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2.5 SUBSTRUCTURE

2.5.1 Introduction

The bridge substructure includes all elements that support the superstructure. Substructure elements deliver the superstructure reaction loads down to the foundation soil or bedrock. In addition, substructures must also control deflections and settlements so as not to create serviceability problems for the riding surface or unintended overloads of the superstructure. There are three main substructure components: abutments, piers, and wingwalls.

2.5.1.1 Abutments

Abutments function to support the ends of the bridge and to retain the soil fill under the approach. Refer to Figure 2.5.1.1-1 for details of common abutment types. Abutments must therefore resist vertical loads from the superstructure (live loads and superstructure self-weight), plus lateral loads due to soil pressure under the approach. Lateral loads may also come from superstructure longitudinal forces due to temperature effects, vehicle braking forces, etc. An abutment is designed to resist these longitudinal forces only if the bearings above are fixed. Unintended superstructure longitudinal forces are delivered to the abutment when abutment expansion bearings have “frozen” due to corrosion or debris accumulation.

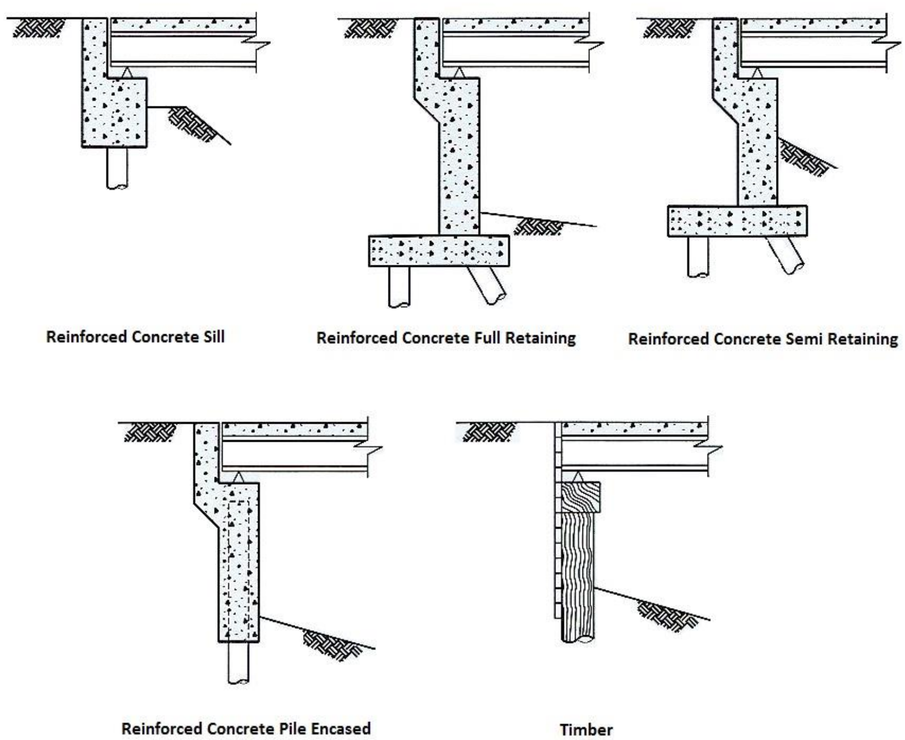

Figure 2.5.1.1-1: Typical Abutments

To resist the loads described above, abutments must act as both compression and bending elements. For shorter abutment heights (less than 6 feet), bending due to lateral soil pressure is not significant. For taller abutment heights, the bending becomes a significant factor in the structure's safe design.

Almost any type of material may be used to construct an abutment. The most common is reinforced concrete, although masonry, timber, plain (un-reinforced) concrete, and (rarely) steel abutments have been built. Current Wisconsin Department of Transportation (WisDOT) standards detail reinforced concrete and timber as materials to be used for typical highway crossings. Abutment material type is defined by the material retaining the embankment.

To accurately fill out an inspection report, an inspector should know the correct terminology for the various abutment components. These include:

- **Stem/breast wall:** The stem, sometimes called breast wall, is the main body of the abutment. It functions to deliver the superstructure reaction loads to the foundation and to retain much of the soil behind the abutment.

- **Bearing/bridge seat:** The bearing seat, sometimes called bridge seat, is the top surface of the stem/breast wall or cap upon which the bearing devices for the superstructure are placed.

- **Backwall:** Backwalls, located at the ends of the girders, retain the soil under the approach from spilling onto the bearing seat. It may also provide support for concrete approaches and provide anchorage for expansion joint devices.

- **Cheek wall:** Cheek walls are features placed at either end of the abutment to protect the fascia bearings from the elements. They also serve as architectural features to hide the bearings.

Figure 2.5.1.1-2: Reinforced Concrete Sill Abutment

2.5.1.2 Piers

Piers are intermediate support points for a bridge, used mainly for medium to long structures. Piers must resist vertical loads from the superstructure (live loads and superstructure self-weight) and superstructure longitudinal forces due to temperature effects, vehicle braking forces, etc. A pier is designed to resist these longitudinal forces only if the bearings above are fixed. Unintended superstructure longitudinal forces are delivered to the pier when the pier expansion bearings have "frozen" due to corrosion or debris accumulation. To resist the above loads, piers must act as both compression and bending elements. Piers must also resist lateral forces transverse to the bridge centerline. These forces come from wind pressures against the girders, centrifugal effects of traffic on curved bridges, stream flow, etc. Most piers act as cantilever beams to resist loads longitudinal to the bridge centerline. Depending on the configuration of its elements, piers act as frames, cantilevers beams or shear walls to resist loads transverse to the bridge centerline. Refer to Figure 2.5.1.2-1 for details of common pier types.

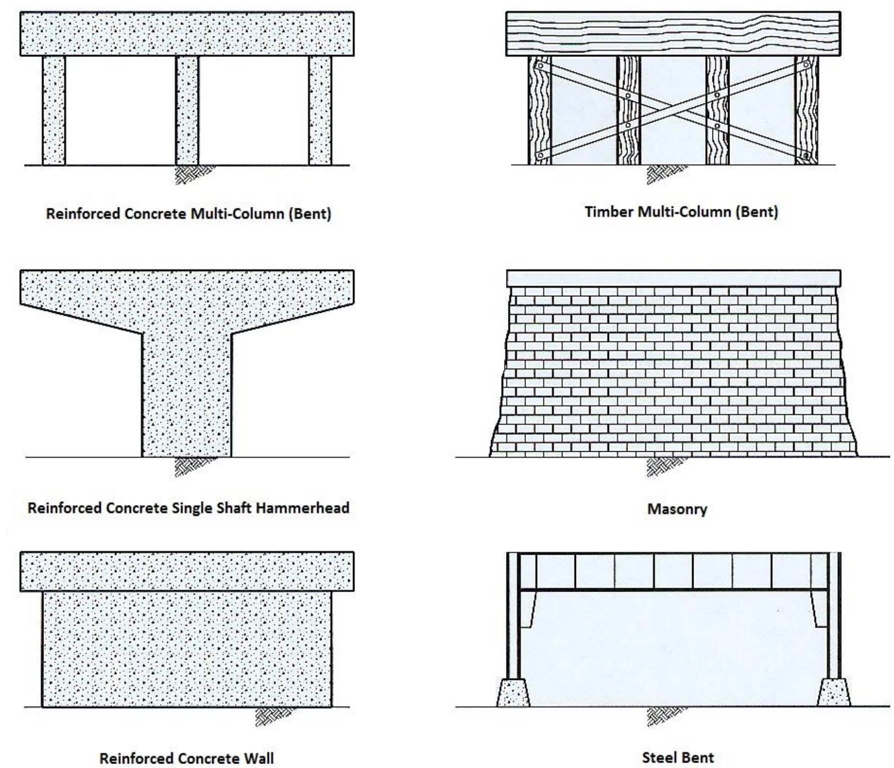

Figure 2.5.1.2-1: Typical Piers

Almost any type of material may be used to construct a pier. The most common is reinforced concrete, although masonry, timber, steel, and (rarely) plain concrete have been built. Current WisDOT standards detail reinforced concrete as the material to be used for typical highway crossings.

To accurately fill out an inspection report, an inspector should know the correct terminology for the various pier components. These include:

- **Pier cap:** A pier cap is the horizontal component of a pier upon which the bearing devices for the superstructure are placed. It also acts to tie the column tops together on multi-column piers to form a frame for resisting loads transverse to the bridge centerline. When used on a multi-column pier, pier caps behave as bending members. When used above pier walls, pier caps are simply an architectural feature formed by thickening the wall, although bending may come into play if the cap cantilevers over the ends of the wall.

  Column: A column differs from a pile in the way that it is supported. A column will be supported by a concrete pedestal or footing that can be beneath the ground level or exposed. A pile will extend well past the ground level into more substantial bearing material, such as bedrock or stone that will provide the substructure with structural stability. If a column's pedestal or footing is buried it may be difficult to tell the difference between a column and a pile without looking at the bridge plans.

- **Solid wall:** A solid pier wall is another component of a pier, many times the only component visible. They are essentially very wide solid shafts of constant thickness that behave as shear walls. They behave as beam/columns to resist axial compressive forces and bending longitudinal to the bridge centerline. They are often used within streams or rivers because they offer less resistance to water flow than multicolumn piers. For recording purposes, a vertical member may be considered a wall (versus a stem) when its height is less than its width.

- **Web wall:** Web walls are the concrete infill between the columns and pier caps of multicolumn piers. Web wall thicknesses are always less than column widths. They are used to change multicolumn pier lateral behavior from a frame to a shear wall,.

- **Hammerhead:** Hammerhead piers are comprised of a horizontal component (similar to a pier cap) of a pier upon which the bearing devices for the superstructure are placed. However, the horizontal members are placed over a single vertical pier stem with a width much smaller than a pier wall. Hammerheads caps are pure bending members that cantilever over either side of the stem. Hammerhead piers are coded as a cap and a column when exposed height is greater than width. If width is greater than the exposed height the hammerhead pier is coded as a cap and pier wall.

- **Stem:** Stems are solid shaft vertical pier components that behave as a cantilever beam/column to resist axial compressive forces and bending longitudinal and transverse to the bridge centerline. For recording purposes, a vertical member may be considered a stem or column (versus a wall) when its height exceeds its width.

- **Crash wall:** Crash walls are placed between the columns of multicolumn piers or between the stems of two individual piers supporting separate bridges. Their purpose is to protect the pier base from rail car, ship or vehicle impacts. Normally, the thickness of a crash wall is the same as the column/stem width to prevent snagging during a collision. For recording purposes, when a crash wall is fully supported by a foundation (footing or piling) and the wall supports columns, the crash wall may be considered a pier wall. If the crash wall is placed between the columns after-the-fact, the crash wall is considered secondary (it does not support the columns but rather braces) and shall not be considered a pier wall.

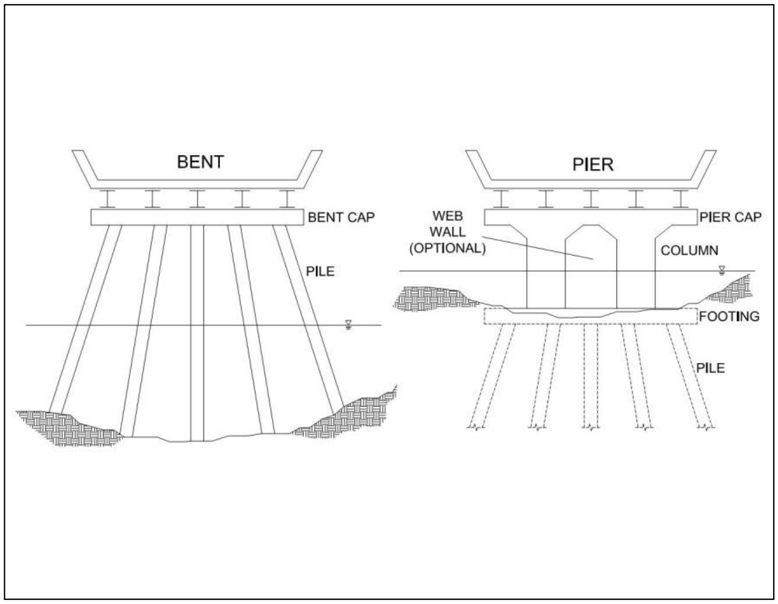

Figure 2.5.1.2-2: Diagram showing differences between a Bent and Pier

Figure 2.5.1.2-3: Reinforced Concrete Columns and Pier Cap

Figure 2.5.1.2-4: Hammerhead Pier

Figure 2.5.1.2-5: Crash Wall

2.5.1.3 Wingwalls

Wingwalls are found at abutment ends to retain and enclose the approach fill. Without them, the approach fill would spill or wash out, causing settlement of the roadway. Wingwalls resist lateral pressures due to the approach fill and carry no vertical loads other than their self-weight. Depending on the original design criteria, three geometries may be used to properly retain the fill. These are straight wings parallel to the abutment, U-wings parallel to the roadway, and flared wings that form an acute angle between both the roadway and abutment. Wingwalls may or may not be rigidly attached to the abutment body.

Almost any type of material may be used to construct a wingwall. The most common is reinforced concrete, although masonry, timber, and steel have been built. Current WisDOT standards detail reinforced concrete and timber as the material to be used for typical highway crossings.

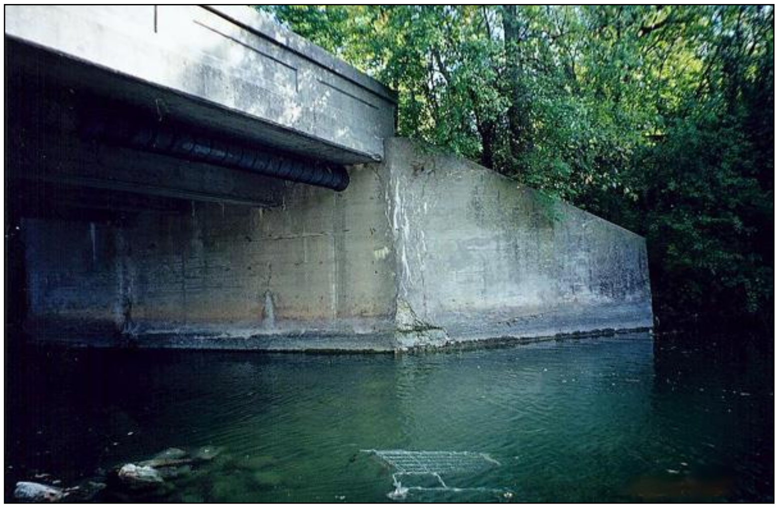

Figure 2.5.1.3-1: Reinforced Concrete Wingwall

For recording purposes, only integral wingwalls should be evaluated as a wingwall. A reinforced concrete wingwall is considered to be integral if it is monolithic with the abutment. Timber and steel wingwalls are considered to be integral wingwalls, even with the presence of a joint at the end of the abutment on flared wingwalls. R-numbered structures (numbered retaining walls) are not considered wingwalls and should be inspected and reported separately from the bridge inspection. Non-integral wingwalls or non R-numbered structures shall be evaluated under the most appropriate retaining wall element.

2.5.1.4 Integral Wingwall (Element 8400)

This element defines the wingwalls integral with the abutment which extend past the bridge seat for parallel wingwalls, or at the skew point when the wingwalls are turned back.

Steel wingwalls and timber wingwalls are considered to be integral wingwalls, even with the presence of a joint at the end of the abutment on flared wingwalls. Steel wingwalls and timber wingwalls are considered monolithic up to the first construction joint (integral plank butt joint, etc.) past the bridge fascia. All other extensions are not to be included within the quantity measurement nor the condition ratings.

Reinforced concrete wingwalls and prestressed concrete wingwalls are considered integral wingwalls when poured monolithic with the concrete abutment. Non-monolithic wingwalls without “R” numbers are considered retaining walls. Therefore, retaining wall elements will be used for the evaluation of these wingwalls. Non-integral wingwalls with “R” numbers will not be coded as part of the bridge inspection.

Masonry wingwalls that are monolithic with the abutment (i.e. have the stones overlapping at the corners) will be considered integral wingwalls. Non-integral wingwalls without “R” numbers are considered retaining walls. Therefore, retaining wall elements will be used for the evaluation of these wingwalls. Non-integral wingwalls with “R” numbers will not be coded as part of the bridge inspection.

Element Level Inspection

On the inspection report form, integral wingwalls are recorded in units of "each". For each wingwall, the most severe defect Condition State is assigned to the entire element. This will quantify the wingwall's condition and help to generate quantity/cost estimates for future remedial work.

Element Defect

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

- Wall Movement (8902)
- Wall Deterioration (8903)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.1.5 Foundation Types

Three foundation types are used to support substructure elements. Piles are by far the most common of the three in Wisconsin. Piles are structural members that transmit all of the bridge live and dead loads into the underlying soil or bedrock. They are often used when soils immediately below the substructure unit are inadequate to resist the bearing pressures or satisfy settlement criteria. They are driven into the ground with a pile driver and rely on soil friction and/or end bearing to deliver the bridge loads into the earth. Piles may be driven vertically or at a batter (angled) to resist lateral loads. Materials used for piles include steel, reinforced concrete, timber, and prestressed concrete. In Wisconsin, steel H-piles and pipe piles filled with concrete (cast-in-place or CIP piles) are the most common.

Footings are the second type of foundation. Located at the base of the substructure unit, footings spread out and transmit the weight of all bridge live and dead loads to the supporting soil or bedrock. They also provide stability against substructure unit overturning and sliding due to lateral soil pressures. In Wisconsin, footings are normally only used to bear on sound bedrock and only when the bedrock is located close to the bottom of the substructure.

Caissons are the third type of foundation. Caissons are drilled shafts which can offer larger diameters and deeper depths when compared to driven piles. Caissons will typically be used for larger construction projects with large loads or on bridge projects with restrictive site locations. Caissons can have rebar cages placed into the drilled shafts before the concrete is poured for added strength depending on the diameter and depth. A common failure is the caisson walls collapsing prior to the addition of concrete.

Typically, foundations are buried underground and should not be visible when the bridge is in service. However, the top of foundation may be designed to be exposed. An exception is pile bent foundations. Pile bents are substructure units with the piles extending above grade. After driving, the pile tops are tied together with a conventional pier cap.

2.5.2 Steel Substructure Elements

Other than piles, steel is not commonly used for substructure elements in new designs. However, it was often used in the past to form the bents or bent towers of large bridges. Some shorter span structures even used this substructure type. It is unusual, but not unheard of, to see an abutment or wingwall built from steel.

The most common defect found on steel substructures is corrosion, and the heaviest corrosion is generally found below failed and leaking expansion joints. Other defects of concern are fatigue cracks, vehicle collision damage, overload damage, and fire damage.

2.5.2.1 Steel Column (Element 202)

The columns of steel piers are primary load-carrying elements, resisting both compressive axial loads and bending moments. Columns may be pipes or fabricated box shapes. Steel piers consist of two or more steel columns connected along their tops by a pier cap built of steel or reinforced concrete.

A column differs from a pile in the way that it is supported. A column will be supported by a concrete pedestal or footing that can be beneath the ground level or exposed. A pile will extend well past the ground level into more substantial bearing material, such as bedrock or stone that will provide the substructure with structural stability. If a column's pedestal or footing is buried it may be difficult to tell the difference between a column and a pile without looking at the bridge plans.

Element Level Inspection

On the inspection report form, columns are recorded in units of "each". For each column, the most severe Condition State is assigned to the entire element. This will quantify the column's condition and help to generate quantity/cost estimates for future remedial work.

Safety Inspection

During the Element Level Inspection of steel columns, it is important to remember that the entire purpose of bridge inspection is to ensure public safety. A structural inspection must also be carried out, regardless of the coating condition. The following will serve as a guide for what the inspector should be looking out for to judge an element's ability to carry the design loads, and to identify current or future structural problems.

Inspection of steel columns should include the following items:

- Looking for local compression overload damage in the form of local member component buckling, plate waviness or crippling. This may be evident near the ground line of abutment piles where maximum bending compressive stresses occur.

- Looking for global buckling which will take the form of a bow or sweep in the member. This could be the result of a structural overload or differential settlement.

- Examining the member ends for cracks and loose fasteners. Suspect fasteners may be checked for looseness by twisting by hand or tapping the heads with a hammer.

- Checking corroded areas for excessive section loss that may be increasing member stress. Particular attention should be given to members adjacent to the splash zones of roadways, near the water line for water crossings, and any detail that would tend to trap water and debris.

- Inspecting for cracking and distortion, such as a kink that would suggest the member has experienced collision damage.

- Checking the pier for plumbness visually or with a plumb bob.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)
- Microbial Induced Corrosion (8901)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow

• Condition State 3	Poor	Orange
• Condition State 4	Severe	Red

2.5.2.2 Steel Tower/Trestle (Element 207)

This element is intended to be used for truss framed tower supports or built up steel towers. This element is intended to capture large supports and towers associated with suspension bridges, cable stayed bridges, moveable bridges, or similar structural configurations.

A tower or trestle element will be three dimensional in nature with lateral and torsional bracing along all sides of the substructure unit. Pier bents with a single strut running between the two does not constitute trestle bracing.

Element Level Inspection

On the inspection report form, a steel column tower is recorded in units of lineal feet of vertical height. This quantity is the sum of the heights of each built-up or framed tower supports. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element’s condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

• Corrosion	(1000)
• Cracking	(1010)
• Connection	(1020)
• Distortion	(1900)

Structural Defects

• Settlement	(4000)
• Scour	(6000)

- Microbial Induced Corrosion (8901)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

Figure 2.5.2.2-1: Steel Towers/Trestles – Condition State 1

2.5.2.3 Steel Abutment (Element 219)

This includes the sheet material retaining the embankment and abutment extensions. This is for all steel abutments regardless of protective system. The abutment material type is coded as the main fill retaining material. Therefore, if an abutment is constructed with timber piles and a steel lagging behind retaining the fill, then Steel Abutment will be used in conjunction with Timber Pile elements.

Element Level Inspection

On the inspection report form, a steel abutment is recorded in units of lineal feet. This measurement is taken as the length of the abutment taken along the skew (if present). Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)
- Distortion (1900)

Settlement Defects

- Settlement (4000)
- Scour (6000)
- Microbial Induced Corrosion (8901)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.2.4 Steel Pile (Element 225)

This element defines steel piles that are visible for inspection. Piles exposed by erosion or scour and piles visible during an underwater inspection are also included in this element. This element is for all steel piles regardless of protective system. Some abutment types may also use exposed steel piles, most notably timber abutments. Steel piles are driven and left to extend from the ground to the abutment cap. After the abutment cap (usually reinforced concrete) is placed, timber lagging is placed at the back face of the piles. Backfill is placed behind the lagging, and this process is repeated until the pile cap is reached. The steel abutment piles must therefore resist vertical loads from the superstructure and pier cap, as well as lateral soil pressures from the fill under the approach. In this sense, the piles are acting as beam/columns to resist axial compressive loads and bending moments. Maximum bending stresses occur near the ground line, which is also where corrosion is most likely to take place.

As discussed in the Steel Column Element section, a pile will extend well past the ground level into more substantial bearing material, such as bedrock or stone that will provide the substructure with structural stability. Piles can be easily confused with columns without first looking at the bridge plans if a pedestal or footing is not exposed.

For coding purposes, piles used to support abutment lagging are considered separate from the abutment and shall be coded separately as pile elements. Piles used to support wingwall lagging are considered part of the wingwall and shall be evaluated under Integral Wingwall (Element 8400).

Cast-in-place or CIP piling shall be evaluated as Steel Pile (Element 225). Inspectors can only evaluate what they can inspect, which in the case of these piles is the exposed steel shell. The inspector shall note under the Steel Pile element that the piling is CIP piling. The inspector should verify from the original bridge plans if the concrete is reinforced or not.

Figure 2.5.2.4-1: Heavy Corrosion at the Ground Line on Painted Steel Piles - Condition State 4

Element Level Inspection

On the inspection report form, steel piles are recorded in units of “each”. For each pile, the most severe Condition State is assigned to the entire element. This will quantify the pile’s condition and help to generate quantity/cost estimates for future remedial work. The inspector should pay close attention to corrosion and section loss which can lead to structural reduction of the member. These defects can be accelerated in wet environments such as waterways. If a pile is partially exposed, the unit of the element remains “each” and the entire pile shall be evaluated based on the exposed area.

Element Defect

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)

- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)
- Microbial Induced Corrosion (8901)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.2.5 Steel Pier Cap (Element 231)

Figure 2.5.2.5-1: Steel Box Pier Cap

Pier caps are primary load-carrying bending members. Because they must carry large girder reaction loads, steel pier caps are often fabricated into box shapes, although I-shaped members are also used for short crossings. Pier cap boxes are usually large enough for an inspector to enter and examine its interior. Steel pier caps may work in conjunction with steel columns to form a frame or they may bear on top of individual concrete pier columns.

A distinction needs to be made regarding the difference between a steel pier cap and a steel cross girder. Both function to deliver the girder end reactions to the pier columns. However, on pier caps, the superstructure girders bear on the cap's top flange. Bearing devices keep the girders independent from the cap.

Similar to a cap, cross girders support superstructure girders which are welded or bolted directly to the cross girder web. There are no bearing devices separating these two components. Any bearing devices are located on the underside of the cross girder at the pier columns. Cross girders are considered superstructure elements as they are supported by bearing. Refer to Chapter 4 for additional information on girder elements.

Element Level Inspection

On the inspection report form, a steel pier cap is recorded in units of lineal feet. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Safety Inspection

During the Element Level Inspection of steel pier caps, it is important to remember that the entire purpose of bridge inspection is to ensure public safety. The main purpose of pier caps is to transmit superstructure loads to the pier columns. A structural failure could mean a localized bridge failure requiring shutting down part or all of the bridge.

Flexural Areas: Bending zones are located throughout the length of a pier cap, except at the ends when rotation is allowed at the top of exterior columns. Positive bending areas are located between the supports. Negative bending locations are directly over the interior columns and above the exterior columns when a rigid connection is provided.

Maintenance inspection in the flexural areas of steel pier caps should include the following items:

- Examining the flexure zones and tension flanges for corrosion and loss of cross-sectional area, which is the most common steel defect. About 10 percent flange section loss or greater will begin to raise the stress level an appreciable amount.
- Removing spot areas of debris accumulation to check for corrosion. Bird waste often found on the flanges is acidic and traps moisture and debris, accelerating corrosion.
- Checking rivet/bolt heads on built-up components, as corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

- Looking for pack rust, noted by individual plate bending between fasteners. Pack rust may be present between the plies of riveted/bolted connections such as field splices or secondary member connections.

- Looking for overload damage in the form of compression flange buckling and tension flange elongation or fracture in the high moment flexural regions.

- Looking for rotation in the pier cap due to eccentric connections.

- Examining suspect fasteners for looseness by twisting by hand or tapping the heads with a hammer.

- Checking the pier cap for distortion or scraping from traffic impacts.

- Sighting down the member's length to check vertical and horizontal alignments, as well as for any canting (lateral bending or twisting). This type of damage may be due to overloads, traffic impact or support settlement.

Shear Zones: The zones of highest shear stresses are located at the columns or piles. Most steel pier caps make use of vertical bearing stiffeners at their supports.

Maintenance inspection in the shear areas of pier caps should include the following items:

- Looking for web crippling where bearing stiffeners are not used. Web crippling is a permanent wrinkling or buckling of the web due to overloads.

- Checking for web section loss due to corrosion. Web section loss makes the web less stiff and more susceptible to crippling.

- Checking the bearing stiffeners for corrosion and any associated buckling due to overloads.

Safety Inspection - Fatigue

Primary bending members are susceptible to fatigue damage. Fatigue cracks usually show up as rust stains or rusty breaks in the paint, propagating perpendicular to the direction of stress.

Hot-rolled Pier Caps – Hot-rolled beams may sometimes be used as pier caps for smaller bridges with multi-column piers. Fatigue inspection of these hot-rolled steel beams should include the following items:

- Looking for welded repairs which increase the static strength of a member, but greatly reduce the fatigue strength. These include patch plates fillet welded over heavily corroded areas producing sudden geometric changes and poor quality plug welds used to fill mis-drilled bolt holes. Weld cooling also creates high residual tensile stresses in the base material.

- Investigating bearing stiffeners that are erroneously welded to the tension flange. These welds act as stress risers and could be a crack initiation point. Carefully check the welds and flange on these floor system components for cracks.

Fabricated Pier Caps: In-plane bending fatigue prone details on fabricated girder pier caps are similar to those found on hot-rolled beams. In addition, fatigue inspection in the flexural areas of fabricated steel pier caps should include the following items:

- Investigating groove welds used to join the ends of web plates or different size flange plates. These welds may be found ground flush or with the reinforcement left in place. In either case, though fatigue cracks are not normally expected to be found, poor welding or poor inspection may have left internal flaws within the weld metal, especially on older bridges.

- Examining intersecting welds. High residual tensile stresses, internal flaws, and low fatigue strengths are created when welds intersect at attachments. Common intersecting weld locations are at a transverse stiffener/web/flange junction or bearing stiffener/web/flange junction.

Box Pier Caps: In-plane bending fatigue prone details on box girder pier caps are similar to those found on fabricated open girders. In addition, fatigue inspection in the flexural areas of steel box girders should include the following items:

- Investigating back-up bars that are welded together end-to-end located within tension or stress reversal zones. These bars carry the same longitudinal stresses as the pier cap box and may produce fatigue cracks due to low quality welds joining the bars or discontinuity of the bars.

- Investigating any web or flange longitudinal stiffeners that are welded together end-to-end and are within tension or stress reversal zones. Pay particular attention to all questionable details located along the tension flanges.

- Checking all welded attachments inside the box pier cap including the transverse stiffeners and diaphragms.

Riveted and Bolted Members: Though welded structures are most often associated with fatigue concerns, mechanically fabricated members are also susceptible to fatigue damage. Vulnerable locations are essentially the same for welded and riveted members, that is, at connections.

Miscellaneous: Fatigue inspection of miscellaneous components should include looking for stress risers on tension flanges such as tack welds, gouges, and indiscriminately placed attachment welds. These may occur on any welded or riveted/bolted member listed above. Flaws such as these should be marked, recorded, and ground smooth. Until the areas are repaired, the member should be closely monitored to spot crack development.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)
- Microbial Induced Corrosion (8901)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.2.6 Nonredundant Steel Tension Member Steel Substructures

Bridges can be either Nonredundant Steel Tension Member (NSTM) or non-NSTM depending on whether they are load path redundant or not. A bridge is considered load path redundant if it has three or more primary load-carrying members spanning between supports. If a bridge has two or less primary load-carrying members running between supports it does not have load path redundancy and therefore considered a NSTM bridge.

NSTM bridges contain NSTM (NSTMs), and these members require special attention during an inspection. A NSTM is in tension or has a tension element whose failure would probably cause a portion of or the entire bridge to collapse. There must not be any other member or system of members that will serve the functions of the member in question should it fail. Fatigue failures are the main cause of concern for steel NSTMs since fatigue failures are brittle and give no warning before imminent collapse.

There is one type of steel substructure member classified as NSTM. This member is a single I-girder or box girder pier cap supported by two columns. The pier cap's tension flange is the NSTM element.

Steel pier caps should not be confused with steel cross girders. Pier caps are elements separate from the superstructure. Superstructure girders bear on the pier cap's top flange, separated by bearing devices. Cross girders are part of the superstructure. The superstructure girders are directly connected to the cross girder web by welding or bolting. Any bearing devices are located on the underside of the cross girder.

Wisconsin policy requires that qualified personnel conduct NSTM bridge inspections. Prior to performing the fieldwork, the policy requires this team to develop an inspection plan which identifies all NSTM on the bridge. It also requires a historical review of all available bridge information (original construction documents, rehabilitation plans, etc.) so that the team is aware of any suspect details or previous deficiencies.

Field inspection for a NSTM bridge is "hands-on," meaning a visual inspection of all NSTMs should be performed from within arm's reach. Every square foot of a NSTM should be examined. To accomplish this, debris needs to be cleaned off all members so that a thorough inspection can be made. For box pier caps, the interior and the exterior must be examined. The inspection team should look for the same deficiencies as on any steel member, paying particular attention to any fatigue cracks that may be found. An inspector seeing and reporting such a flaw is the only line of defense against a sudden NSTM failure and potential total collapse of a bridge.

The condition of each NSTM should be recorded on the NSTM Bridge Inspection Form with deficiencies noted or an "ok" to indicate the member has been examined.

Figure 2.5.2.6-1: NSTM Riveted Steel Box Girder Pier Cap. Note that the superstructure girders bear on the pier cap’s top flange by way of bearing devices

2.5.3 Reinforced Concrete Substructure Elements

Concrete is by far the most common material used to construct bridge substructure elements. Around the turn of the 20th century, massive concrete substructures were built to replicate the more commonly used masonry substructures. The ease of placement, formability, and long term durability of concrete was quickly recognized, and this led to the near elimination of building masonry substructures.

2.5.3.1 Reinforced Concrete Column (Element 205)

Reinforced concrete columns and shafts refer to pier elements. The term “column” is used for piers with two or more vertical supporting members, while the term “shaft” refers to piers with one vertical supporting member. They are primary load-carrying members that directly support pier caps, hammerheads, and sometimes girders.

Figure 2.5.3.1-1: Reinforced Concrete Multi Column Piers

Columns/shafts are primarily compression members, but they must also resist lateral bending moments due to wind loads, eccentric loading at their tops, superstructure longitudinal forces, and differential substructure settlements.

Element Level Inspection

On the inspection report form, columns and shafts are recorded in units of “each”. It is the inspector’s task to examine each column or shaft and reasonably assign the most severe Condition State to the whole element. This will quantify the column/shaft’s state of deterioration and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of reinforced/prestressed concrete pier columns and shafts should include the following items:

- Checking the column's base for transverse flexural cracks. These cracks indicate excessive column bending. Sources for this bending may be from expansion bearings that have corroded and locked up above the pier. Superstructure expansion/contraction will then pull the pier cap along, bending the columns. Excessive lateral forces due to wind or centrifugal effects may also cause bending.

- Checking the pier cap/column interface for horizontal or diagonal flexural cracks. These cracks will originate at the inside corner of the cap/column junction and are a sign of excessive lateral bending.

- Checking the mid-height of the column for flexural cracks, as this is a sign of structural overloads or differential substructure settlement.

- Examining the entire column for vertical cracks and crushed concrete. This could be the result of a serious structural overload.

- Checking the entire column for delaminations, spalls, and exposed reinforcing/prestressing steel. Suspect areas are in roadway splash zone or bridge drainage areas, at water lines for water crossings or at grade. These defects reduce these members' cross sectional area, resulting in higher stresses.

- Looking for leaching, and noting if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.

- Checking the column/shaft for plumb visually or with a plumb bob.

- Checking previously repaired areas for soundness by hammer tapping.

- Noting if any soil, rock or debris has been piled against the column/shaft. This will cause lateral forces on the member not originally accounted for in the original design.

- Noting any abrasion of the concrete surface for columns or shafts located within a waterway.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)

- Exposed Rebar (1090)

- Cracking (RC) (1130)
- Abrasion/Wear (PSC/RC) (1190)
- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

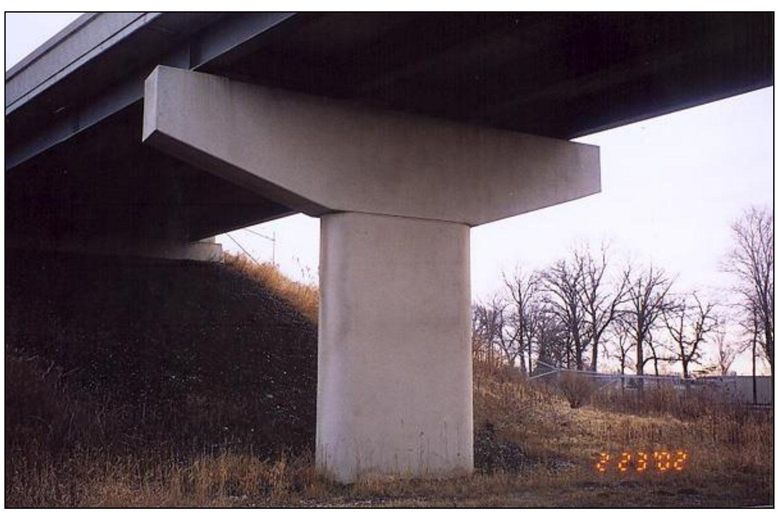

Figure 2.5.3.1-2: Hammerhead Pier Reinforced Concrete Column – Condition State 1 (The cap of the hammerhead pier is reported under Element 234).

Figure 2.5.3.1-3: Concrete Column with Vertical Crack - Condition State 2

Figure 2.5.3.1-4: Transverse Flexural Cracks at the Base of a Column - Condition State 2

Figure 2.5.3.1-5: Column Spall with No Exposed Rebar - Condition State 2

Figure 2.5.3.1-6: Delaminated and Spalled Column - Condition State 3

Figure 2.5.3.1-7: Spalling on a Reinforced Concrete Shaft - Condition State 3

Figure 2.5.3.1-8: Heavily Spalled Column - Condition State 4

2.5.3.2 Reinforced Concrete Pier Wall (Element 210)

Reinforced concrete pier walls refer to solid pier walls,. Solid pier walls are primary load-carrying members that support the superstructure. Crash walls are safety devices located near grade or the water line, and web walls are secondary members used for lateral pier support. All web walls and most crash walls shall be coded under Cross Bracing or Struts (Assessment 9250). The exception is when a crash wall also acts as a pier wall. That is, it has a full length foundation and supports the pier columns.

Figure 2.5.3.2-1: Reinforced Concrete Pier Wall

Pier walls are primarily compression members, but they must also resist lateral forces due to wind loads, and bending moments due to eccentric loading at their tops, superstructure longitudinal forces, and differential substructure settlements. Crash walls typically only resist traffic impact loads, and web walls resist lateral wind forces.

Element Level Inspection

On the inspection report form, a pier wall is recorded in units of lineal feet. This measurement is taken as the length of the pier wall from end to end taken along the skew (if present.) The total quantity is the sum of all pier wall lengths in the structure. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element’s condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of reinforced concrete pier walls should include the following items:

- Checking the wall’s base for transverse flexural cracks. These cracks indicate excessive column bending. Sources for this bending may be from expansion bearings that have corroded and locked up above the pier. Superstructure expansion/contraction will then pull the pier cap along, bending the wall.

- Examining the entire wall for vertical or diagonal cracks. Diagonal cracks in web walls may be the result of excessive lateral shear.

- Checking the entire wall for delaminations, spalls, and exposed reinforcing steel. Suspect areas are in roadway splash zone or bridge drainage areas, at water lines for water crossings or at grade. These defects reduce these members' cross sectional area, resulting in higher stresses.

- Looking for leaching, and noting if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.

- Examining the top surface (bearing seat) of walls without pier caps for cracking and spalling. The pedestals and grout pads under the bearings should also be checked for cracking, spalls, and deterioration that reduce the bearing area. Deterioration in these areas may be caused by the lack of reinforcing steel in older bridges, frozen expansion bearings that transmit lateral forces to the pier not intended in the original design, and salt-laden water leaking through expansion joints.

- Visually checking the wall for plumb.

- Checking previously repaired areas for soundness by hammer tapping.

- Noting if any soil, rock or debris has been piled against the wall. This will cause lateral forces on the member not originally accounted for in the original design.

- Noting any abrasion of the concrete surface for pier walls located within a waterway.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)

- Exposed Rebar (1090)

- Cracking (RC) (1130)

- Abrasion/Wear (PSC/RC) (1190)

- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

Figure 2.5.3.2-2: Cracked, Delaminating and Spalled Reinforced Concrete Pier Wall – Condition State 3

Figure 2.5.3.2-3: Disintegration of a Reinforced Concrete Pier Wall – Condition State 3

2.5.3.3 Reinforced Concrete Abutment (Element 215)

Reinforced concrete abutments are classified according to their function and placement relative to the embankment. The most common types in Wisconsin are:

- **Sill:** Short height abutments using a single row of vertical piles for support. They are placed at the top of the embankment and use a sloped berm in front to contain the soil under the approach. Reinforcing steel is nominal since bending between the piles and shear forces are small relative to the capacity of the abutment body. Although this is the least expensive and easiest abutment to construct, it requires the longest bridge spans in order to clear the berms.

- **Full Retaining:** Tall abutments designed as cantilever retaining walls to hold back soil under the approach. Because of this function, the main reinforcing steel is placed vertically at the back face of the abutment. A spread footing, supported by the soil or two rows of piles, anchors the abutment stem below grade. Full retaining abutments are advantageous in that span lengths are minimized, but their disadvantages include high construction costs, minimal horizontal clearances and sight distances, and they are collision hazards.

- **Semi Retaining:** Similar to full retaining abutments, semi retaining abutments use small sloped berms placed between the roadway underpass and bearing seat. The berm allows greater horizontal clearances, sight distances, and better protection from errant vehicles.

- **Pile Encased (Integral):** Medium to tall abutments used when site conditions render a bridge using sill abutments more costly. Piles are driven into the ground and left extending up the full abutment height. The piles are then encased in concrete, forming part of the abutment stem. This abutment type is called “integral” in that the superstructure is locked to the top of the abutment, allowing the superstructure and substructure to act as a unit. Integral abutments therefore offer the advantage of eliminating expansion joints which often leak, damaging deicing chemicals onto the superstructure. The drawback is that the abutment and piles must be able to resist any creep, shrinkage, and thermal movements of the superstructure.

Figure 2.5.3.3-1: Reinforced Concrete Semi Retaining Abutment

Girder superstructures, primarily prestressed concrete girder superstructures bear on top of the abutment and have full height concrete diaphragms between them. When the concrete diaphragms retain fill, they shall be evaluated as part of the concrete abutment. If it is known that a backwall is behind the full height diaphragms, the diaphragms will then be evaluated as an assessment. When a diaphragm retains fill it is acting as an abutment element and therefore shall be evaluated with the abutment element.

Mechanically stabilized earth (MSE) walls have been built for bridges in Wisconsin. This relatively new soil retaining system uses precast concrete panels in conjunction with steel straps to reinforce the fill behind the panels and under the approach. The steel straps act as shear reinforcing for the soil, forcing it to act as a large mass rather than as many individual particles that could easily slide. The concrete panels prevent the fill from washing out of the soil mass. MSE walls eliminate the sloped embankment in front of an abutment, similar to a full retaining abutment. When MSE walls are used on bridges, sill abutments supported on either spread footings or piles are normally placed on top of the soil mass and adjacent to the top of the wall. Because of this and due to the fact that the precast panels carry no vertical loads, MSE walls should never be considered as reinforced concrete abutments. They often have their own structure number, and should be treated as retaining walls separate from the bridge structure. MSE walls without their own structure number, however, shall still be treated as a structure separate from the bridge. Since retaining wall inspection is not currently mandatory in Wisconsin, the inspector should provide comments on the Bridge Inspection Report form as to whether the MSE wall is in good, fair, or poor condition. If warranted, MSE walls in poor condition may be considered a critical finding and the Program Manager should be notified.

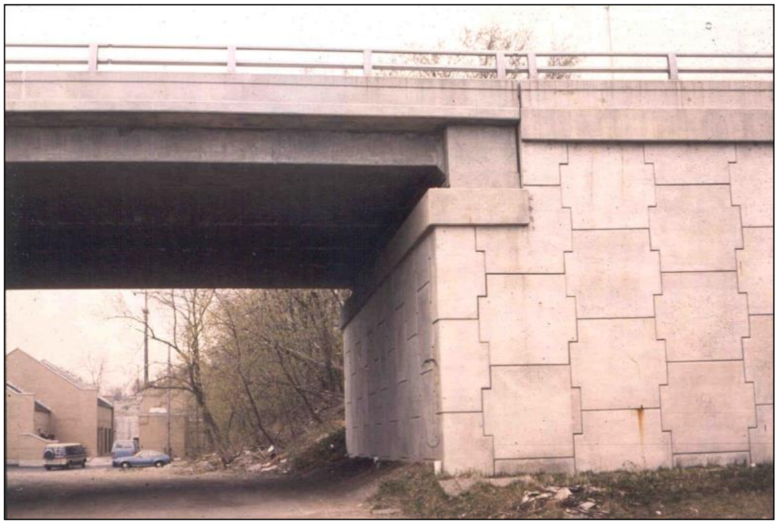

Figure 2.5.3.3-2: Sill Abutment and MSE Wall

Element Level Inspection

On the inspection report form, reinforced concrete abutments are recorded in units of lineal feet. This measurement is taken as the length of the abutment taken along the skew (if present). The total quantity is the sum of all abutments. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of reinforced concrete abutments should include the following items:

- Examining the abutment and backwall for vertical or diagonal cracks. Vertical cracks are often the result of shrinkage, while diagonal cracks may indicate a shear overload or differential pile settlement.

- Checking the entire abutment for delaminations, spalls, and exposed reinforcing steel. Suspect areas are in roadway splash zone or bridge drainage areas, at water lines for water crossings or at grade.

- Looking for leaching, and noting if it is stained with rust, since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls. Fill under the approach may retain moisture during rains or spring thaws, so leaching may be seen at cracks where this moisture escapes.

- Checking the construction joint between the backwall and bearing seat for deterioration.

- Examining the top surface (bearing seat) of abutments for cracking and spalling. The pedestals and grout pads under the bearings should also be checked for cracking, spalls, and deterioration that reduce the bearing area. Deterioration in these areas may be caused by the lack of reinforcing steel in older bridges, frozen expansion bearings that transmit lateral forces to the abutment not intended for in the original design, and salt-laden water leaking through expansion joints.

- Looking for the presence of debris or standing water on the bearing seat. Debris suggests a failed/leaky expansion joint. Standing water indicates that the bearing seat is back-pitched. Salt-laden standing water ponding on the bearing seat will eventually migrate to the reinforcing steel, causing corrosion, delaminations, and spalls.
- Checking tall abutments for plumb visually or using a plumb bob.
- Checking previously repaired areas for soundness by hammer tapping.
- Checking that any weep holes present are clear and functioning properly.
- Noting any abrasion of the concrete surface for abutments located within a waterway.
- Looking for granular soil deposits outside base of wall caused by failed weep holes or excessive joint gaps.
- Noting any MSE wall panels that are shifting out of place or allowing fill to wash out from behind.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)
- Exposed Rebar (1090)
- Cracking (RC) (1130)
- Abrasion/Wear (PSC/RC) (1190)
- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)

- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

Figure 2.5.3.3-3: Reinforced Concrete Abutment - Condition State 1

Figure 2.5.3.3-4: Vertical Crack in an Abutment – Condition State 2

Figure 2.5.3.3-5: Abutment Delaminations Under the Bearing – Condition State 2

Figure 2.5.3.3-6: Large Spall on Abutment Bearing Seat – Condition State 3

2.5.3.4 Reinforced Concrete Pile Cap/Footing (Element 220)

These elements are typically located within waterways and serve as foundations for either piers or abutments. Footings are most often supported on piles, however the footing may be a spread footing. It is not common for pile caps or footings to be exposed, so a review of the original plans is very helpful to determine if they are exposed by design or by scour.

Inspection of these two elements is difficult, but can be performed visually and by using a probe. Pile caps and footings located only a foot or two below the water surface can often be visually inspected by wading or from a boat, assuming that the water is not too murky. A probing rod may also be used to check the soundness of concrete. Dragging or scraping the rod along the element surface may reveal locations of cracks or spalls.

Element Level Inspection

On the inspection report form, reinforced concrete pier caps and footings are recorded in units of "lineal feet". The measurement is taken as the length of the element from end to end along the skew (if present). The total quantity is the sum of all the respective element lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of reinforced concrete pier caps and footings should include the following items:

- Visually examining the element to look for cracks, delaminations, spalls, and exposed reinforcing steel.

- Noting any abrasion of the concrete surface.

- Dragging or scraping a probing rod along the surface of the concrete to check for the presence of cracks, spalls or abrasion. This technique is particularly useful in murky water.

- Walking along the top of the element, if possible, to feel for large spalls or areas of abrasion.

- Note any evidence of scour in the inspection report.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)
- Exposed Rebar (1090)
- Cracking (RC) (1130)
- Abrasion/Wear (PSC/RC) (1190)
- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow

- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.3.5 Reinforced Concrete Pile (Element 227)

These elements define reinforced concrete piles that are visible for inspection. Piles exposed by erosion or scour and piles visible during an underwater inspection are included in these elements. These elements are for all reinforced concrete piles regardless of protective system.

Element Level Inspection

On the inspection report form, prestressed and reinforced concrete piles are recorded in units of “each”. Therefore, each element will be individually rated and assigned to a Condition State. It is the inspector’s task to examine each pile and reasonably assign the most severe Condition State to the entire element. This will quantify the concrete’s condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)
- Exposed Rebar (1090)
- Cracking (RC) (1130)
- Abrasion/Wear (PSC/RC) (1190)
- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.3.6 Reinforced Concrete Pier Cap (Element 234)

Pier caps are primary load-carrying bending members on single columns (hammerheads) or multicolumn piers. They may be bending members on pier walls if their ends cantilever over the ends of the wall, but they are most often used as architectural features in this situation. They often must carry large girder reaction loads and many times work in conjunction with the columns to form a frame for resisting lateral loads.

Figure 2.5.3.6-1: Reinforced Concrete Pier Cap

Element Level Inspection

On the inspection report form, a pier cap is recorded in units of lineal feet. The measurement is taken as the length of the cap from end-to-end along the skew (if present). The total quantity is the sum of all pier cap lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element’s condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of reinforced concrete pier caps should include the following items:

- Examination for vertical flexural cracks, either on the underside between columns or top side above columns or shafts. Wide cracks in a flexural region indicate a serious structural overload.

- Checking for deteriorated concrete in the flexural zones that is causing debonding of the reinforcing steel. This is especially critical near the ends of the reinforcing steel bars, since a certain length of the bar must be embedded within sound concrete to fully develop its strength. The deterioration may be delaminations, spalls, and longitudinal cracks.

- Looking for shear cracks over and near the supports. Shear cracks will be diagonal, extending up from the column towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be hanging from the reinforcing stirrups. Maximum crack widths should be measured and noted on the bridge inspection report.

- Checking the entire member for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement or prestressing steel. Since section loss associated with reinforcing and prestressing steel corrosion can reduce a member’s strength, measure this loss if possible and record it in the inspection report.

- Looking for leaching and noting if it is stained with rust, since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.

- Checking the member under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

- Checking previously repaired areas for soundness by hammer tapping.

- Checking the entire abutment for delaminations, spalls, and exposed reinforcing steel. Suspect areas are in roadway splash zone or bridge drainage areas, at water lines for water crossings or at grade.

- Examining the top surface (bearing seat) of pier caps for cracking and spalling. The pedestals and grout pads under the bearings should also be checked for cracking, spalls, and deterioration that reduce the bearing area. Deterioration in these areas may be caused by the lack of reinforcing steel in older bridges, frozen expansion bearings that transmit lateral forces to the pier not intended for in the original design, and salt-laden water leaking through expansion joints.

- Looking for the presence of debris or standing water on the bearing seat. Debris suggests a failed/leaky expansion joint. Standing water indicates that the bearing seat is dished. Salt-laden standing water will eventually migrate to the reinforcing steel, causing corrosion, delaminations and spalls.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)
- Exposed Rebar (1090)
- Cracking (RC) (1130)
- Abrasion/Wear (PSC/RC) (1190)
- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

Figure 2.5.3.6-2: Reinforced Concrete Pier Cap - Condition State 1

Figure 2.5.3.6-3: Delamination on the Underside of a Pier Cap – Condition State 2

Figure 2.5.3.6-4: Delaminations on the Underside of a Pier Cap - Condition State 2

Figure 2.5.3.6-5: Pier Cap with Widespread Spalling – Condition State 3

2.5.4 Prestressed Concrete Substructure Elements

2.5.4.1 Prestressed Concrete Column (Element 204)

This element is for all prestressed concrete columns regardless of protective system. These elements include cast in place columns that are post-tensioned (not externally post-tensioned).

A column differs from a pile in the way that it is supported. A column will be supported by a concrete pedestal or footing that can be beneath the ground level or exposed. A pile will extend well past the ground level into more substantial bearing material, such as bedrock or stone that will provide the substructure with structural stability. If a columns pedestal or footing is buried it may be difficult to tell the difference between a column and a pile without looking at the bridge plans.

Element Level Inspection

On the inspection report form, prestressed concrete columns are recorded in units of "each". For each column, the most severe Condition State is assigned to the entire element. This will quantify the column's condition and help to generate quantity/cost estimates for future remedial work.

Element Defect

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)
- Exposed Prestressing (1110)
- Cracking (PSC) (1110)
- Abrasion/Wear (PSC/RC) (1190)
- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.4.2 Prestressed Concrete Pile (Element 226)

This element defines prestressed concrete piles that are visible for inspection. Piles exposed by erosion or scour and piles visible during an underwater inspection are included in these elements. These elements are for all prestressed concrete piles regardless of protective system.

Element Level Inspection

On the inspection report prestressed concrete piles are recorded in units of “each”. For each pile, the most severe Condition State is assigned to the entire element. This will quantify the pile’s condition and help to generate quantity/cost estimates for future remedial work.

Element Defect

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)
- Exposed Prestressing (1110)
- Cracking (PSC) (1110)
- Abrasion/Wear (PSC/RC) (1190)

- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.4.3 Prestressed Concrete Pier Cap (Element 233)

This element defines those prestressed concrete pier caps that support girders and transfer load into piles or columns. Pier caps are primary load-carrying bending members on single columns (hammerheads) or multicolumn piers. They may be bending members on pier walls if their ends cantilever over the ends of the wall, but they are most often used as architectural features in this situation. They often must carry large girder reaction loads and many times work in conjunction with the columns to form a frame for resisting lateral loads.

Element Level Inspection

On the inspection report form, a prestressed concrete cap is recorded in units of lineal feet. This quantity is the length of the cap. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Defect

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Delaminations/Spalls/Patched Areas (1080)
- Exposed Prestressing (1110)
- Cracking (PSC) (1110)
- Abrasion/Wear (PSC/RC) (1190)
- Precast Concrete Connections (8906)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.5 Timber Substructure Elements

Because of its availability, timber is used most frequently for bridge substructure elements in rural areas of the state. However, older bridges with timber substructure elements can be found in urban areas.

Figure 2.5.4.3-1: Timber Abutment and Wingwalls

2.5.5.1 Timber Column (Element 206)

Columns for timber piers bear on reinforced concrete pedestals located at the ground line. Piers of either type are laterally stabilized through the use of timber bracing (these elements should be rated under Element 8250 Cross Bracing or Struts). Tops of the timber columns are tied together with a timber, reinforced concrete or rolled steel pier cap.

A column differs from a pile in the way that it is supported. A column will be supported by a concrete pedestal or footing that can be beneath the ground level or exposed. A pile will extend well past the ground level into more substantial bearing material, such as bedrock or stone that will provide the substructure with structural stability. If a columns pedestal or footing is buried it may be difficult to tell the difference between a column and a pile without looking at the bridge plans.

Figure 2.5.5.1-1: Timber Pier Columns

Figure 2.5.5.1-2: Timber Columns, Cap, and Cross-Bracing – Condition State 1

Since timber columns are vertical elements, the very permeable end grain is directly exposed to rain. Thin lead or zinc sheets are often draped over the element ends to keep them dry.

Element Level Inspection

On the inspection report form, timber columns are recorded in units of "each". It is the inspector's task to examine each column and reasonably assign the most severe Condition State to the entire element. This will quantify the column/shaft's state of deterioration and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of timber columns found on substructure elements should include the following items:

- Checking the cap/column interface for bearing failures. Bearing failures on timber members loaded parallel to the grain will “broom out”.

- Checking the mid-height of pier columns for flexural cracks, which are signs of structural overloads or differential pier deflection.

- Examining the entire element for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fruiting bodies and depressed areas of the wood surface.

- Check for wood crushing due to fasteners. This is often seen at dead-men (tie back rod) connections. This may be due to timber decay or settlement causing overloading on the tie back members.

- Looking for any splitting of sawn timber members. Excessively long or wide splits may be a sign of a structural overload.

- Examining the entire member for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the member is tapped with a hammer.

- Looking for fire damage. The remaining dimensions should be measured to determine the severity of section loss and potential loss of load capacity.

- Checking fasteners (bolts, lag screws) for corrosion or slipping. Check also for fastener looseness by striking with a hammer. The location of any missing fasteners should be noted.

- Sighting the substructure to look for out of plumbness. A plumb bob may also be used. The column should also be sighted along its length to check for bowing. Excessive deflections indicate that the member has been overstressed or that the bridge is experiencing differential settlements. The measured or estimated amount of deflection should be recorded.

- Performing probe tests in areas suspected to be experiencing decay. See Section 2.4.4.1 Timber Slab (Element 54) for a description of this procedure.

- Drilling or boring suspect members to estimate the extent of decay.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

• Connection	(1020)
• Decay/Section Loss	(1140)
• Checks/Shakes/Cracks/Splits/Delamination	(1150)
• Abrasion/Wear	(1180)
• Distortion	(1900)

Structural Defects

• Settlement	(4000)
• Scour	(6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

• Condition State 1	Good	Green
• Condition State 2	Fair	Yellow
• Condition State 3	Poor	Orange
• Condition State 4	Severe	Red

2.5.5.2 Timber Tower/Trestle (Element 208)

This element defines framed timber supports, and is for all timber trestle/towers regardless of protective system. This element is intended to be used for truss framed trestles or towers and is intended to capture large supports and towers associated with large deck truss bridges.

A tower or trestle element will be three dimensional in nature with lateral and torsional bracing along all sides of the substructure unit. Pier bents with a single strut running between the two does not constitute trestle bracing.

Element Level Inspection

On the inspection report form, a timber tower/trestle is recorded in units of lineal feet of vertical height. This quantity is the sum of the heights of each built-up or framed tower support. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Connection (1020)
- Decay/Section Loss (1140)
- Checks/Shakes/Cracks/Splits/Delamination (1150)
- Abrasion/Wear (1180)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.5.3 Timber Pier Wall (Element 212)

This element defines those timber pier walls that include pile, timber sheet material, and filler. This is for all pier walls regardless of protective system. This element will rarely be found on Wisconsin bridges.

Element Level Inspection

On the inspection report form, a pier wall is recorded in units of lineal feet. This measurement is taken as the width of the pier wall along the skew (if present). The total quantity is the sum of all the pier wall lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Connection (1020)
- Decay/Section Loss (1140)
- Check/Shake/Cracks/Splits/Delamination (1150)
- Abrasion/Wear (1180)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.5.4 Timber Abutment (Element 216)

This element is for the timber sheet material retaining the embankment. Typically this is the timber lagging running between piling.

Timber abutments are constructed by two methods. The first type is the timber bent abutment. It is built by first driving timber or steel piles into the ground. These piles extend beyond grade approximately to the girder bearing elevation. Sawn timber lagging is then placed along the back face of the piles to the abutment cap, forming a wall. The embankment is then created by backfilling behind the lagging wall. In this manner, the timber lagging holds back the soil by spanning between the piles and would be considered the Timber Abutment. The piles (either timber or steel) would be coded as the respective material pile.

Another type is timber crib abutments. Rectangular timber elements are stacked to form a cell, similar to how a log cabin is built. This cell is then filled with soil to form the embankment. Timber crib abutments act as gravity retaining devices, using the mass of the crib and contained fill material to resist sliding from exterior soil lateral pressures. There are no piles visible in front of crib abutments.

Element Level Inspection

On the inspection report form, an abutment is recorded in units of lineal feet. The measurement is taken as the length of the abutment along the skew (if present). Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element’s condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of timber abutments should include the following items:

- Examining the lagging or cribbing for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fruiting bodies and depressed areas of the wood surface. Suspect locations are where moisture can become trapped, such as at the abutment pile interface locations.
- Looking for any splits of individual boards.

- Checking the lagging or cribbing for excessive deflections. Excessive deflections may allow the soil behind the boards to spill or wash out, causing settlement to the approach above.

- Looking for any broken lagging boards. This may occur at a weak spot in the wood such as a knot.

- Examining the entire member for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the element is tapped with a hammer.

- Looking for fire damage.

- Hammer tapping random and suspect areas to evaluate the wood's soundness.

- Performing probe tests in areas suspected to be experiencing decay. See Section 2.4.4.1, Timber Slab (Element 54) for a description of this procedure.

- Drilling or boring suspect members to estimate the extent of decay.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Connection (1020)
- Decay/Section Loss (1140)
- Check/Shake/Cracks/Splits/Delamination (1150)
- Abrasion/Wear (1180)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

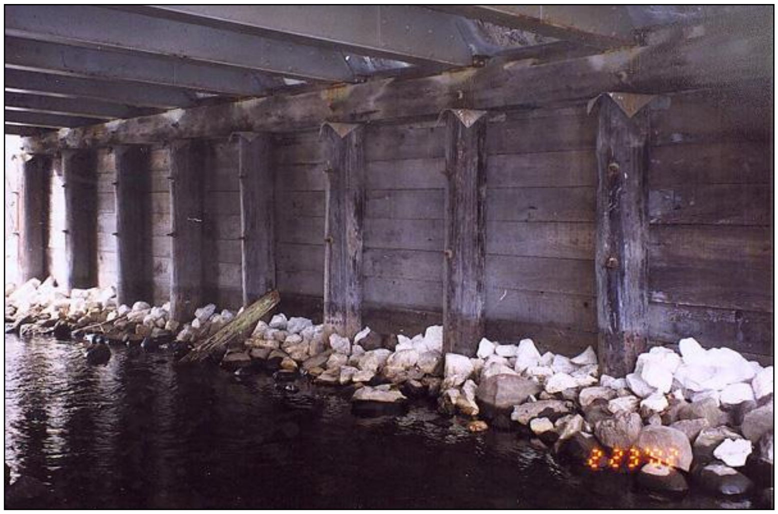

Figure 2.5.5.4-1: Timber Abutment, Pier Cap, and piles - Condition State 2

Figure 2.5.5.4-2: Bulging of a Timber Abutment (Settlement Defect) – Condition State 2

2.5.5.5 Timber Pile (Element 228)

This element defines timber piles that are visible for inspection. Piles exposed to erosion or scour and piles visible during an underwater inspection are included in this element. This element is for all timber piles regardless of protective system.

This element is not to be confused with Element 206 Timber Columns, which are designed to be supported by a footing. Timber piles are driven into the ground and supported by bearing and surface friction forces. Timber piles are typically constructed to be covered, whether it is embankment fill, stream bed, etc. Once erosion or scour exposes the piling, then this element shall be utilized.

Timber piles are often used to support the wood lagging of timber abutments and wingwalls. These piles cantilever up from the ground to receive vertical bearing loads from the superstructure and abutment cap and lateral soil pressures from the fill under the approach. The piles are acting as beam/columns to resist axial compressive loads and bending moments. Maximum bending stresses occur near the ground line, which is also where decay is most likely to take place due to the presence of moisture. Timber or reinforced concrete caps are used to tie the abutment piles together. The piles should be individually rated and should not be considered as part of the abutment element. When timber piling restrains wingwall lagging, the piling is evaluated under the appropriate wingwall element.

Timber piling is also used for timber pile bents, where the piling is intended to be exposed. The method of inspection is the same between abutment and pier piling.

Figure 2.5.5.5-1: Timber Piling – Most in Condition State 2

Figure 2.5.5.5-2: Split and Decayed Timber Piling- Condition State 3

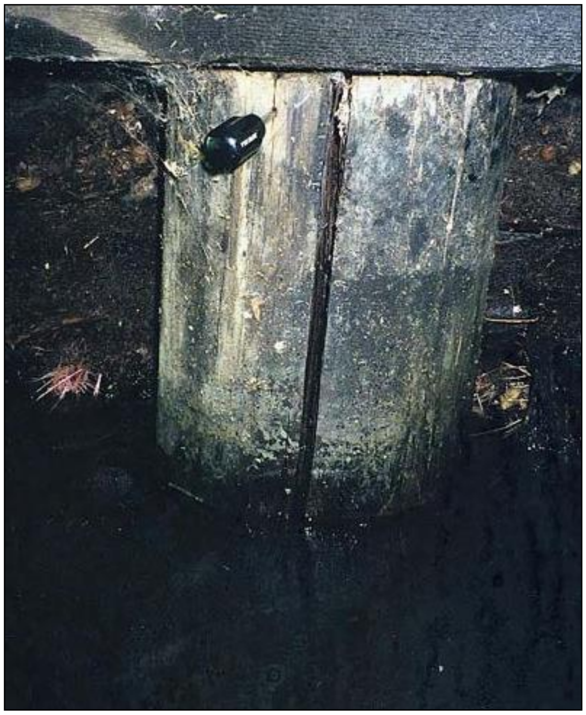

Figure 2.5.5.5-3: Split Timber Pile - Condition State 3

Figure 2.5.5.5-4: Timber Pile Decay at Ground Line – Condition State 3

Element Level Inspection

On the inspection report form, piles are recorded in units of "each". The total quantity is the sum of all piles visible for inspection. Therefore, each element will be individually rated and assigned to a Condition State. It is the inspector's task to examine each pile and reasonably assign the appropriate Condition State to the entire element. This will quantify the timber's condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of timber piling found on substructure elements should include the following items:

- Checking the cap/pile interface for bearing failures. Bearing failures on timber members loaded parallel to the grain will "broom out".
- Checking the mid-height of pier piles for flexural cracks, which are signs of structural overloads or differential pier deflection.
- Examining the entire element for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fruiting bodies and depressed areas of the wood surface.
- Check for wood crushing due to fasteners. This is often seen at dead-men (tie back rod) connections. This may be due to timber decay or settlement causing overloading on the tie back members.
- Looking for any splitting of sawn timber members. Excessively long or wide splits may be a sign of a structural overload.
- Examining the entire member for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the member is tapped with a hammer.
- Looking for fire damage. The remaining dimensions should be measured to determine the severity of section loss and potential loss of load capacity.
- Checking fasteners (bolts, lag screws) for corrosion or slipping. Check also for fastener looseness by striking with a hammer. The location of any missing fasteners should be noted.
- Sighting the substructure to look for out of plumbness. A plumb bob may also be used. The pile should also be sighted along its length to check for bowing. Excessive deflections indicate that the member has been overstressed or that the bridge is experiencing differential settlements. The measured or estimated amount of deflection should be recorded.
- Performing probe tests in areas suspected to be experiencing decay. See Section 2.4.4.1 Timber Slab (Element 54) for a description of this procedure.
- Drilling or boring suspect members to estimate the extent of decay.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Connection (1020)
- Decay/Section Loss (1140)
- Check/Shake/Cracks/Splits/Delamination (1150)
- Abrasion/Wear (1180)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.5.6 Timber Pier Cap (Element 235)

Timber pier caps are often used on timber substructure elements. Their purpose is to tie the tops of the piles or columns together to help create a frame and also to deliver superstructure loads to the piles or columns.

Element Level Inspection

On the inspection report form, a pier or abutment cap is recorded in units of lineal feet. The measurement is taken as the length of the element from end to end along the skew (if present). The total quantity is the sum of all the element lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of timber pier caps should include the following items:

- Checking for cap crushing at the girder bearings, piles or columns. These are the most suspect areas because they tend to collect and retain the most moisture and debris, creating ideal environments for fungal growth and insect attack.

- Looking for shear related damage at and near the supports. Overloads result in high shear stresses that cause horizontal splits to form along the length of the cap, approximately mid-height. Splits will allow fungi and insects access to the untreated interior of a cap.

- Examining the high flexural regions of the cap for signs of overload damage such as crushing near the tension surface, and transverse cracking at the compression surface.

- Looking for splits or checks along the entire cap.

- Examining the entire member for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fruiting bodies and depressed areas of the wood surface or plant growth on the top surface.

- Checking the ends of the cap for decay and hollowing. These regions tend to collect roadway runoff, debris and sunlight.

- Examining the entire member for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the beam is tapped with a hammer.

- Looking for fire damage.

- Checking fasteners (nails, bolts, lag screws, deck clips) for corrosion or slipping. Check also for fastener looseness by striking with a hammer. The location of any missing fasteners should be noted.

- Sighting along the length of the cap for excessive vertical or lateral deflections. Check also for cap rotation that may be caused by eccentric beam loading. The measured or estimated amount of deflection should be recorded.

- Hammer tapping random and suspect areas to evaluate the wood's soundness.

- Performing probe tests in areas suspected to be experiencing decay. See Section 2.4.4.1, Timber Slab (Element 54) for a description of this procedure.

- Drilling or boring suspect planks to estimate the extent of decay.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Connection (1020)
- Decay/Section Loss (1140)
- Check/Shake/Cracks/Splits/Delamination (1150)
- Abrasion/Wear (1180)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

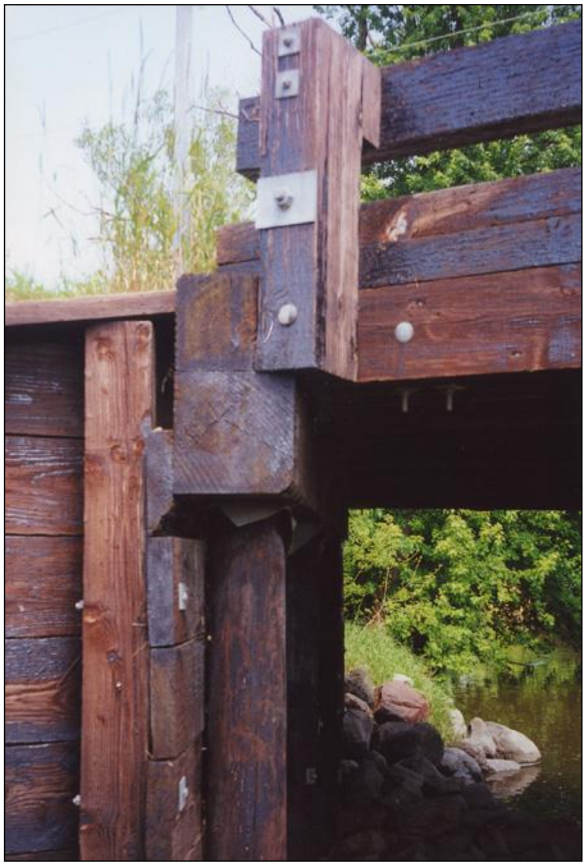

Figure 2.5.5.6-1: Timber Pier Cap and Abutment - Condition State 1

Figure 2.5.5.6-2: Split Pier Cap End (Note Plant Growth) - Condition State 3

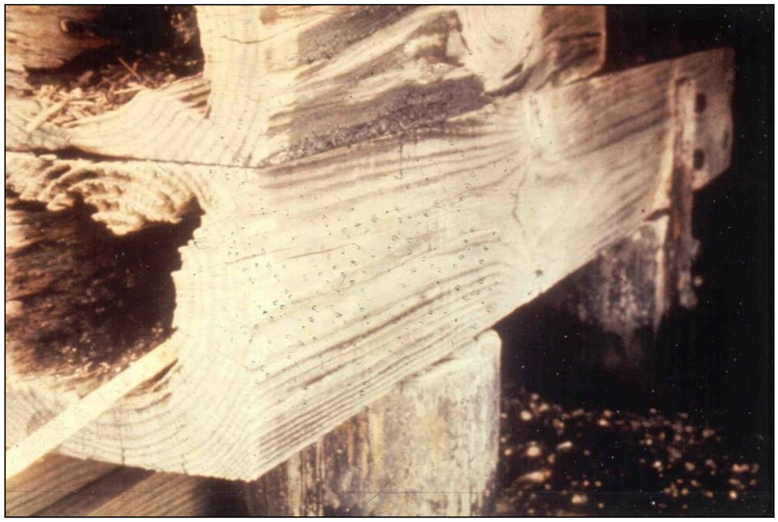

Figure 2.5.5.6-3: Severe Insect Infestation Inside of a Pier Cap – Condition State 4

2.5.6 Masonry Substructure Elements

Masonry has been used for bridge substructure elements for thousands of years. Even after steel and reinforced concrete gained favor over masonry arch superstructures in the 1800s, masonry was still used for piers, abutments, and wingwalls. Eventually, concrete substructures won favor over masonry, and new masonry bridge substructure construction is mostly limited to use as a decorative effect on small, local bridges.

Bridge aesthetics are becoming more of a concern for owners building bridges in highly visible areas. It is interesting to note that concrete form liners having the look of an old masonry pier or abutment are becoming quite popular. The creative use of paint can make these elements look deceivingly realistic when viewed from a distance. The inspector should be careful not to inspect these substructures as masonry units but as reinforced concrete.

2.5.6.1 Masonry Pier Wall (Element 213)

Masonry pier walls are solid, primary load-carrying members that support the superstructure. They are generally compression members, but they must also resist lateral forces due to wind loads, bending moments due to eccentric loading at their tops, superstructure longitudinal forces, and differential substructure settlements. Masonry pier walls are unreinforced masonry and are therefore built wide and heavy enough so that tensile stresses due to bending are virtually eliminated.

Masonry pier caps, or horizontal members comprised of masonry or stone block located on the top of Masonry Pier Walls that extend beyond the faces of the pier wall shall be evaluated under the Masonry Pier Wall element.

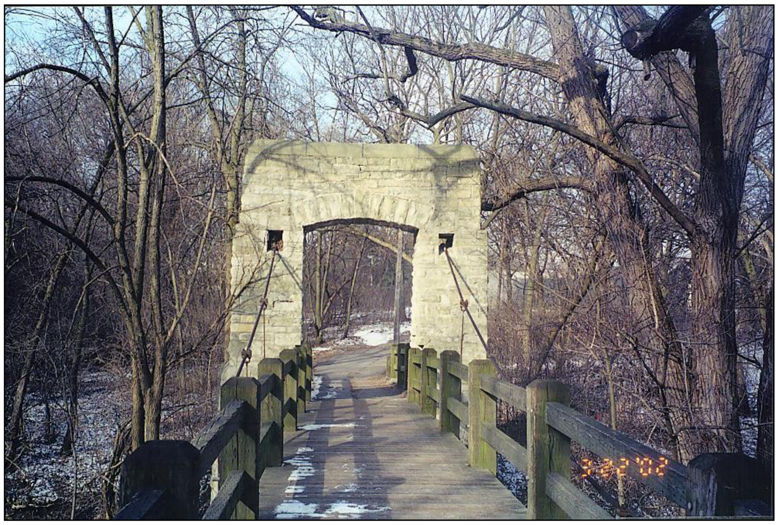

Figure 2.5.6.1-1: Masonry Tower (Pier) for a Suspension Bridge

Element Level Inspection

On the inspection report form, masonry pier walls are recorded in units of lineal feet. The measurement is taken as the length of the wall from end to end along the skew (if present). The total quantity is the sum of all pier wall lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of masonry pier walls should include the following items:

- Looking for cracked, split, spalled, loose or missing stone masonry units. This would suggest weathering due to freeze/thaw effects. Missing or crushed masonry units result in a loss of pier cross sectional area, increasing the axial stresses.
- Check for bulging or misalignment of the masonry units. This may be due to overloading of the masonry wall or settlement of the substructure unit.
- Looking for cracked, broken, deteriorated, loose or missing mortar. This would suggest weathering due to freeze/thaw effects. Missing or crushed mortar results in a loss of pier cross sectional area, increasing the axial stresses.
- Looking for leaching. This indicates water is flowing through the mortar joints, leaching out cementitious minerals. Extended leaching will weaken the mortar.
- Checking areas exposed to drainage and roadway runoff. The runoff may cause scaling of the masonry units.
- Hammer tapping random and suspect areas to evaluate the masonry's soundness.
- Examining previous repair areas for soundness.
- Checking the pier for plumb visually or using a plumb bob.
- Looking for vegetation growing inside of cracks or between the mortar and masonry unit. Plant roots can exert prying forces that further deteriorate these materials.
- Noting any abrasion of the masonry for pier walls located within a waterway.
- Examining the top surface (bearing seat) of pier walls for cracking and spalling. Deterioration in these areas may be caused by frozen expansion bearings that transmit lateral forces to the pier not intended for in the original design.
- Noting if any soil, rock or debris has been piled against the pier wall. This will cause lateral forces on the element not originally accounted for in the original design.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects.

However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Mortar Breakdown (1610)
- Split/Spall/Patched Area (1620)
- Masonry or Panel Displacement (1640)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.6.2 Masonry Abutment (Element 217)

Masonry abutments are solid, primary load-carrying members that support the superstructure. Similar to masonry wingwalls, masonry abutments also act as gravity retaining walls to contain the soil located under the approach. They rely purely upon their self-weight and any soil bearing on top of them to provide enough frictional resistance at their footings to prevent sliding. In addition, since unreinforced masonry cannot resist tensile stresses very well, they are built wide and heavy enough so that tensile stresses due to bending from lateral soil pressures are virtually eliminated.

Figure 2.5.6.2-1: Masonry Abutment

Element Level Inspection

On the inspection report form, masonry abutments are recorded in units of lineal feet. This measurement is taken as the length of the abutment along the skew (if present). The total quantity is the sum of all abutment lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Level Inspection of masonry abutments should include the following items:

- Looking for cracked, split, spalled, loose or missing stone masonry units. This would suggest weathering due to freeze/thaw effects. Missing or crushed masonry units result in a loss of abutment cross sectional area, increasing the axial stresses.
- Checking the abutment surface for bulges. This defect suggests unstable soil, and the roadway above will also likely show signs of settlement.
- Looking for cracked, broken, deteriorated, loose or missing mortar. This would suggest weathering due to freeze/thaw effects. Missing or crushed mortar results in a loss of abutment cross sectional area, increasing the axial stresses.
- Looking for leaching. This indicates water is flowing through the mortar joints,
- Leaching out cementitious minerals. Long-term leaching will weaken the mortar.
- Checking areas exposed to drainage and roadway runoff. The runoff may cause scaling of the masonry units.
- Examining previous repair areas for soundness.

- Checking the abutment for plumb visually or using a plumb bob.
- Noting any abrasion of the masonry for abutments located within a waterway.
- Examining the top surface (bearing seat) of the abutment for cracking and spalling. Deterioration in these areas may be caused by frozen expansion bearings that transmit lateral forces to the pier not intended for in the original design.
- Checking to make sure weep holes in the abutment are functioning.
- Looking for vegetation growing inside of cracks or between the mortar and masonry unit. Plant roots can exert prying forces that further deteriorate these materials.
- Checking to make sure surface drains are functioning properly and not allowing water to penetrate the approach fill behind the abutment.
- Hammer tapping random and suspect areas to evaluate the masonry's soundness.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Mortar Breakdown (1610)
- Split/Spall/Patched Area (1620)
- Masonry or Panel Displacement (1640)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

• Condition State 1	Good	Green
• Condition State 2	Fair	Yellow
• Condition State 3	Poor	Orange
• Condition State 4	Severe	Red

Figure 2.5.6.2-2: Masonry Abutment with Moderate Mortar Deterioration – Condition State 2

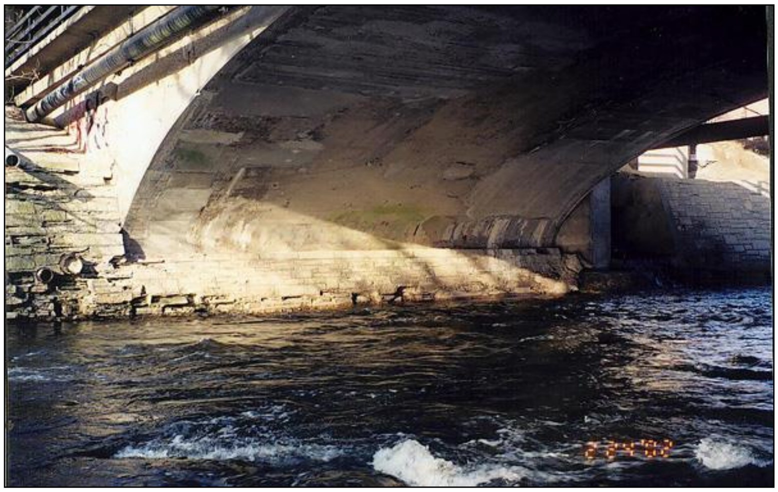

Figure 2.5.6.2-3: Masonry Abutment with Moderate Unit Deterioration – Condition State 3

Figure 2.5.6.2-4: Split and Spalled Masonry Units – Condition State 3

2.5.7 Other Material Substructure Elements

Other materials are intended to be used for members that are constructed of materials not otherwise defined.

2.5.7.1 Other Material Column (Element 203)

This element is for all other material columns regardless of protective system.

Element Level Inspection

Other columns are recorded in units of “each” on the inspection report form. Therefore, each element will be individually rated and assigned a Condition State. It is the inspector’s task to examine each column and reasonably assign the most severe Condition State to the entire element. This will quantify the element’s condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)
- Delamination/Spall/Patched Areas (1080)
- Deterioration (1220)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.7.2 Other Material Pier Wall (Element 211)

This element defines those pier walls constructed of other materials. This is for all pier walls regardless of protective systems.

Element Level Inspection

On the inspection report form, other pier walls are recorded in units of lineal feet. This measurement is taken as the length of the wall from end to end along the skew (if present). The total quantity is the sum of all pier wall lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)

- Delamination/Spall/Patched Areas (1080)
- Deterioration (1220)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.7.3 Other Material Abutment (Element 218)

This includes the sheet material retaining the embankment, and integral wingwalls and abutment extensions. This is for all abutments regardless of protective systems.

Element Level Inspection

On the inspection report form, other abutments are recorded in units of lineal feet. This measurement is taken as the length of the abutment along the skew (if present) and the lengths of monolithic wingwalls. The total quantity is the sum of all abutment and monolithic wingwall lengths. Where multiple condition states exist within a unit of measure only the predominant defect in severity and extent is recorded. The other defects located within the unit of measure shall be captured by the inspector under the element or appropriate defect notes. The sum of all of the reported condition states must equal the total quantity of the element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)
- Delamination/Spall/Patched Areas (1080)
- Deterioration (1220)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition State Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow
- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.7.4 Other Material Pile (Element 229)

This element defines other material piles that are visible for inspection. Piles exposed from erosion or scour and piles visible during an underwater inspection are included in this element. This element is for all other material piles regardless of protective system.

Element Level Inspection

Other piles are recorded in units of "each" on the inspection report form. Therefore, each element will be individually rated and assigned a Condition State. It is the inspector's task to examine each pile and reasonably assign the most severe Condition State to the entire element. This will quantify the element's condition and help generate quantity/cost estimates for future remedial work.

Element Defects

Refer to Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.). The order of the defect numbering indicates the controlling defect. Given multiple defects of the same condition state within a unit of measure, the lowest numbered defect controls. Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Material Defects

- Corrosion (1000)
- Cracking (1010)
- Connection (1020)
- Delamination/Spall/Patched Areas (1080)
- Deterioration (1220)
- Distortion (1900)

Structural Defects

- Settlement (4000)
- Scour (6000)

Condition States Commentary

Appendix A defines the Condition States for each individual defect. The defects are expounded on and critical areas are discussed to aid the inspector in determining the severity of a defect. The WisDOT Field Manual tabulates the element defects listed above and bases the Condition States on the progression of severity for each defect. The Condition States are comprised of general descriptions and uniquely colored to follow the severity the description represents.

- Condition State 1 Good Green
- Condition State 2 Fair Yellow

- Condition State 3 Poor Orange
- Condition State 4 Severe Red

2.5.8 Substructure NBI Condition Ratings

Part of every Routine Inspection is rating the substructure according to the Federal Highway Administration (FHWA) General Condition Rating Guidelines. The numeric condition ratings of these guidelines describe existing bridge components as compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition and 0 describing failed components.

Because only a single number is used to rate the substructure, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, such as isolated heavy spalling. However, widespread heavy spalling would certainly influence the rating. A proper rating will therefore consider the severity of deterioration plus the extent to which it is distributed throughout the substructure.

National Bridge Inventory (NBI) ratings are used to evaluate the state of deterioration of the substructure material. Since material condition is independent of a bridge's load-carrying capacity, postings or original design capacities less than current legal loads will not influence the rating. Similarly, temporary substructure support does not change or improve the condition of the substructure material. Therefore, temporary strengthening methods will not influence the substructure rating.

The NBI general condition ratings found in the FHWA guidelines apply to decks, superstructures, and substructures. Ratings 9 to 6 apply to components built of any material, while ratings 5 to 0 mention specific defects or deterioration that can be applied to certain materials. Because the NBI general condition ratings apply to a wide range of components and materials, Wisconsin has developed supplemental rating guidelines. These supplemental rating guidelines are used to assist the inspector in properly assigning condition ratings to specific components constructed of the most commonly used materials. The general condition ratings, along with the Wisconsin supplemental rating guidelines for substructures, are as follows:

Code (Rating) **Description**

N **NOT APPLICABLE**

Wisconsin Supplemental Rating Guidelines:

Used only for culverts and spandrel arches where footings cannot be seen.

9 **EXCELLENT CONDITION**

Wisconsin Supplemental Rating Guidelines:

There are no noticeable or noteworthy deficiencies that affect the condition of the substructure. There may be insignificant scrape marks caused by drift or collision.

8 **VERY GOOD CONDITION –** no problems noted.

Wisconsin Supplemental Rating Guidelines:

Concrete Substructure – there may be shrinkage cracks, light scaling or insignificant spalling which does not expose reinforcing steel. There may be insignificant damage caused by drift or collision with no resulting misalignment. Corrective action is not required.

Steel Substructure – there may be insignificant damage caused by drift or collision with no resulting misalignment. Corrective action is not required.

Timber Substructure – there may be insignificant damage caused by drift or collision with no resulting misalignment. Corrective action is not required.

Masonry Substructure – there may be insignificant spalling of the masonry units. Damage caused by drift or collision may have occurred, but with no resulting misalignment. Corrective action is not required.

7 **GOOD CONDITION –** some minor problems.

Wisconsin Supplemental Rating Guidelines:

Concrete Substructure – there may be minor cracking with possible leaching or spalls with no detrimental effect on bearing area. Leakage of expansion devices may have caused minor cracking to start. Minor scouring may have occurred.

Steel Substructure – leakage of expansion devices may have started minor rusting without measurable section loss. Minor scouring may have occurred.

Timber Substructure – insignificant decay, cracking or splitting. Minor scouring may have occurred.

Masonry Substructure – there may be minor cracking or the mortar or spalls/cracking of the masonry units with no detrimental effect on bearing area. Minor scouring may have occurred.

6 **SATISFACTORY CONDITION –** structural elements show some minor deterioration.

Wisconsin Supplemental Rating Guidelines:

Concrete Substructure – minor deterioration or disintegration, spalls, cracking or leaching with little or no loss of bearing area. Shallow, local scouring may have occurred near the foundation.

Steel Substructure – corrosion, but no measurable section loss. Shallow, local scouring may have occurred near the foundation.

Timber Substructure – some initial decay, cracking or splitting. Fire damage is limited to surface scorching with no measurable section loss.

Masonry Substructure – minor deterioration or disintegration, spalls or cracking of the masonry units or mortar with little or no loss of bearing area. Shallow, local scouring may have occurred near the foundation.

5 **FAIR CONDITION –** all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.

Wisconsin Supplemental Rating Guidelines:

Concrete Substructure – measurable but minor section loss may exist, with possible exposed reinforcing steel. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

Steel Substructure – corrosion with measurable but minor section loss. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

Timber Substructure – moderate decay, cracking or splitting. A few secondary members may need replacement. Fire damage is limited to surface charring with minor, measurable section loss. There may be some exposure of piles as a result of erosion, reducing penetration.

Masonry Substructure – minor deterioration or disintegration, spalls or cracking of the masonry units and mortar with little or no loss of bearing area. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

4 **POOR CONDITION –** advanced section loss, deterioration, spalling or scour.

Wisconsin Supplemental Rating Guidelines:

Concrete Substructure – structural cracks and advanced deterioration. Additional backfilling is required. Extensive scouring or undermining of the footing is affecting the stability of the unit and requiring corrective action.

Steel Substructure – corrosion with extensive section loss. Additional cross bracing is required. Extensive scouring or undermining of the footing is affecting the stability of the unit and requiring corrective action.

Timber Substructure – substantial decay, cracking, splitting or crushing of primary members, requiring replacement. Fire damage with significant section loss that may reduce the load-carrying capacity of the member. Extensive exposure of piles as a result of erosion, thus reducing penetration and affecting the stability of the unit.

Masonry Substructure – structural cracks and advanced deterioration of the masonry units and mortar. Additional backfilling is required. Extensive scouring or undermining of the footing is affecting the stability of the unit and requiring corrective action.

3 **SERIOUS CONDITION –** loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.

Wisconsin Supplemental Rating Guidelines:

Concrete Substructure – severe disintegration. Reinforcing steel is exposed with advanced stages of corrosion. There is severe section loss in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary (not just precautionary) to maintain the safety and alignment of the structure.

Steel Substructure – there is severe section loss in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary (not just precautionary) to maintain the safety and alignment of the structure.

Timber Substructure – there is severe section loss in critical stress areas. Major fire damage is present that will substantially reduce the load-carrying capacity of the member. Bearing areas are seriously deteriorated with considerable loss of bearing. Settlement may have occurred. Shoring is considered necessary (not just precautionary) to maintain the safety and alignment of the structure.

Masonry Substructure – severe disintegration of the masonry units and mortar. There is severe section loss in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affect the stability of the unit. Settlement may have occurred. Shoring is considered necessary (not just precautionary) to maintain the safety and alignment of the structure.

2 **CRITICAL CONDITION –** advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.

Wisconsin Supplemental Rating Guidelines:

Concrete Substructure – concrete cap is soft and spalling with reinforcing steel exposed with no bond to concrete. The top of the cap is split or a column has undergone a shear failure. Scouring is sufficient that the substructure is near a state of collapse. Piers have settled.

Steel Substructure – members have critical section loss. Holes in the web and/or knife-edged flanges are typical. Scouring is sufficient that the substructure is near a state of collapse. Piers have settled.

Timber Substructure – the primary members are crushed or split and ineffective. Piers have settled.

Masonry Substructure – scouring is sufficient that the substructure is near a state of collapse. Piers have settled.

1 **"IMMINENT" FAILURE CONDITION –** major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structural stability. Bridge is closed to traffic but corrective action may put it back in light service.

Wisconsin Supplemental Rating Guidelines:

Bridge is closed. Corrective action may put it back in light service.

0 **FAILED CONDITION –** out of service, beyond corrective action.

Wisconsin Supplemental Rating Guidelines:

Bridge is closed. Replacement is necessary.

One suggested method for establishing a substructure rating is to identify phrases within the general condition/Wisconsin supplemental guideline language that describe a substructure condition more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose a reinforced concrete substructure has extensive delaminations, plus spalling with exposed reinforcing steel. The spalls occur on the tension side of the caps and on random sides of the columns, but section loss of the reinforcing steel is minimal. Condition rating 4 indicates that there is advanced deterioration and spalling. Condition rating 3 indicates that deterioration and spalling have seriously affected the primary structural components, and that the reinforcing steel is in the advanced stages of corrosion. Using the method described above, Condition rating 3 describes a situation more severe than what actually exists on the substructure. Therefore, a rating of 4 would be appropriate.

Another method to help narrow down the substructure rating number is to group the numbers in more general categories. Ratings of 9 to 7 apply to substructures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition. It is also important to note that there is a significant change from a substructure in condition rating 5 (minor section loss, structural elements sound) to condition rating 4 (advanced section loss, advanced deterioration). A reduction in load-carrying capacity can be measured/calculated when a substructure enters condition rating 4.