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3.1 GENERAL

3.1.1 Introduction

The most common movable structure in the transportation network is the movable bridge. Although there are other movable structures in the network, such as movable components of ferry terminals, weigh scales, and other similar type structures, Part 3 of this manual will mainly refer to movable bridges. Many of the principles and systems of movable bridges are similar to those of other movable structures. No matter what type of movable structure, the primary reference document will be the structure’s own Operation and Maintenance (O & M) Manual.

A movable bridge is a bridge across a navigable waterway that has at least one span which can be temporarily moved in order to increase the vertical clearance for vessels sailing through the channel. Such a bridge is built where site conditions preclude constructing a bridge with only fixed spans that has an acceptable vertical profile. Although military movable bridges have been erected since ancient times, it was not until the advent of transportation canals and railways that many permanent movable bridges were built as part of a country’s infrastructure. Because the early movable bridges were manually powered, ingenious mechanisms were devised to gain mechanical advantage. By 1900, the now common types of movable bridges had been developed and many were patented.

Part 3 of the Wisconsin Department of Transportation (WisDOT) Structure Inspection Manual is concerned primarily with the electrical, mechanical, and hydraulic machinery for operating and stabilizing the movable span. Inspection of the superstructure and substructure of the movable bridge will not be addressed herein because these tasks are similar to those for fixed bridges, which are treated in Part 2. However, the interaction between the movable structure and the machinery will be addressed. An understanding of the mechanical/structural interaction of the movable bridge is important for adequate inspection and maintenance of the machinery.

The addition of electrical and mechanical systems within a movable bridge defines the structure as complex. NBIS Metric #19: Inspection Procedures – Complex Bridges states:

- Complex bridges have the following identified:
 - Specialized inspection procedures which clearly identify the complex features, specify the inspection interval of those features, describe any specific risk factors unique to the bridge, and clearly detail inspection methods and equipment to be employed.
 - Additional inspector training and experience required to inspect complex bridges.
- Complex bridges are inspected according to those procedures.

3.1.1.1 Inspection Forms

The following Inspections formed are to be utilized and uploaded as part of any Moveable Bridge inspection:



For Bascule Bridges:

- DT 2014 Movable Bridge Electrical Inspection Report
- DT 2015 Movable Bridge Structural Inspection Report
- DT 2016 Movable Bridge Hydraulic Inspection Report
- DT 2017 Movable Bridge Mechanical Inspection Report

For Vertical Lift Bridges:

- DT 2027 Movable Bridge Electrical Inspection Report
- DT 2028 Movable Bridge Hydraulic Inspection Report
- DT 2029 Movable Bridge Mechanical Inspection Report
- DT 2030 Movable Bridge Structural Inspection Report

3.1.1.2 Local Lift Bridge Aids

The Lift Bridge Aids Program applies to moveable bridges on connecting highways. A Program Manager from the Department’s Bureau of Transit, Local Roads, Railroads and Harbors administers the program. This is covered under section 86.32(2)(a) of the Wisconsin statutes.

86.32(2)(a)(a) Cities, villages and towns shall be reimbursed for actual costs, as approved by the department, incurred in maintaining and operating lift bridges. Documentation of costs shall be submitted by each city, village and town by January 31 and reimbursement shall be made, starting in 1982-83, on the first Monday in July for costs incurred during the prior calendar year. If the amount appropriated under s. 20.395 (1) (ft) is insufficient to pay the actual costs approved by the department for the maintenance and operation of lift bridges, the department shall prorate the amount appropriated in the manner it deems desirable.

The cities currently included in the program:

Green Bay and Manitowoc in the North East Region

Racine and Milwaukee in the South East Region

Must get the previous calendar year expenses & projected expenses for the next calendar year submitted by Jan. 31st of each year. The previous year expenses, along with projected expenses for the upcoming year are reported on form DT2088 with all supporting documentation. The Regional Inspection Program Manager, or their delegate reviews the documentation and the Statewide Inspection Program manager in the Bureau of Structures signs off on the documentation.



3.1.2 Inspection Procedures

It is necessary for the inspector to identify the inspection interval of the unique movable bridge components and describe the inspection procedure used to carry out the inspection. This is accomplished through the use of the WisDOT field inspection forms. There is space available for the inspector to document the procedures utilized prior to and during the inspection of the bridge. As an alternative, a more complex or lengthy inspection procedure may be a separate document that is uploaded during the entry of the structure inspection. The inspector should note the operator was called to notify him of inspection of the bridge, whether any electrical control boxes were shut down during inspection and describing any specific procedures used while observing of the structure during operation, as an example.

Sample inspection procedures for a movable bridge are included below for reference:

Olde Oneida Bascule Bridge over the Fox River Navigational System Canal at Appleton, Wisconsin

Movable Bridge Inspection Procedures

Bridge Description – This movable bridge carries one lane of traffic in each direction and accommodates pedestrians by sidewalks on both sides. Its single leaf trunnion-style bascule span is driven by an electro-mechanical system that is operated on-site from the control house at its northwest quadrant.

Bridge Owner and Contact:

City of Appleton; Chad M. Weyenberg, P.E., Project Engineer, telephone: (920) 832-5915, email: chad.weyenberg@appleton.org

Inspection Interval:

An inspection will be made of the bascule span’s mechanical and electrical system and its structural elements associated with operation as a movable structure at an interval not to exceed 12 months.

Inspection Forms:

The following WisDOT forms provide a systematic procedural checklist of items to inspect. All applicable items on them shall be fully completed while on-site during inspection.

- *Movable Bridge Electrical Inspection Report*
- *Movable Bridge Structural Inspection Report*
- *Movable Bridge Mechanical Inspection Report*



Complex Features:

The above referenced inspection forms provide a comprehensive list of the specialized electrical, mechanical and structural features of this movable bridge to be inspected. Noteworthy ones include the following:

- *Barrier gate at south end of bridge providing positive restraint to approaching vehicles during bridge openings*
- *Toe locks that hold the end of the movable span closed for safe vehicle passage*
- *Safety interlocking system as part of the control system for bridge operation*
- *Motor brakes that stop the moving bascule leaf and machinery brakes that keep the leaf stationary*
- *Counterweight system that minimizes load on machinery system and motors in all positions of opening*
- *Breaks between movable and non-movable structural components in roadway and sidewalks*

Risk Factors:

The following are risk factors for inspection staff, the public and the bridge:

- *Certain features of this bridge require the bascule span to be operated for inspecting them. This requires inspectors to fully understand where those safe areas are that they must be during test operations.*
- *Unanticipated operation of the bridge during inspection can be hazardous. Before performing any test operation, a clear protocol for communication between the bridge operator and all inspection staff must be established and understood by all parties. A clear line of communication between the operator and primary point of contact for the inspection team must be established and maintained. Communication can be via cell phone, walkie-talkie or similar device.*
- *Inspection of the electrical control system requires working near energized components that can pose potential electrocution hazards.*
- *Safety for motorists and pedestrians during test operations is of paramount importance. Attention must be paid to ensuring the bridge and both sidewalks on the movable span and its adjacent approaches are clear of all motorists and pedestrians before and during test operations.*
- *The bridge's safety interlocking system is designed to protect the public and various components of the bridge during operation by only allowing steps of operation to be performed in a specific sequence. For example, the brakes holding the movable span closed cannot be released until all traffic gates and the barrier gate have been lowered;*



power to the drive motors cannot be applied until the brakes have been released and the toe locks have been withdrawn, etc. Manual bi-passes on the control console allow portions of the interlocking system to be overridden for emergency short term situations such as the failure of a position sensing device that would otherwise render the bridge inoperable. When testing interlocking system bypasses during inspection, special attention must be paid to potential risks it may present to highway traffic, pedestrians and bridge equipment. After testing bypasses, the interlocking system must be immediately restored to its fully functional condition.

- *Nonredundant Steel Tension Member (NSTM) bascule girders.*
- *Operate bridge as many times as necessary to observe operation of all items listed on the movable bridge inspection forms.*

Inspection Methods and Equipment:

This movable inspection was separate from the routine and NSTM inspection. The following inspection equipment should be on-hand for inspecting this movable bridge:

- *Flotation vest for inspection of the timber fender system and navigation lights*
- *Reflective vest for inspection of areas on and adjacent to the roadway*
- *Fall protection for working in areas that present a potential fall hazard.*
- *Flash light or helmet mounted head lamp for inspecting components in areas with limited lighting such as the counterweight pit, electrical cabinets and interior of machinery gear box.*
- *Camera with zoom and flash capability*
- *A clip board for neatly recording information on the inspection forms and securely them during the inspection. Alternately, an electronic tablet can be used to electronically record and secure inspection data.*
- *Disruptions to bridge users during test operations should be minimized by planning in advance what elements of the bridge's mechanical, electrical and structural can be concurrently observed and inspected during each test operation.*

Inspection Team Member Roles:

The Inspection Team Leader is in charge of the inspection team and is responsible for planning, preparing for, performing, and documenting the overall movable bridge inspection. All inspections must be conducted under the supervision of the Inspection Team Leader. The Inspection Team Leader is also responsible for performing quality assurance, verifying all key elements of each of the movable bridge's functional systems have been inspected and proper condition states have been assigned and entered for them on the inspection forms. The Inspection Team Leader must supervise and coordinate work performed by the



Lead Inspectors for each functional discipline and ensure they fully complete in a timely manner all required inspection documentation.

Lead Inspectors are responsible for inspecting the specific mechanical, electrical, hydraulic and structural systems of the movable bridge for which they have experience and technical expertise. A single individual may serve as the Lead Inspector for more than one bridge system discipline if they have the necessary training and relevant recent experience in inspection, design, maintenance, and/or construction of movable bridges. The experience must be in the specific system discipline for which the individual has the responsibility to lead. Each Lead Inspector must directly oversee on-site all work performed by any supporting staff assisting them during the inspection.

Planning and Preparing for the Inspection:

Adequate preparation must be performed in advance of the movable bridge inspection. This will help ensure a complete, comprehensive and efficient inspection can be completed during one site visit. A list of all components of each functional system to be inspected should be reviewed.

Steps must be taken to ensure all components will be accessible for inspection and for observation during test openings of the bridge. Access methods and associated equipment for achieving arms-length reach of all components to be inspected must be identified and mobilized.

Any specific traffic control needs for the inspection must be arranged. Any traffic lane reductions for accommodating an under-bridge access unit must be planned. Specific time-of-day restrictions during peak traffic periods that would restrict when operational testing can be performed must be identified and conveyed to the inspection team so they can schedule their inspection tasks around bridge planned bridge openings accordingly.

Arrangements must be made to have the bridge thoroughly cleaned before the inspection so that any dirt and debris is removed that would otherwise inhibit making of complete visual observations and taking of precise measurements.

Inspection of functional system components during bridge test openings is essential for a thorough and complete inspection. Arrangements must therefore be made to ensure an operator will be present during the inspection. Prior to the day of the inspection, if the bridge has not been recently opened, it should be operated through a full opening and closing cycle to ensure all of its systems will be functional for test operations during the inspection. The functionality of any backup power system or alternate incoming power source should also be verified in advance of the inspection so its operation can be observed during the inspection.

Movable bridge inspection planning must address provisions for inspector safety. All applicable personal protective equipment needed during the inspection must be identified and secured to ensure it will be on site. Such equipment may include reflective vest, safety boots, hard hat, eye protection, fall protection and flotation vests. The protocol for communicating between team members and with the bridge operator must be identified and any equipment needed to support it must be identified to ensure it will be on site.

In planning the inspection, the inspection team leader must facilitate coordination between lead discipline inspectors to ensure they understand how they must interface with one



another during the inspection. This coordination should include reviewing and scheduling what each inspector will concurrently do during test openings. This will serve to maximize what can be inspected during each operation and thereby limit how many traffic-disrupting openings are needed to complete and a comprehensive inspection. The inspection team leader should compile inspection reports and any measurement data from previous inspections of the bridge and facilitate each discipline lead inspector reviewing previous findings for the specific functional systems they will be inspecting.

All potentially useful reference materials to have available on-site during the inspection must be identified. Examples of these include plans of the bridge including those for its specialty functional systems and completed forms from previous inspections.

A list of all tools that may potentially be needed for the inspection should be prepared and those tools secured before the day of the inspection.

Inspection forms for recording all inspection data and observations should be printed for use during the inspection.

Performing the Inspection:

The names of the inspection team leader and lead inspectors and their qualifications for each functional system shall be recorded on the inspection forms.

An on-site safety meeting must be conducted with all members of the inspection team at the start of the inspection. This will promote a clear understanding of communication protocol between each inspection team member. The bridge operator must be included in this meeting to confirm communication procedures between the operator and inspectors and review procedures for ensuring all inspection staff are in safe locations prior to initiating any bridge openings.

The movable bridge inspection must be performed in a thorough, comprehensive and complete manner. The elements listed in the bridge inspection forms should be used as a guide to assure complete inspections. Information shall be entered for all items listed on the forms. All components of each functional system of the bridge shall be inspected during each inspection. If, for any reason, a specific component cannot be inspected, it must be noted on the bridge inspection form. Any items on the form not applicable to the bridge shall be noted with "N/A" to ensure nothing was accidentally overlooked.

Full documentation of the inspection must include high quality photographs. They should be taken to document all issues observed during the inspection. All photographs shall be referenced on the inspection forms. When there is more than one of the same elements on the bridge, the photograph's reference should clearly say which one it is.

Functional testing of all components during bridge operation must be performed. Where there is more than one of the same components on the bridge, each one should be separately observed under operation.

The bridge operator should be interviewed as part of the inspection to obtain their input regarding any issues they may be aware of or have witnessed during bridge openings. Information provided by the operator about any issues should be recorded on the inspection forms.



An important part of the movable bridge inspection is identifying and documenting any short term repair needs that may be needed for the bridge's functional systems.

3.1.3 Inspector Qualifications

Movable bridges are large, complex, pieces of machinery. Each part of a movable bridge has a relationship to, and must interact with, many other parts. In order for a movable bridge to operate efficiently and to provide a long and serviceable life, all parts of the bridge must be maintained properly. Proper maintenance requires that all functional systems (including electrical, mechanical, hydraulic, and structural) must be inspected and evaluated by personnel who are sufficiently experienced in that line of work.

The personnel who perform inspection of movable structures should have experience beyond that which may be sufficient for the inspection of fixed bridges. This may seem obvious for the inspection of electrical, mechanical, and hydraulic equipment. It is also true for the inspection of the structural components of a movable structure. As with a fixed bridge, the structural members of a movable bridge must safely withstand the stresses imposed by the dead loads, live loads, and other loads typically encountered. In addition, many of the primary and secondary structural members should also withstand the stresses imposed by the operating equipment and the movement of the bridge. It takes significant first-hand experience on movable structures and with the applicable codes to adequately understand these relationships, evaluate the conditions of the various components, and to recommend appropriate courses of action.

Inspection Team Leader

The lead person (Inspection Team Leader) designated to manage the inspection of a movable bridge should be familiar with all functional systems that are a part of that bridge. The Inspection Team Leader should have the knowledge and experience to understand and evaluate all of the inspection findings. The total experience should be broad in nature, so that the individual understands the inter-relationships inherent in movable structures and inherent for the specific type/style of movable structure being inspected. The Inspection Team Leader must meet the National Bridge Inspections Standard's (NBIS) definition of an inspection team leader.

The Inspection Team Leader is in charge of the inspection team and is responsible for planning, preparing for, performing, and documenting the overall movable bridge inspection. All inspections must be conducted under the supervision of an Inspection Team Leader. The Inspection Team Leader is also responsible for performing quality control, verifying all key elements of each of the movable bridge's functional systems have been inspected and proper condition states have been assigned and entered for them on the inspection forms.

The inspection team leader for movable bridges shall meet the following minimum requirements:

- Be certified by the State of Wisconsin as a Movable Bridge Inspection Team Leader
- Completed the NHI 3-day Nonredundant Steel Tension Member Inspection Techniques for Steel Bridges course (if responsible for leading the bi-annual NSTM inspection).
- Completed the 10-day FHWA-NHI Safety Inspection of In-Service Bridges course



- Acquire a minimum of 3 years Inspection experience during a 10 year period performing a combination of the following services for movable structures, having similar type or style to that being inspected.
 - Design of new movable structures or rehabilitations of existing ones
 - Construction oversight of new movable structures or rehabilitation of those existing
 - Maintenance and/or troubleshooting of movable bridges
 - Movable bridge safety inspections
 - Previously acting as inspection team leader during safety inspections of movable structures.

The following qualification is also strongly recommended:

- Attended the Heavy Movable Structures (HMS) bi-annual symposium or similar, for continued information exchange on movable structures

The Inspection Team Leader can also serve as a Lead Inspector if that person has the required qualifications in the functional discipline that they will be responsible for inspecting.

Lead Inspectors:

The inspection teams should include structural, electrical, mechanical, and when appropriate, hydraulic Lead Inspectors. A single individual may serve as Lead Inspector in more than one of the areas if the individual possesses the necessary experience. Each Lead Inspector should have experience in the inspection, design, maintenance, or construction of sufficient movable structures of the type/style being inspected to understand their function and operation; this experience should include past inspection experience of movable structures. This experience should be in the specific systems for which the individual is leading the inspection, e.g., the Lead Electrical Inspector should have this experience in electrical systems. Each Lead Inspector must supervise and monitor any work performed by anyone assisting in the efforts.

Lead Structural Inspector Qualifications:

The Lead Structural Inspector is the individual who will lead the inspection of the structural elements of the movable bridge. The Lead Structural Inspector for a movable bridge shall meet the following minimum requirements:

- Acquire a minimum of 3 years Inspection experience during a 10 year period performing a combination of the following services for movable structures, having similar type or style to that being inspected
 - Construction oversight of new movable structures or rehabilitation of existing ones.
 - Design of new movable structures or rehabilitations of existing ones
 - Maintenance and/or trouble shooting of movable bridges



- Movable bridge safety inspections

Lead Electrical Inspector Qualifications:

The Lead Electrical Inspector is the individual who will lead the inspection of the electrical and control system elements of the movable bridge. The Lead Electrical Inspector shall meet the following minimum requirements:

- Acquire a minimum of 3 years of experience during a 10 year period, performing electrical and control systems inspection for movable structures or inspection of similar type electrical and control systems

The following qualifications are also recommended:

- Have a Bachelor's of Science Degree in Electrical Engineering or be a Journeyman Electrician
- Knowledge of movable bridge operations

Lead Mechanical Inspector Qualifications:

The Lead Mechanical Inspector is the individual who will lead the inspection of the mechanical operating system of the movable bridge. The Lead Mechanical Inspector shall meet the following minimum requirements:

- Acquire a minimum of 3 years of experience during a 10 year period, performing mechanical operating system inspection for movable structures or inspection of similar type mechanical operating systems

The following qualifications are also recommended:

- Have a Bachelor's of Science Degree in Mechanical Engineering
- Knowledge of movable bridge operations

Lead Hydraulic Inspector Qualifications

The Lead Hydraulic Inspector is the individual who will lead the inspection of the hydraulic elements of movable bridges that are operated by hydraulic cylinders or hydraulic motors. The Lead Hydraulic Inspector shall meet the following minimum requirements:

- Acquire a minimum of 3 years of experience during a 10 year period, performing hydraulic operating system inspection for movable structures or inspection of similar type hydraulic operating systems

The following qualifications are also recommended:

- Have a Bachelor's of Science Degree in Mechanical Engineering
- Knowledge of movable bridge operations



Other individuals:

Other individuals may assist in the inspection. It is recommended that each of these inspectors have experience in the inspection, design, maintenance, or construction of sufficient movable structures of the type/style being inspected to understand their function and operation; this experience should include past inspection experience of movable structures. However, if their experience level is less than the recommended experience, their efforts should be closely supervised and monitored by the Lead Inspector or another inspector possessing at least the minimum recommended experience for a Lead Inspector.

All members of the inspection team, their roles and their qualification shall be recorded in the area of the inspection form labelled “team members”.

3.1.4 Inspection Safety

Nothing is more important during a bridge inspection than safety. This includes safety of the public, the bridge operating and maintenance staff, and the bridge inspection team. The inspectors need to be alert and aware of the work environment and safety issues. They should not rely solely upon bridge operating and maintenance staff to create a safe environment. The team leader should take an active role in arranging pedestrian and vehicular traffic control and de-energizing electrical equipment. For basic safety requirements, refer to Part 1, of this manual. Also, potential personnel and public safety hazards are discussed in Chapter 1.3 of the American Association of State Transportation and Highway Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual.

Before beginning a movable bridge inspection, a test opening should be performed to determine if the movable span is operable and if there are any serious defects which need special consideration or that would preclude a safe inspection. Such issues should be resolved with the bridge maintenance and design groups if possible. While the inspection is underway the inspector should be cognizant of the mechanisms which are intended to stabilize the movable span. No components should be disconnected that would thereby create an unsafe condition. After completion of the inspection, the inspector should check the operating equipment to make certain that it is energized and ready for operation. A test opening should then be made in order to verify that the bridge is in at least as good a condition as before the inspection began.

Electrical and hydraulic equipment presents special hazards to the inspection team. Before handling or inspecting any equipment the inspector should verify that the equipment is de-energized. This can be done by using local disconnect switches or turning off protection devices (such as circuit breakers) electrically upstream of the equipment. If the disconnect switch or protection device is not within eyesight of the equipment, an official site lockout procedure should be implemented. This is required to prevent someone who is unaware of the work underway from energizing a device while it is being inspected. The minimum requirements for such a procedure include notifying all personnel of the inspection work by posting signs, physically preventing the device from being returned to operation (such as pad-locking a switch), and encouraging the inspector be alert.

The inspector should be aware that a panel or device may be powered from a second utility source or a stand-by generator. Therefore removing power from a single source may be



insufficient to de-energize a panel. An inspector should always test the equipment with a voltmeter or similar power detector to determine whether the equipment is safe to inspect.

Special attention should be given to all rotating or moving machinery. Portions of the inspection will require the inspector to observe the machinery and equipment while in operation. Because any rotating equipment can be a hazard, the inspector should be very careful not to come into contact with the machinery or let hair or loose clothing be caught in the machinery.

Extreme caution should be used when inspecting hydraulic equipment. Never loosen or disconnect any hydraulic system component before verifying that the component is not under pressure. Fluid samples should be taken only from the correct sampling ports. Any spilled hydraulic fluid should be cleaned up immediately.

With older bridges the inspector may encounter electrical panels and enclosures that may be difficult to open and even harder to properly seal after inspection. The inspection of a bridge should not be destructive and the inspector should always take care to seal all panels and equipment properly to prevent later damage. Before attempting to open any panel, the inspector should determine if the panel is warped or damaged. If the equipment is damaged, do not inspect it unless there is a maintenance crew readily available to repair or replace the damaged equipment. Otherwise, the inspector should note in his report that the equipment is inaccessible due to damage. Leaving a panel open, or cracked, can expose the bridge wiring to corrosion or damage and expose people to electrical contact which could lead to permanent injury, disability, or death.

Unless otherwise instructed, the inspector should not attempt to repair or modify the bridge equipment. Accurately recording any deficiencies and notifying the appropriate maintenance authority immediately will enable the repairs to be made in a documented and orderly manner.

The inspector should always use appropriate safety equipment while on the bridge or roadway. This includes, at a minimum, the use of a hard hat, safety glasses, safety reflecting vest, appropriate footwear, and clothing that is not loose. Life vests and safety harnesses shall be used when inspecting over the water or areas with a fall hazard, as required by Occupational Safety and Health Administration (OSHA) and US Coast Guard regulations. Each inspector is responsible for his own safety and should take all necessary actions required to minimize risk.

Lock Out / Tag Out Procedure

Prior to the inspection of a movable bridge inspection, it is imperative that the Bridge Operator is contacted and acknowledges that inspectors will be assessing the condition of all the structural and mechanical components. If the bridge controls for the structure are not located on site, it is recommended that the control box for that structure undergo the lock out/tag out procedure to ensure that a third party unaware of inspectors within the structure do not accidentally operate the machinery creating a potentially life threatening situation. This procedure is an industry recommended procedure to reinforce safety in potentially hazardous areas.

More information on this program can be viewed at:



<https://www.osha.gov/dts/osta/lototraining/>

The operation of the movable components of the bridge during the inspection should only occur after confirming with the inspectors to do so. Similarly, the inspectors may require the bridge to be operated in order to see and hear any potential defects during the opening/closing procedure. Clear communication between the Bridge Operator and Inspectors is of the utmost importance. Failure to do so may be life threatening.

3.1.5 Emergency Notification

Just as serious structural deficiencies may lead to localized failures or collapse of a bridge, mechanical and electrical defects can cause a movable span to become unstable in either, or both, the closed or open position. In Part 1, procedures are detailed for reporting serious structural defects and the actions to be taken to limit live loading or temporarily close the bridge to traffic (both on the bridge and in the waterway). The Critical Findings Procedure is used when conditions require emergency notification. While the process is nearly identical for movable bridges as it is for typical bridges, the Movable Bridge inspection team leader must also contact the U.S Coast Guard. The Coast Guard is the governing body of navigable waterways and must be informed when a Critical Finding is discovered. Notification must be made regardless of the amount of daily boat traffic (or lack thereof) under the bridge.

When a critical finding is observed the movable bridge Inspection team leader shall notify the Coast Guard Sector Lake Michigan at (414) 747-7100 or Coast Guard Sector Upper Mississippi River at (314) 269-2500.

Serious defects of the span drive or stabilizing machinery (see Chapter 5) should be reported in a manner similar to structural deficiencies. A movable span may be unstable in any position (open, closed, or in-between) due to defects in the span drive or stabilizing machinery. Much depends on the type of movable bridge and redundancy of the overall system. Because of the variations in movable bridge design, no firm rules can be set down. It is a matter of analyzing each situation. Following are examples of some situations that occurred on movable bridges:

1. Bridge Type: Single-leaf, simple trunnion bascule.
Type of Drive: Type 1-AD, all brakes on motor shaft.
Defect: Cracks in both pinion shafts emanating from corners of keyways. Very toe-heavy span imbalance for all opening angles. Improper brake setting creating much vibration when stopping.
Analysis: Because span drive contains differential and all brakes are on input shaft the drive is non-redundant. If one pinion shaft fails the toe-heavy leaf would descend uncontrolled.
Critical Findings classification – Severe.
2. Bridge Type: Double-leaf rolling lift (Scherzer) with rear floor break far behind center of roll.



Type of Drive: Type 1-ND with hydraulic motor and disc brake on motor shaft. Drive shafting is not dependably “wound-up” when bridge is closed.

Defect: Tail locks cannot be driven.

Analysis: Because rear floor break is at a far distance behind the center of roll, live load can be applied to the leaf behind the center of roll. That load creates a moment tending to open the leaf, which is resisted by the tail locks and the wind-up of the span drive. Because the tail locks cannot be driven to support the leaf, and the drive shafting is not prestressed, an appreciable live load on the rear of the leaf would cause the leaf to rotate (be unstable) while under traffic until the brake and shafting rotate sufficiently to provide resisting torque (assuming the braking capacity is adequate). Shore rear of leaf to prevent downward motion of tail behind the center of roll when subjected to live load.

Critical findings classification: Urgent.

3. Bridge Type: Tower drive vertical lift.

Type of Drive: Tower drive

Defect: Cracks in trunnion shafts at the fillet in shaft near face of counterweight sheave. Bridge is not to be operated until remedial measures are determined based on fatigue stress analysis.

Critical findings classification: Urgent.

The above three examples for machinery defects illustrate that a knowledge of the structural/mechanical interaction involved in the load path is necessary in assessing the need for machinery defect notification and repairs.

3.1.6 Classification of Movable Bridges

The motions of all movable spans are a combination of rotation and translation. The difference between the types results from the selection of the axes of displacement. Movable spans may be categorized on the basis of the displacements and axes of displacement as follows:

<u>Displacement</u>	<u>Movable Bridge Type</u>
Rotation about a fixed horizontal axis	Trunnion Bascule
Rotation about a fixed vertical axis	Swing
Translation along a fixed horizontal axis	Retractile
Translation along a fixed vertical axis	Vertical Lift
Rotation about a horizontal axis that simultaneously translates	Rolling Lift Bascule



All the movable bridge types listed above have sub-types, some of which are described subsequently.

Figure 3.1.5-1 (a) depicts a simple trunnion bascule bridge with a counterweight fastened to the bascule girders. Usually the trunnions are fixed to the bascule leaf and rotate in bearings mounted on the bascule pier. The leaf rotates about the fixed horizontal axis, similar to a “see-saw.” A counterweight may fully or partially balance the leaf structure. There are many sub-types of trunnion bascules, distinguished by the location and amount of the counterweight, as will be described later.

Rotation about a horizontal axis that simultaneously translates distinguishes the rolling lift bascule (sometimes called a rolling lift bridge). The most common rolling lift bascules are those based on concepts in a series of patents granted to William and Albert Scherzer starting in 1893. Almost all rolling lift bascules are nominally balanced by counterweights fixed to the bascule girder. The counterweights may be located above the deck, or below it, or outboard of the moving span. Figure 3.1.5-1 (b) depicts a single-leaf rolling lift bascule bridge with the counterweight below the deck.

Most early 20th century movable bridges were of the swing type, with rotation about a fixed vertical axis as shown in Figure 3.1.5-1 (c). The swing bridges are often termed draws (the swing span or draw length = L). If L_1 equals L_2 the draw is said to be symmetrical, common for most swing bridges, otherwise it is known as a “bobtail” swing span. Swing bridges have sub-types based on the type of rotational bearing at the pivot pier.

Retractable bridges translate horizontally, usually along a straight path which may be normal to or at an angle to the channel, as shown in Figure 3.1.5-1 (d). If the translation is at an angle to the channel (approximately 45 degrees), as in the figure, the movable span does not have to be lifted or depressed in order to clear a path for motion.

Figure 3.1.5-1 (e) depicts a span that moves vertically along a fixed vertical axis in order to obtain additional vertical clearances for navigation. It is termed a vertical lift bridge. There are many sub-types, distinguished mainly by the location of the span drive machinery. The modern vertical lift bridge design is credited to Waddell who designed the South Halsted Bridge across the Chicago River, which was completed in 1895 along the lines of his U.S. Patent.

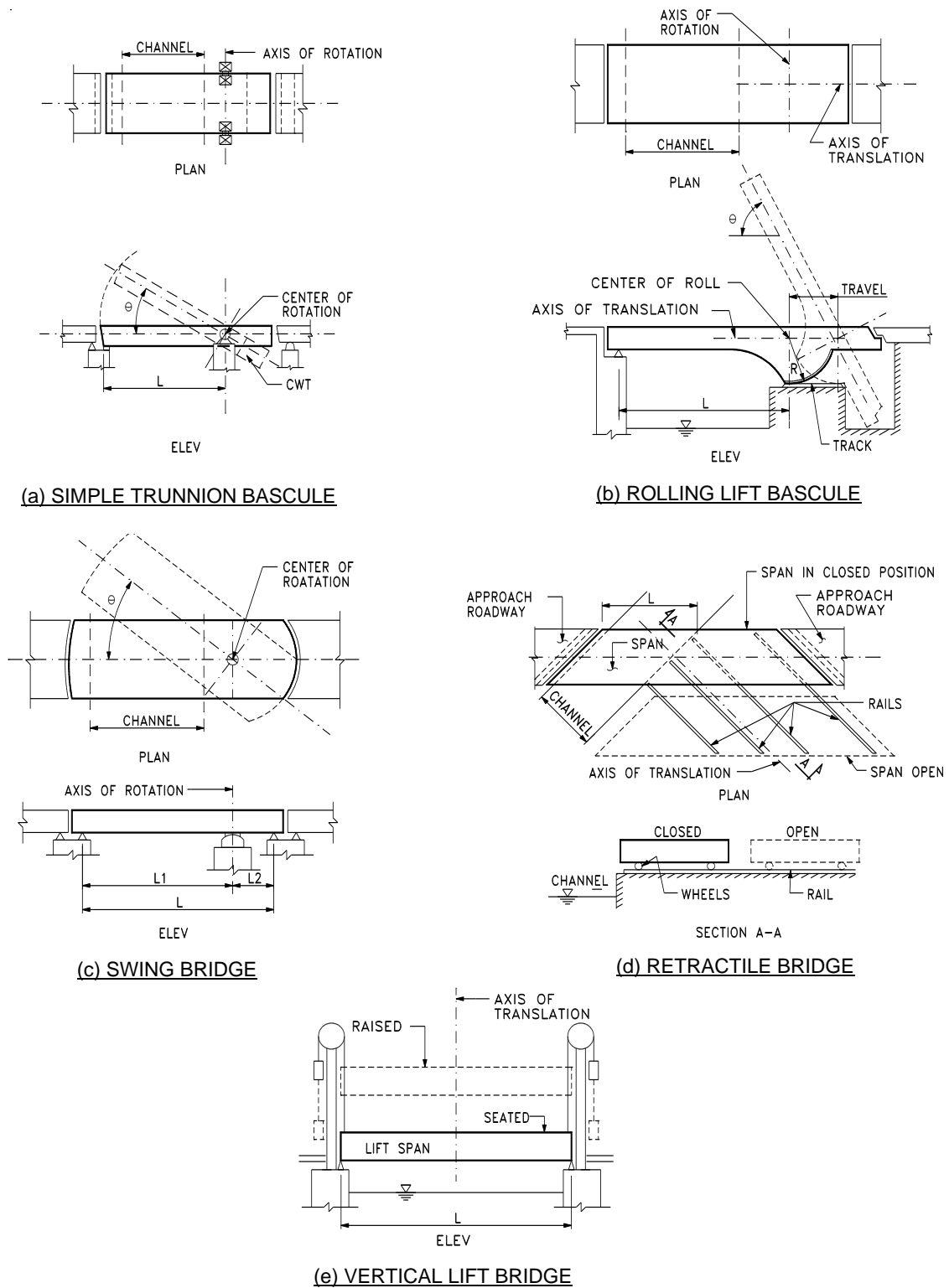


Figure 3.1.5-1: Basic Motion of Movable Bridges.

**3.1.7 Short History of Movable Bridges in Wisconsin**

In the early years of this country's history, transportation was by foot, by horseback or horse drawn wagons, and by watercraft. Commercial transportation by water grew quickly and became the primary mode for shipping goods to market. In the second half of the 19th century a conflict arose between the expanding commercial navigation interests and the growing need for more and better land transportation. Fast growing cities, such as Milwaukee, needed more bridges so that people and goods could be moved from one side of a river to the other side. At the same time, fast growing railroads generally required relatively low level bridges to cross rivers. The U.S. Congress established navigation as the primary mode of transportation and prohibited the construction of bridges or other obstructions over navigable waterways. Only bridges authorized by an act of Congress could be constructed over a navigable waterway, and these had to be either movable or have sufficient height to allow the passage of vessels. To this day, at the intersections of land traffic and water traffic, water traffic has the primary right of way. Although an act of Congress is no longer required for the construction of a bridge, a rigorous permitting process is in place.

According to the 1994 National Directory - Heavy Movable Structures, Inc., Bridge Edition, there were 93 movable bridges in Wisconsin or on rivers bordering Wisconsin. Of these, 65 support highway or pedestrian traffic and 28 support railway traffic. The oldest of these bridges date from the beginning of the 20th century. Generally, the railway bridges are owned by private companies and the highway bridges are owned by the State of Wisconsin, the county, or local municipalities. The publicly-owned movable bridges in Wisconsin are listed in Figures 3.1.6-1 and 3.1.6-2.

Prior to 1900, most of the movable bridges were swing spans or vertical lift spans. More recently, most of the highway movable bridges constructed in Wisconsin have been bascule bridges. The most recent bridges include: North Emmer Lane in Milwaukee, State Street in Racine, Ray Nitschke Bridge (Main Street) in Green Bay, Kinnickinnic Avenue in Milwaukee, Eighth Street in Manitowoc, Eighth Street in Sheboygan, Maple-Oregon Street in Sturgeon Bay, Wisconsin Street in Oshkosh and 17th Street in Two Rivers.



Waterway	Miles From Mouth	Roadway Name	Location	Struct. No.	Type	Owner	Year Built
Fox Rvr.	1.58	USH-141/Main St.	Green Bay	B-05-0311	RL-B	City	1998
Fox Rvr.	1.81	STH-29/Walnut St.	Green Bay	B-05-0269 (2)	RL-B	State	1986
Fox Rvr.	2.27	STH-54/Mason St.	Green Bay	B-05-0134	ST-B	State	1973
Fox Rvr.	17.36	STH-96/Ferry St.	Wrightstown	B-05-0736	ST-B (Fixed)	State	1934
Fox Rvr. Cnl.	23.78	Wisconsin Ave./ Island St.	Kaukauna	B-44-0081	VL	City	1984
Fox Rvr. Cnl.	26.53	Island Park Trail	Little Chute	B-44-0287	ST-B	Village	2016
Fox Rvr. Cnl.	31.37	Lawe St.	Appleton	P-44-0719	ST-B	City	1954
Fox Rvr. Cnl.	31.74	Olde Oneida St.	Appleton	P-44-0724	ST-B	City	1959
Fox Rvr. Cnl.	37.52	STH-114/Tayco St.	Menasha	B-70-0097 (2)	RL-B	State	1993
Fox Rvr. Cnl.	37.91	Racine St.	Menasha	B-70-0001 (2)	RL-B	State	1952
Fox Rvr.	55.97	USH-45/Main St.	Oshkosh	B-70-0056 (2)	RL-B	State	1973
Fox Rvr.	56.22	Oregon/Jackson St.	Oshkosh	B-70-0011 (2)	RL-B	State	1956
Fox Rvr.	56.72	STH-44/Wisconsin St.	Oshkosh	B-70-0247 (2)	RL-B	State	2008
Fox Rvr.	58.01	STH-21/Congress Ave.	Oshkosh	B-70-0091 (2)	RL-B	State	1982
Manitowoc Rvr.	0.29	USH-10 WB/8 th St.	Manitowoc	B-36-0142	RL-B	City	1995
Manitowoc Rvr.	0.43	USH-10 EB/10 th St.	Manitowoc	B-36-0128 (2)	RL-B	City	1987
Menominee Rvr.	0.7	Ogden St.	Marinette	B-38-0016 (3)	RL-B	State	1973
Root Rvr.	0.31	STH-32/Main St.	Racine	B-51-0069	ST-B	City	1988
Root Rvr.	0.53	STH-38/State St.	Racine	B-51-0080	ST-B	City	1996
Sheboygan Rvr.	0.69	8 th St.	Sheboygan	B-59-0154	NC-B	City	1995
St. Croix Rvr.	0.3	US-10	Prescott	B-47-0040	RL-B	State	1990
St. Croix Rvr.	23.4	SR-64	St. Joseph (Houlton) WI/ Stillwater MN	B-55-0919	VL	State	1931
St. Louis Rvr.	13.91	DM&IR Rwy./SR-39	Oliver WI	B-16-0755	Sw (fixed)	Railroad	?
Sturgeon Bay	2.80	STH-42/STH-57	Sturgeon Bay	B-15-0004 (3)	RL-B	State	1978
Sturgeon Bay	4.18	Maple-Oregon St.	Sturgeon Bay	B-15-023 (3)	RL-B	State	2008
Sturgeon Bay	4.30	Michigan St.	Sturgeon Bay	B-15-0100 (3)	RL-B	State	1930
East Twin Rvr.	0.48	17 th St.	Two Rivers	B-36-0189	RL-B	City	2013
Wolf Rvr.	2.40	STH-116/Main St.	Winneconne	B-70-0913 (2)	RL-B	State	1934

- RL-B = Rolling Lift Bascule (Scherzer Type) = -0002 Unit
- ST-B = Simple Trunnion Bascule = -0003 Unit
- NC-B = Simple Trunnion Bascule without counterweight
- Sw = Swing span
- VL = Vertical Lift bridge

Figure 3.1.6-1: Movable Bridges in Wisconsin Outside of Milwaukee – On Public Roadways.



Waterway	Miles From Mouth	Roadway Name	Location	Struct. No.	Type	Owner	Year Built
Kinnickinnic Rvr.	1.67	STH-32/ Kinnickinnic Ave.	Milwaukee	B-40-0591	ST-B	City	1999
Kinnickinnic Rvr.	1.78	1 st St.	Milwaukee	P-40-0830	ST-B	City	1958
Menomonee Rvr.	1.08	Plankinton Ave.	Milwaukee	P-40-0539	ST-B	City	1984
Menomonee Rvr.	1.37	6 th St. (N)	Milwaukee	B-40-0414(2)	ST-B	City	2002
So. Menomonee Cnl.	1.51	6 th St. (S)	Milwaukee	B-40-0413(2)	ST-B	City	2002
Menomonee Rvr.	1.95	Emmber Lane	Milwaukee	B-40-0605 (6 & 7)	ST-B	City	2000
Menomonee Rvr.	2.14	16 th St.	Milwaukee	B-40-0550	ST-B	City	1929
Milwaukee Rvr.	0.79	STH-32/Broadway	Milwaukee	B-40-0952	ST-B	City	1982
Milwaukee Rvr.	0.94	Water St.	Milwaukee	B-40-0548	ST-B	City	1987
Milwaukee Rvr.	1.21	St. Paul Ave.	Milwaukee	P-40-0523	VL	City	1966
Milwaukee Rvr.	1.28	Clybourn Ave.	Milwaukee	P-40-0868	VL	City	1968
Milwaukee Rvr.	1.37	Michigan St.	Milwaukee	P-40-0886	VL	City	1978
Milwaukee Rvr.	1.46	Wisconsin Ave.	Milwaukee	B-40-0488	VL	City	1975
Milwaukee Rvr.	1.61	USH-18 EB/ Wells St.	Milwaukee	B-40-0544	VL	City	1985
Milwaukee Rvr.	1.70	Kilbourn Ave.	Milwaukee	P-40-0881	ST-B	City	1929
Milwaukee Rvr.	1.79	USH-18 WB/ State St.	Milwaukee	B-40-0980	ST-B	City	1924
Milwaukee Rvr.	1.9	Highland Ave.(Ped.)	Milwaukee	B-40-907	VL	City	1998
Milwaukee Rvr.	2.06	Juneau Ave.	Milwaukee	B-40-757	VL	City	2012
Milwaukee Rvr.	2.12	McKinney Ave./ Knapp St.	Milwaukee	B-40-0062	VL	City	2004
Milwaukee Rvr.	2.29	Cherry St.	Milwaukee	P-40-0864	ST-B	City	1940
Milwaukee Rvr.	2.58	Pleasant St.	Milwaukee	B-40-0406	VL	City	1972

- RL-B = Rolling Lift Bascule (Scherzer Type) = -0002 Unit
- ST-B = Simple Trunnion Bascule = -0003 Unit
- NC-B = Simple Trunnion Bascule without counterweight
- Sw = Swing span
- VL = Vertical Lift bridge

Figure 3.1.6-2: Movable Bridges In Milwaukee – On Public Roadways.



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