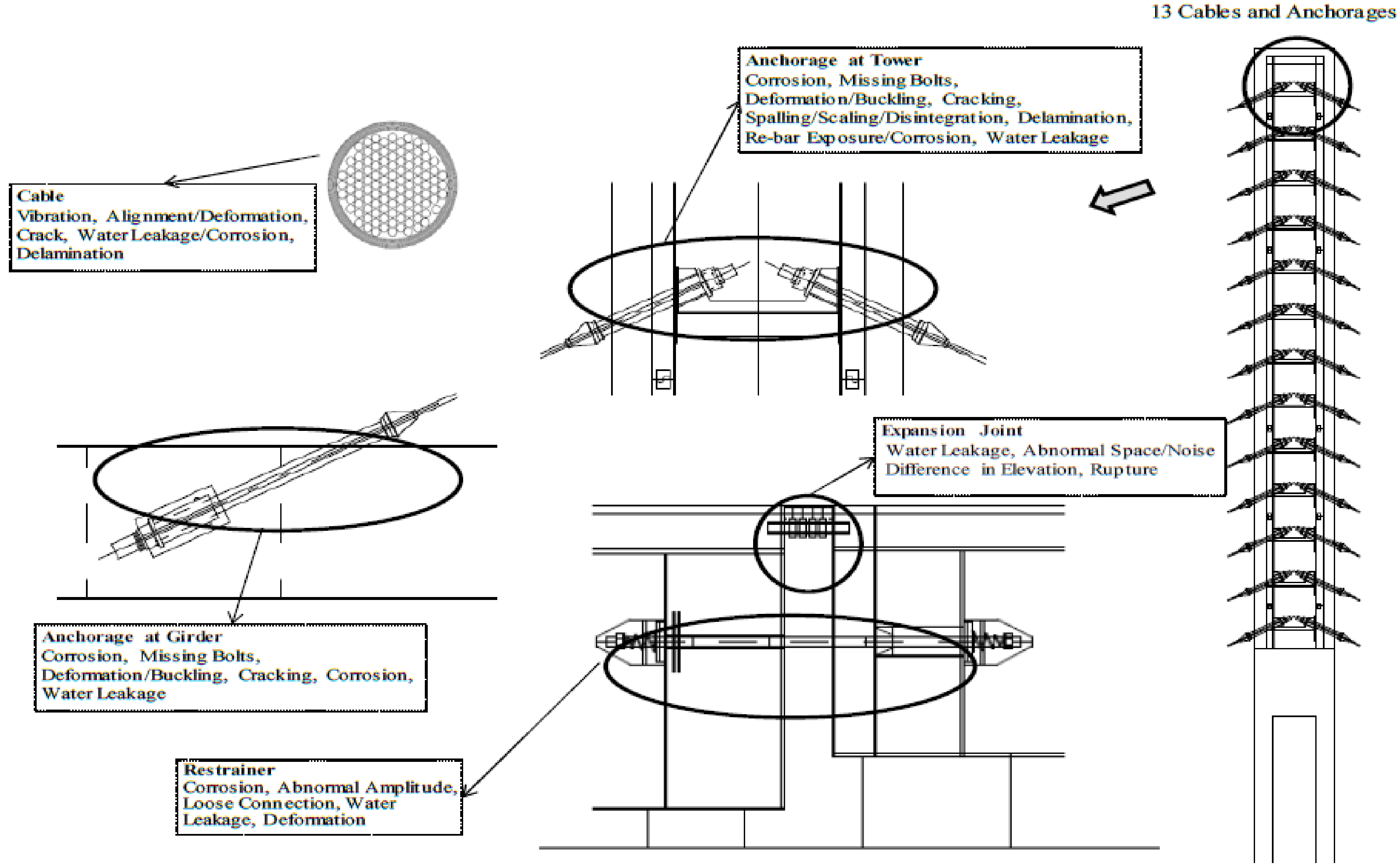
Steel Vertical Bearing (P9, 10)



Steel Type Bearing
Abnormal Displacement, Corrosion, Loose Connection, Paint Deterioration, Bed (support) Damage

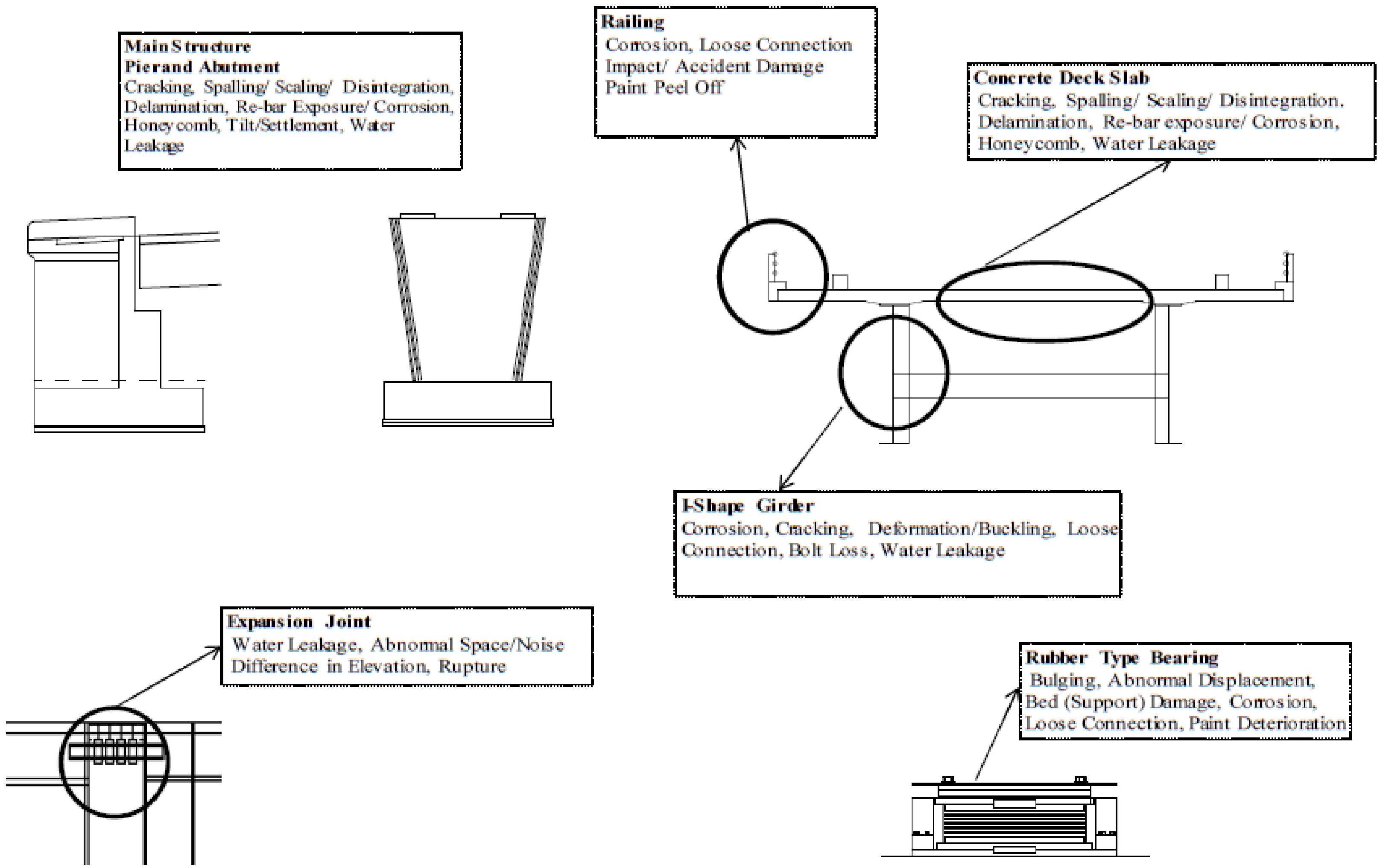


Main Span (Cable, Anchorage, Joint and Restrainer)



Restrainer (P8, P10) and Expansion Joint (A1, A2, P4, P8, P10)

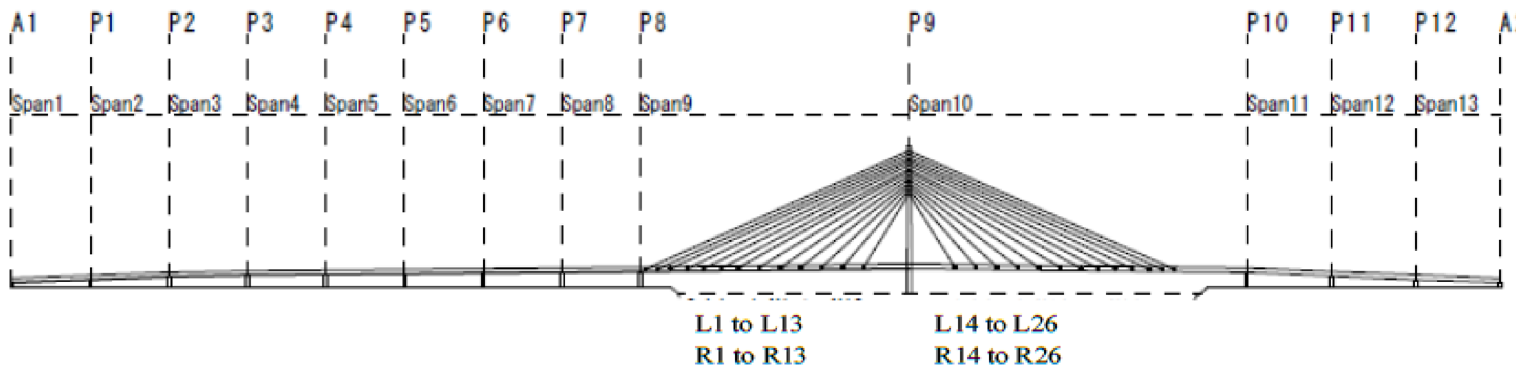
Approach Viaduct



Expansion Joint (A1, A2, P4, P8, P10)

Laminated Rubber Bearing (Approach Viaduct)

Numbering of Members



Cable Grouping and Numbering

<table>
<tr><td></td><td>P8</td><td colspan="2">P9</td><td>P10</td></tr>
<tr><td rowspan="2">Left</td><td colspan="2">Cable 1</td><td colspan="2">Cable 2</td></tr>
<tr><td colspan="2">L1 toL13</td><td colspan="2">L14 to L26</td></tr>
<tr><td rowspan="2">Right</td><td colspan="2">Cable 3</td><td colspan="2">Cable 4</td></tr>
<tr><td colspan="2">R1 to R13</td><td colspan="2">R14 to R26</td></tr>
</table>

Span Numbering

Span 1 to Sapn 13

Pier and Abutment Numbering

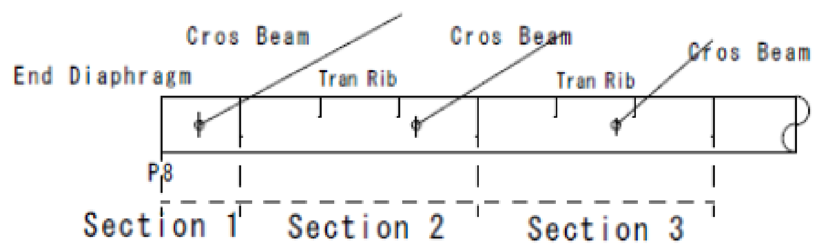
Abutment 1 and Abutment 2
Pier 1 to Pier 12

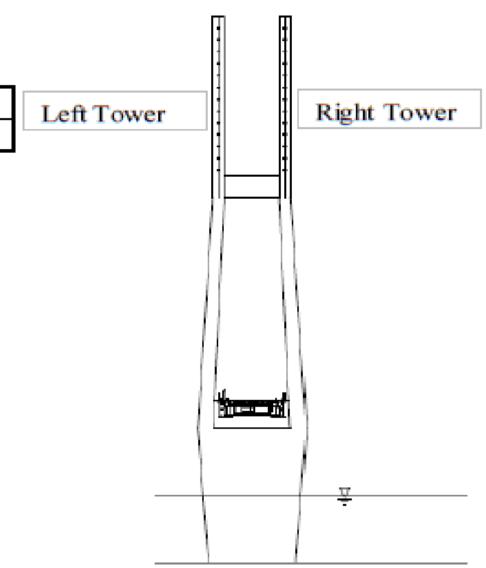
Section for Girder in Cable Stayed Bridge

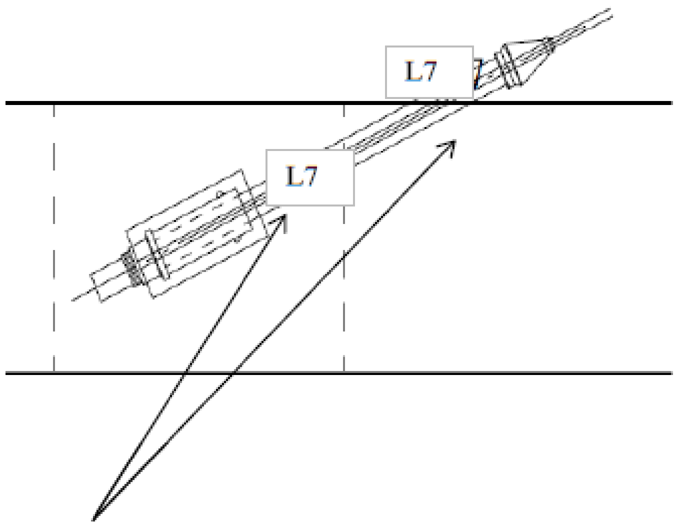
<table>
<tr><td>P8</td><td colspan="2">P9</td><td>P10</td></tr>
<tr><td colspan="2">Section 1 to 15</td><td colspan="2">Section 16 to 33</td></tr>
</table>

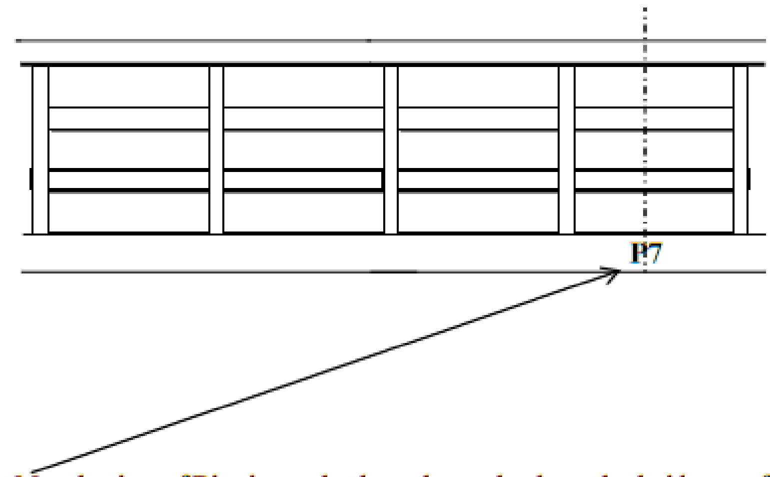
Tower

Left Tower
Right Tower



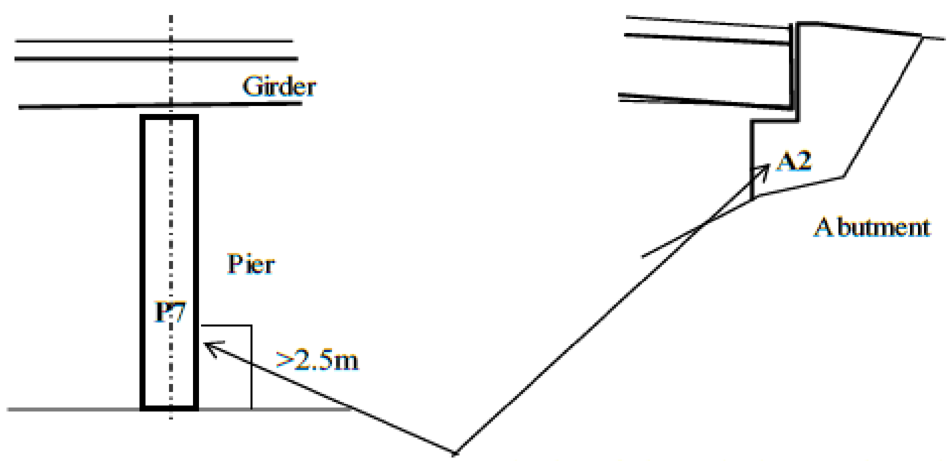






Numbering of Pier is marked on the curb along the bridge surface.

Numbering of Cable is marked on the side of Anchorage, Both outside and inside of the PC Box Girder



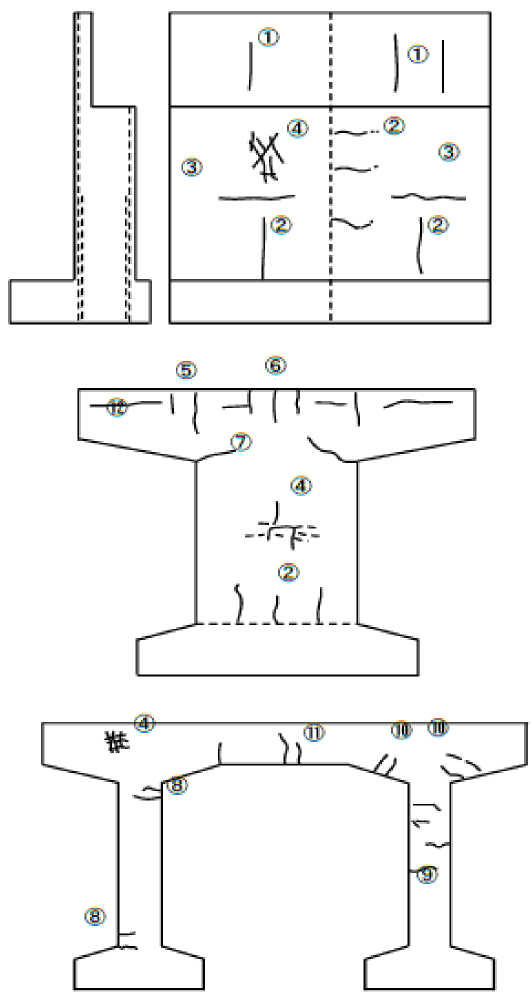
Numbering of Pier and Abutment is marked on the side of the substructures under the bridge.

Condition Data Collection
Special bridges like cable stayed bridges have unique components and materials which are not defined in the BMS Manual for conventional bridges. Bridge Inspectors/Engineers should understand the characteristics and functions beforehand by reviewing the As-Built Drawings and other related documents.

As a reference, some special attributes of cable stayed bridges are listed in the Table below. All other applicable descriptions in the BMS Manual for standard bridges are adopted in this Manual. General patterns of defects in bridges are shown in the following Figures.

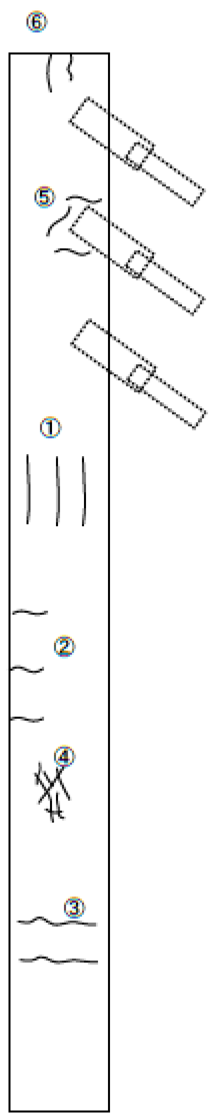
Element	Attribute	Description
Cable	Anchorage at Tower and Girder	Anchorage is to keep the stay cable's tension force for support of bridge. They are quite important parts for the Cable Stayed Bridge. Corrosion and damage of anchorage are contributory to bridge collapse.
	Cable	The cable is the most important attribute for the Cable Stayed Bridge. They suspend girders and put external pre-stressing into the girder. They have coating made of high density polyethylene and cover duct which prevents deterioration of cable. Corrosion and damage of cable are contributory to bridge collapse

General Patterns of Crack Defects on Abutment and Pier



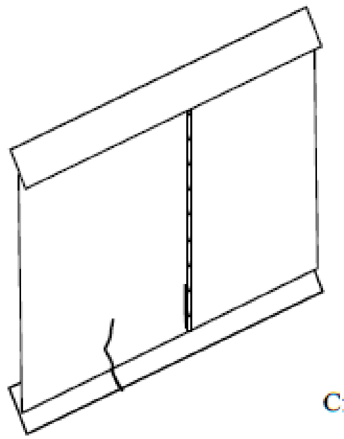
Number	Pattern
1	Crack by regular interval
2	Crack on the concrete casting joint
3	Crack around the changing point of density of reinforcement bar
4	Crack like mesh
5	Crack on topside of overhang beam(coping)
6	Vertical crack on pier center
7	Crack on bottom side of overhang beam(coping)
8	Crack on upper and bottom part of column
9	Crack on column
10	Crack on haunch
11	Bending crack on the span center of beam
12	Horizontal crack on beam

General Patterns of Crack Defects on Tower



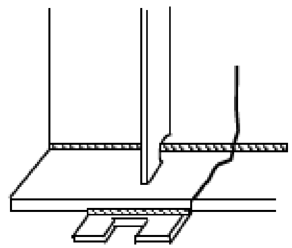
Number	Pattern
1	Crack by regular interval
2	Crack on the concrete casting joint
3	Crack around the changing point of density of reinforcement bar
4	Crack like mesh
5	Crack around anchorage
6	Vertical crack on pier center

General Patterns of Crack Defects on Steel Bridge

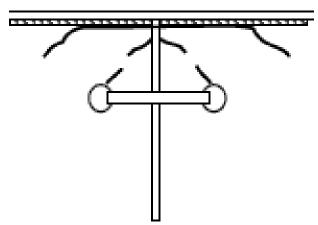


Vertical crack on lower flange or web

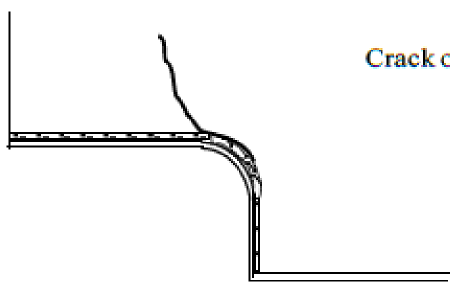
Crack on welding



Crack around welding part of bearing upper plate

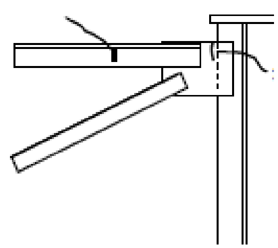


Crack on web connected with cross beam



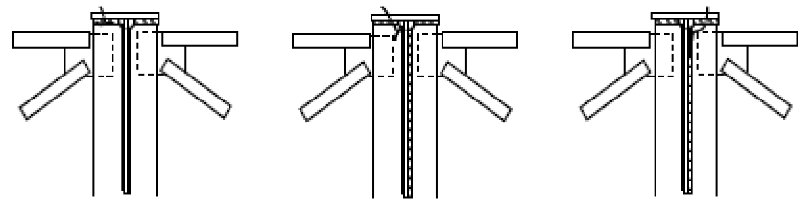
Crack on notch part

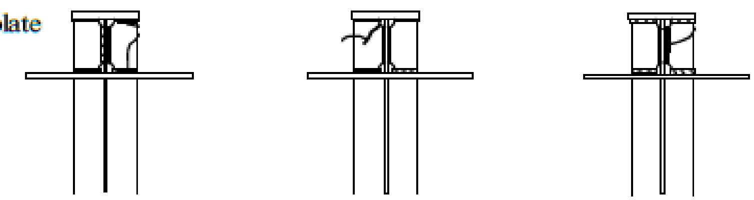
Crack on second member



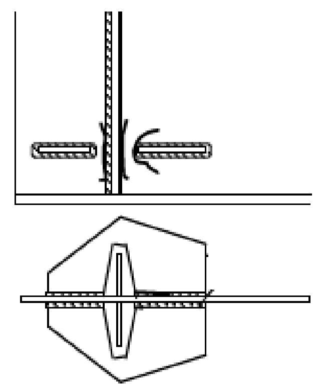
Crack on gusset

Crack around gusset, connecting point with rib, cross beam

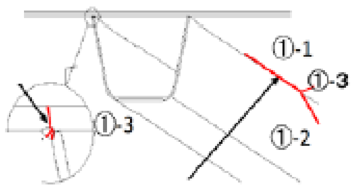




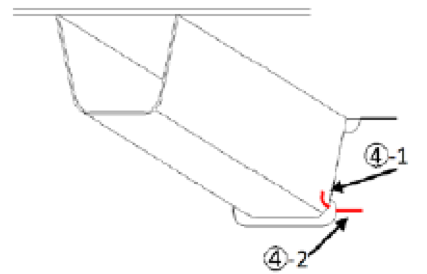
Crack around gusset, connecting point with rib, cross beam



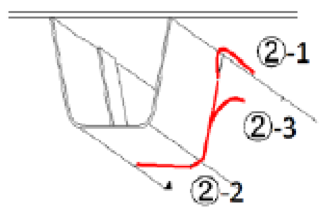
General Patterns of Crack Defects on Steel Deck Plate



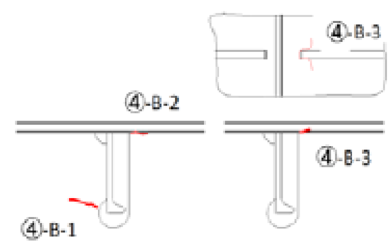
①:Crack on deck and U-rib

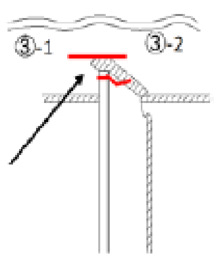


④:Crack on transverse rib



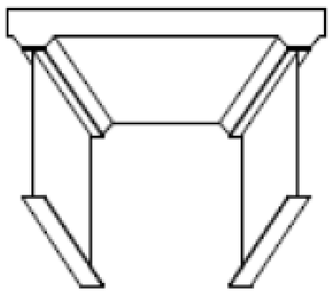
②:Crack on welding portion of U-rib



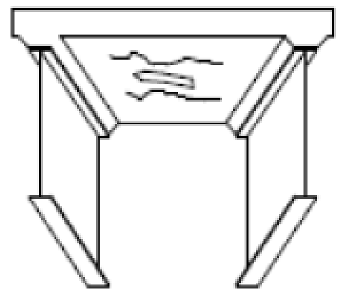


③:Crack on deck and vertical stiffener

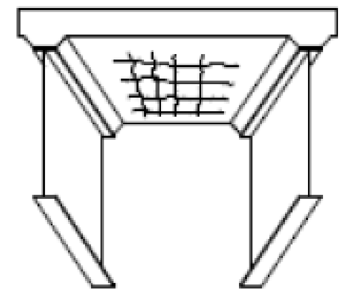
General Patterns of Crack Defects on Concrete Deck



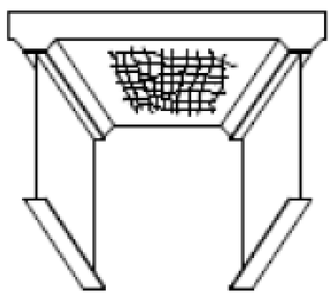
Stage 0
Sound condtion



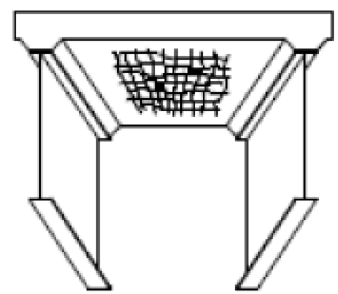
Stage 1
Development of cracks in one direction



Stage 2
Development of cracks in two directions

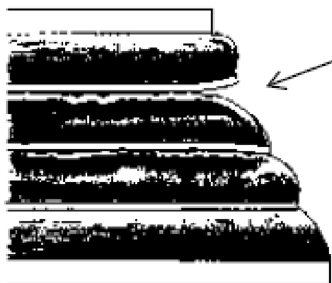


Stage 3
Cracks develop like a mesh

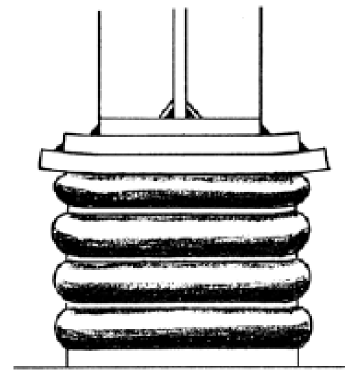


Stage 4
Water penetrates cracks, spallings

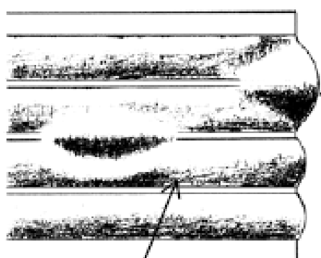
General Patterns of Defects of Rubber Bearing



Detachment between steel plate and rubber

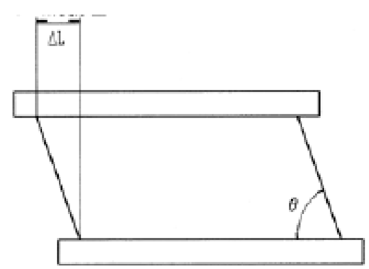


Abnormal vertical defomation

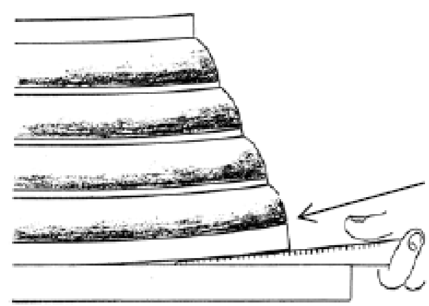


Bulging on side of bearing

Scratch on rubber surface

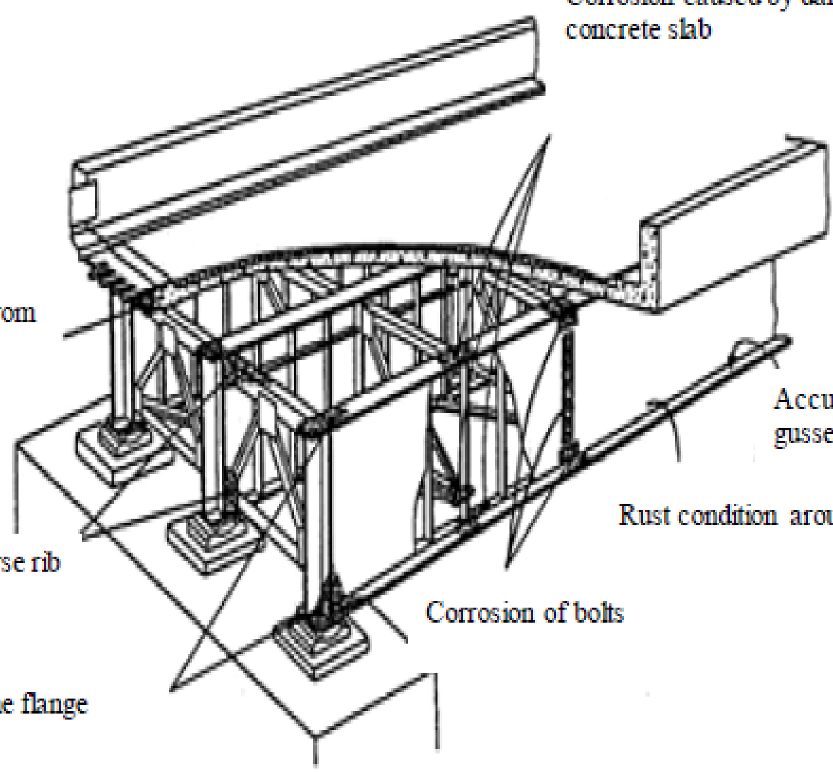


Abnormal horizontal deformation
θ > 50 degrees



Gap on the edge of rubber bearing

Important Inspection Points for Bridges Using Weathering Steel



1	Slab (Concrete, Steel), in particular damaged area where there is water leakage
2	Area around drainage
3	Area around Girder end and middle pier
4	Area with accumulated dust like upperside on lower flange, gusset and so on
5	Joint area and bolts

4 REFERENCES

1. *National Bridge Inspection Standards, in 23 CFR part 650. 2004: USA. p. 74419-74439.*
2. *Hearn, G., NCHRP Synthesis 375, Bridge Inspection Practices. 2007, Transportation Research Board: Washington, D.C.*
3. *FHWA-NHI-12-053, "Bridge Inspector's Reference Manual,"* 2012: Washington, DC.
4. *FHWA-IF-11-045, "Primer for the Inspection and Strength Evaluation of Suspension Bridge Cables,"* 2012: Washington, DC.
5. *FHWA-IF-12-027, "Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges,"* 2012: Washington, DC.
6. *FHWA-NHI-130096, "Cable-Stayed Bridge Seminar,"* 2013: Washington, DC.
7. *FHWA-IP-86-26, "Inspection of Fracture Critical Bridge Members,"* 1986: Washington, DC.
8. AASHTO, *Movable Bridge Inspection, Evaluation and Maintenance Manual,* 1998: Washington, D.C.
9. AASHTO, *Manual for Bridge Element Inspections (MBEI), First Edition,* 2013: Washington, D.C.
10. AASHTO, *Manual for Bridge Evaluation (MBE), 2nd Edition, with 2011 Interim Revisions*: Washington, D.C.
11. FDOT New Directions for Florida Post-Tensioned Bridges, Volume 4 of 5: Condition Inspection and Maintenance of Florida Post-Tensioned Bridges, 2002.
12. *Washington State Bridge Inspection Manual*, M 36-64.03, November 2012.
13. *Indiana Department of Transportation Bridge Inspection Manual*, Dated thru December 2013.
14. *Iowa Department of Transportation Bridge Inspection Manual*, October 2013.
15. *2014 Routine and Fracture-Critical Bridge Inspection and Condition Report for the St Johns Bridge (ODOT Br. No. 06497) Carrying OR Highway 30 Bypass over the Willamette River in Portland, OR.*, HDR Engineering, Inc.: Portland, OR.
16. *Special Bridge Inspection Manual for Cable Stayed Bridge*, 2014, Japan International Cooperation Agency (JICA) with the Department of Public Works and Highways (DPWH): Republic of the Philippines.

Appendix: Complex Components of Bridges Inspection Report Form

COMPLEX COMPONENTS OF BRIDGES
INSPECTION REPORT FORM
Page 1 of 2

Bridge Name:	____________	Date:	____________
Bridge No:	____________	Hours:	____________
Structure ID:	____________	Inspector ID #:	____________
Structure Type:	____________	Team Leader Initials:	____________
Agency:	____________	Assistant Inspector Initials:	____________
Milepost:	____________		
		Team Leader Signature:	____________
Inspected Items:		Assistant Inspector Signature:	____________

Procedures:

Complex Features	Complex Features Type	FCM or FPD Features (If Applicable)	Plans Information		
			Sheet Number	Contract	Sheet Name

Note: FCM = Fracture Critical Member, FPD = Fatigue Prone Detail

COMPLEX COMPONENTS OF BRIDGES

INSPECTION REPORT FORM

Bridge Name:	________	Date:	____________________
Bridge No:	________	Hours:	____________________
Structure ID:	________	Inspector ID #:	____________________
Structure Type:	________	Team Leader Initials:	____________________
Agency:	________	Assistant Inspector Initials:	____________________
Milepost:	________		

Girder or Truss Line	Pier	Location	Feature Inspected	Detail Description	Remarks