Advanced Timber Bridge Inspection

Field Manual for Inspection of Minnesota Timber Bridges

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Chapter 1 Timber Bridge Overview

Timber bridges are an important component of the U.S. highway system, especially in rural areas. The December 2012 National Bridge Inventory (NBI) database includes 48,759 bridge structures that have timber as the primary structural member in the superstructures. Minnesota is reported to have 1,710 bridges containing wood or timber as a superstructure type, however there are additional unreported numbers that also have timber as a decking material on steel beams or as substructure elements such as timber columns, abutments, pilings, pier caps or wing walls (U.S DOT FHWA 2012). These bridges, with spans greater than 20 ft (6 m) have a variety of different types of superstructure construction. The two primary types are beam and longitudinal deck/slab systems. Longitudinal deck/slab systems include nail-laminated, spike-laminated, stress-laminated, and longitudinal glulam bridges. The members may be either sawn lumber, glue laminated (glulam) lumber, or engineered wood products.

Wood is a natural engineering material that is prone to deterioration caused by decay fungi, insect attack, and through mechanical damage. Typically, areas of high moisture content in decking, girders, abutment caps and pilings create conditions suitable for biological damage. Types of biological damage include decay and insect damage caused by a variety of species of fungi and insects such as ants or termites. The application of preservative treatment by pressure methods enhances the durability of timber bridge components, but regular inspections are vital for the identification of damage and implementation of timely repairs and proactive maintenance programs. Mechanical damage might include damaged members or mechanical fasteners.

Concerns have been raised among Minnesota city, county, and state engineers about the current practice of timber bridge inspections. Current timber bridge inspection procedures used in Minnesota and across the United States are mostly limited to visual inspection of the wood components, sounding with a hammer and coring to confirm suspected damage areas. These techniques have generally been adequate for advanced decay detection, but are not reliable when the damage is in the early stage or is located internally in members like piles or pier caps. Routine bridge inspections have the potential to miss decay or deterioration that is not readily apparent using traditional inspection techniques, which can adversely affect the load capacity and service life of the bridge. Advanced inspection techniques for timber bridges have been increasing used. These techniques make use of minimally invasive nondestructive evaluation (NDE) equipment like stress wave timers and resistance microdrills. When used by experienced inspectors, this equipment offers the potential to locate and quantify the extent of decay present in bridge elements, often before it reaches an advanced stage.

The purpose of this field manual is to help promote understanding of materials, inspection techniques, tools and best practices for inspecting timber bridges. The field manual will help provide understanding of when to use these tools and how to interpret the results. In addition, key information will be provided on how to implement the inspection results into bridge data management software. To disseminate the guidance in this field manual, short course training and outreach will be conducted for inspectors and engineers in Minnesota.

Primary Types of Minnesota Timber Bridges

Timber bridges are constructed with timber elements used in the superstructure, substructure or both. Further, the main categories of timber bridge superstructures include beam, deck (slab), truss, arch, and suspension types. This project will address only the most common styles of timber bridges found in Minnesota, which include beam and longitudinal deck superstructures.

Beam Bridges

Beam types of timber bridges consist of a deck system supported by longitudinal solid-sawn or glulam beams that run parallel to the direction of travel. Solid-sawn lumber bridges are constructed of lumber beams that are commonly 6 to 8 inches wide and 12 to 18 inches deep. These timber beams are typically spaced 10 to 16 inches on center with solid timber blocking between beams for lateral stability. Solid-sawn bridges were typically used for clear spans of 15 to 25 ft (Ritter 1990). Longer crossings are achieved by using a series of simple spans supported by intermediate piers. These beams were traditionally treated with creosote with more recent use of copper naphthenate. **Figure 1.1** shows an example of a typical timber beam bridge constructed from solid sawn lumber.

Figure 1.1 Typical solid-sawn beam style timber bridge.

Glulam beams are manufactured from 1-1/2 inch thick construction lumber that is face laminated on their wide dimensions using waterproof structural adhesive. The beams come in a range of widths with the beam depth based on span length and bridge design load. Because of the large size of glulam beams, glulam beam bridges typically require fewer beam lines and are capable of much longer clear spans than conventional sawn lumber beam bridges. They are most commonly used for spans of 20 to 80 feet (Ritter 1990). Originally, the glulam beams were treated with creosote with more recent use of chromate copper arsenate or copper naphthenate. **Figure 1.2** shows a Minnesota creosote treated beam bridge constructed in the 1960s from glulam longitudinal beams.

Minnesota also has a significant number of steel beam bridges with timber decking that is typically covered with a bituminous wear layer. Nail-laminated decks are fabricated from sawn lumber that is generally 2 inches thick and 4 to 12 inches deep. The laminations are placed with the wide dimension vertical and are nailed or spiked together to form a continuous deck. Nail-laminated decks are most commonly used in a transverse orientation on sawn lumber or steel beams. The majority of these decks are creosote treated but new systems may be constructed from glulam members treated with copper naphthenate. **Figure 1.3** shows an example of a Minnesota steel beam bridge with a timber deck.

Figure 1.2 Glulam beam timber bridge construction.

Inspections of the steel beams utilize traditional methods that are not included in this manual but are defined in the Minnesota Bridge Inspection Field Manual (MnDOT 2014). The timber deck may be inspected using a pick hammer and probes, with more detailed inspections including a moisture meter or resistance microdrill.

Figure 1.3. Steel beam bridge with a nail laminated timber deck.

Longitudinal Deck or Slab Bridges

The second most common bridge superstructure in Minnesota is a longitudinal deck or slab style. Longitudinal decks include nail-laminated, spike-laminated, stress-laminated and longitudinal glulam bridges. The members may be either solid sawn or glulam. These bridges are typically constructed in partial width panels that are then connected transversely using a spreader or distributor beam. Glulam longitudinal deck bridges are constructed of panels that are typically 6-3/4 to 14-1/4 inches deep and 42 to 54 inches wide. Sawn lumber slab bridges use 2- to 4-inch-wide lumber, 8 to 16 inches deep, that is nailed or spiked together to form panels. Longitudinal deck bridges are often used for spans up to approximately 36 ft. Longer crossings can be achieved using multiple spans. Older bridges are typically constructed from Douglas fir lumber and treated with creosote. **Figures 1.4 and 1.5** show an example of a spike-laminated bridge and design detail.

Figure 1.4. Typical timber bridge constructed from a spike laminated deck/slab system.

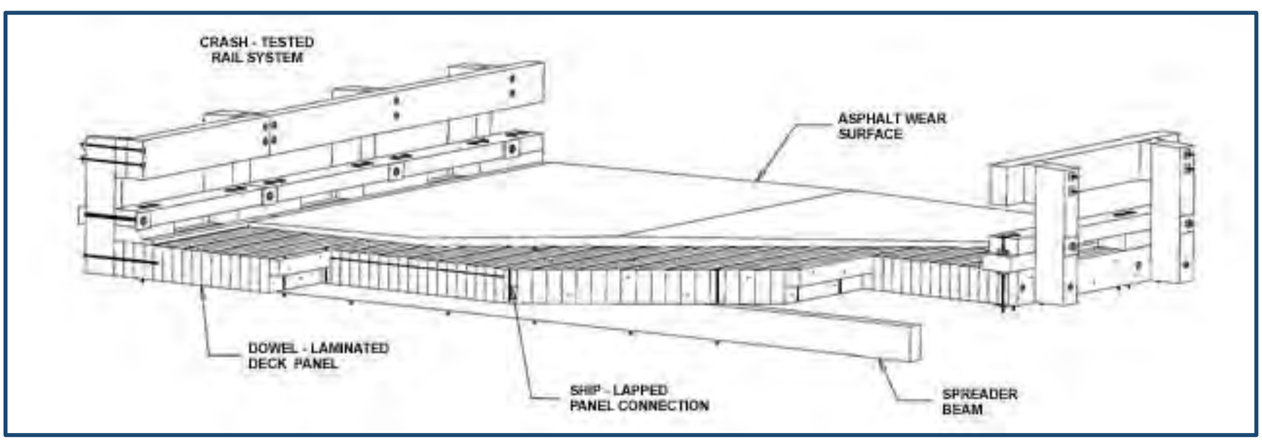

Figure 1.5. Typical cross-section of the design detail for spike laminated/slab span timber bridge. Photo courtesy of Wheeler Lumber, LLC.

Substructure

Most older timber bridges in Minnesota (prior to 2000) contain timber elements in the substructure abutments and piers. Abutments commonly include solid Douglas fir or southern yellow pine piling that has been treated with creosote. The superstructure is connected to the piles by a treated timber cap that is attached to the piles and to the superstructure at the bearings. Pile abutments typically have backwalls and wingwalls that retain the embankment material. Timber piers typically are constructed from southern yellow pine pilings and Douglas fir caps. Since 2000, most new timber bridges are constructed from steel H or cast-in-place (CIP) concrete steel piles. Most cap materials are still solid sawn timber. **Figures 1.6 and 1.7** show examples of timber pile abutments and piers respectively. **Figure 1.8** shows a wingwall commonly found on timber bridges.

Figure 1.6. Timber piling and backwall forming a timber abutment.

Figure 1.7. Timber piling and cap materials forming an intermediate support pier.

Figure 1.8. Timber piling, piling and cap board forming a timber wingwall.

Wood Preservative for Timber Bridges[1]

When considered in its broadest context, a wood preservative is any substance or material that, when applied to wood, extends the useful service life of the wood product. In more practical terms, wood preservatives are generally chemicals that are either toxic to wood-degrading organisms and/or cause some change in wood properties that renders the wood less vulnerable to degradation. Most wood preservatives contain pesticide ingredients, and as such must have registration with the US Environmental Protection Agency (US EPA).

Pressure Treatment Preservatives And Pressure-Treated Wood

For timber bridges, several types of preservatives are used for pressure-treatment of wood at specialized treatment facilities. In these treatment plants, bundles of wood products are placed into large pressure cylinders and combinations of vacuum, pressure (and sometimes heat) are used to force the preservative deeply into the wood. Pressure treated wood and the pressure-treatment preservatives differ from non-pressure preservatives in three important ways:

1. Pressure-treated wood has much deeper and more uniform preservative penetration than wood treated in other manners.
2. Most preservatives used in pressure-treatment are not available for application by the public.
3. Pressure-treatment preservatives and pressure-treated wood undergo review by standard-setting organizations to ensure that the resulting product will be sufficiently durable in the intended end-use.

Standards also apply to treatment processes and require specific quality control and quality assurance procedures for the treated wood product. This level of oversight is needed because pressure-treated wood is used in applications where it is expected to provide service for decades.

Current Ground-contact Preservatives

A number of preservatives for timber bridges are in-service and currently listed for treatment of wood to be used in contact with the ground, either through American Wood Producers Association (AWPA) standards or ICC-ES evaluation reports. It is recommended that bridge components be fabricated to the extent possible prior to treatment. Further, all cuts or borings should be field-treated using copper naphthenate.

Ammoniacal Copper Quat (ACQ-B)

ACQ formulations combine copper and quaternary ammonium compounds (quats) to protect wood from both fungal and insect attack. ACQ-B (Akaline copper quat, Type B) is the earliest ACQ formulation standardized and commercialized. Unlike the other ACQ formulations, it relies primarily on ammonium hydroxide to solubilize the copper. ACQ-B treated wood has a dark greenish brown color that fades to a lighter brown, and may have a slight ammonia odor until the wood dries. It is used primarily in the western wood

[1] Section on wood preservatives adapted from Lebow et. al, 2014.

United States because the ammonia helps the preservative penetrate into more difficult to treat wood species such as Douglas-fir. Like many other soluble copper preservatives, ACQ-B solution, and to some extent the treated wood, can be expected to increase corrosion of aluminum signs and other metal components.

Alkaline copper quat, (ACQ Types A, D and C and ESR-1980)
ACQ Types A, D and C use ethanolamine to solubilize the copper. Wood treated with copper ethanolamine tends to have less odor and a more uniform surface appearance than that treated with copper in ammonia, and thus is more widely used for easily treated species such as the southern pines. ACQ-D is the most commonly used formulation in the eastern United States. Exposure data indicates that the ethanolamine formulation of ACQ-D may not be as effective as the ammoniacal ACQ-B formulation at low concentrations, but is similarly effective at higher concentrations (Figure 2). However, corrosiveness remains a concern. Product literature indicates that ESR-1980 may be less corrosive to aluminum and other metals than the soluble- copper formulations of ACQ. As with other particulate copper formulations, penetration of preservative into less easily treated wood species may be a concern.

Chromated Copper Arsenate
Chromated copper arsenate (CCA) 1940's, and was the predominant preservative in the U.S. from the 1970's through 2003. Since 2003, its use has been limited to non-residential applications, but it is still widely used for treatment of poles, piles and timbers. CCA has decades of proven performance in field trials and in-service applications, but it may have difficulty penetrating difficult to treat wood species such as Douglas fir or larch. Because of the chromium, CCA treating solution and treated wood is less corrosive than many of the other copper-based waterborne preservatives. CCA is classified as a Restricted Use Pesticide by the EPA.

Coal-tar Creosote
Coal-tar creosote is the oldest wood preservative still in commercial use, and remains the primary preservative used to protect wood for railroad ties. The high efficacy of creosote has been well-established through in-service performance and field tests. Creosote-treated wood has a dark-brown to black color and a noticeable odor, which some people consider unpleasant. Workers sometimes object to creosote treated wood because it soils their clothes and photosensitizes the skin upon contact. The treated wood sometimes also has an oily surface, and patches of creosote sometimes accumulate, creating a skin contact hazard. However, the advantages of creosote treated wood often offset the concerns has advantages to offset concerns with its appearance and odor. It has lengthy record of satisfactory use in a wide range of applications at a relatively low cost. Creosote is also effective in protecting both hardwoods and softwoods, and is often thought to improve the dimensional stability of the treated wood. With the use of heated solutions and lengthy pressure periods, creosote can be fairly effective at penetrating even fairly difficult to treat wood species. Creosote treatment also does not accelerate, and may even inhibit, the rate of corrosion of metal fasteners relative to untreated wood. Creosote is a classified as a Restricted Use Pesticide by the US EPA.

Copper Naphthenate (CuN)
Copper naphthenate has been used as a wood preservative since the 1940's, although not as widely as creosote, CCA or pentachlorophenol. In recent years it has been increasingly used as an alternative to pentachlorophenol. Copper naphthenate has been primarily used as an oil-based formulation. The heavy solvent formulation generally provides the greatest durability, and CuN in heavy solvent is currently used for pressure treatment of poles, timbers and glulam beams. Although CuN does not have as extensive of history of in-service durability as CCA, creosote, or pentachlorophenol, its efficacy has been demonstrated in field tests. Copper naphthenate is also dissolved in light solvent for pressure-treatment of above-ground members (such as glulam beams) and for brush-on application of untreated wood that has been exposed when cutting pressure-treated wood.

Pentachlorophenol
Pentachlorophenol has been widely used as a pressure treatment since the 1940's. The active ingredients, chlorinated phenols, are crystalline solids that can be dissolved in different types of organic solvents. A heavy oil solvent is generally used when the treated wood is to be used in ground contact. Wood treated with pentachlorophenol in heavy oil typically has a brown color, and may have a slightly oily surface that is difficult to paint. It also has some odor, which is associated with the solvent. Pentachlorophenol in heavy oil has long been a popular choice for treatment of utility poles, bridge timbers, glulam beams and foundation piles, and the treated wood is quite durable. With the use of heated solutions and extended pressure periods, pentachlorophenol is fairly effective at penetrating difficult to treat species. Pentachlorophenol treatment does not accelerate corrosion relative to untreated wood. Pentachlorophenol is classified as a Restricted Use Pesticide by the US EPA.

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Chapter 2 Inspection Equipment

Overview

Comprehensive inspection protocols for timber bridges include a wide variety of techniques to assess the condition of wood in service. Visual inspection, moisture content assessment, mechanical probing, drilling, resistance microdrilling and stress wave or ultrasound-based technologies may all be used individually or in combination by inspectors. The following equipment is recommended for conducting in-depth inspections of timber bridge elements. The stress wave and resistance drilling equipment is available from several manufacturers. **Table 2.1** and **2.2** lists and **Figure 2.1** shows a complete set of inspection equipment that can be used for timber bridges. Contact information is shown in Appendix A.

Table 2.1. Inspection Equipment Recommendations

Type	Products	Cost Estimate[1]
Safety	Hardhat, safety vest, gloves, safety glasses, lifejacket, signage (when warranted)	$100-$200
Access	Headlamp, flashlight	$100
	Waders, ladder, small flat bottom boat	$200-$1,000
Data Collection	Field notebooks, data forms, digital camera	$150-$350
	Laptop or tablet computer	$300-$750
	Pencil, marking chalk, crayons, paint	$75
Basic Inspection	Tape measure (25-ft, 100-ft)	$25
	Pick hammer, awl, probes, cordless drill	$100-$250
	Plumb-bob, angle detector	$25
Nondestructive Evaluation	Moisture meter with hammer slide and 1- and 3-in. pin probes	$470 plus $250 supplies
	Stress wave timer[2]	$2,350
	Resistance microdrill and supplies[2]	$5,000-$10,000 plus $200 annual supplies
Other	Durable, weather resistant equipment case(s)	$500
	Cell phone or two-way radio, maps, signage	$100-$300
	Rope, extra batteries, truck charger, insect and bee repellant, wasp spray	$100

Note: [1]The cost estimate is based on data collected in 2014. New prices should be obtained from vendors after July 2014.
[2]Various equipment manufacturers and equipment models

Table 2.2. Nondestructive Evaluation Equipment

Type	Products	Cost Estimate[1]
Moisture Meter	J-2000, Delmhorst Instrument Company	$470 plus supplies
Stress Wave Timer	Microsecond Timer, Fakopp Enterprises,	$2,350
	Model 239A Stress Wave Timer, Metriguard Inc.	$5,375
	Sylvatest Trio, Concept Bois Technologie	$9,210
Resistance Microdrill	F-Series (400 mm with paper output only), IML North America, LLC	$4,933
	PD-Series (400 mm with digital data collection plus bluetooth printer)	$8,920
	Resistograph, RINNtech (450 mm with digital data collection and bluetooth printer)	$9,470

Note: [1]The cost estimate is based on data collected in 2014. Discounts are also available for multi-unit purchases. New prices should be obtained from the vendor after July 2014.

Figure 2.1. Inspection equipment used for inspecting timber bridges.

Chapter 3 Visual Inspection Techniques

Signs of Deterioration

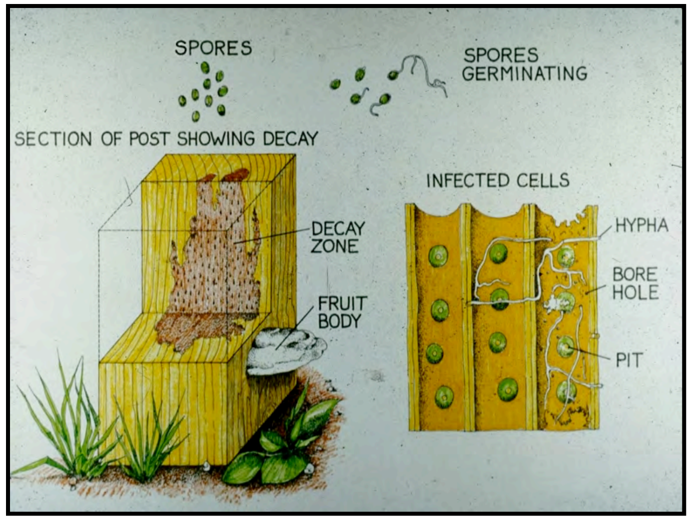

Figure 3.1. Image of decay affecting a timber member. Courtesy of USDA Forest Service, Forest Products Laboratory.

The simplest method for locating external deterioration is visual inspection. An inspector observes bridge elements for signs of actual or potential deterioration, noting areas that require further investigation. When assessing the condition of an element, visual inspection should never be the sole method used. Visual inspection requires strong light and is useful for detecting intermediate or advanced surface decay, water damage, mechanical damage, or failed members. Visual inspection cannot detect early stage decay, when remedial treatment is most effective. A visual inspection should focus on identifying and assessing the extent of the following signs of deterioration.

Fruiting Bodies

Although they do not indicate the amount or extent of decay, fruiting bodies provide a positive indication of fungal attack. Some fungi produce fruiting bodies after small amounts of decay have occurred while others develop only after decay is extensive. When fruiting bodies are present, they indicate the possibility of a serious decay problem. **Figure 3.1** shows an image of a fruiting body indicating internal deterioration or significant decay activity. **Figure 3.2** shows a Douglas fir timber beam that shows visual evidence of a fruiting body on the surface of the member. The presence of decay fungi and fruiting bodies indicate that the member has a high moisture content, usually above 28% on a dry weight basis.

Figure 3.2. Douglas fir bridge member showing visual evidence of a fruiting body on the surface in addition to visual evidence of decayed timber.

Sunken Faces or Localized Collapse

Sunken faces or localized surface depressions can indicate underlying decay. Decay voids or pockets may develop close to the surface of the member, leaving a relatively thin, depressed layer of intact or partially intact wood at the surface as shown in the line drawing of **Figure 3.3.** Crushed wood can also be an indicator of decay. **Figure 3.4** shows a timber abutment bearing cap supporting steel I-beams where the abutment cap has multiple longitudinal cracks or failures, which indicates that the likelihood that the member has advanced decay and deterioration. **Figure 3.5** shows a timber abutment cap that has settled onto timber pilings as the result of significant internal decay that was not readily apparent in a visual inspection.

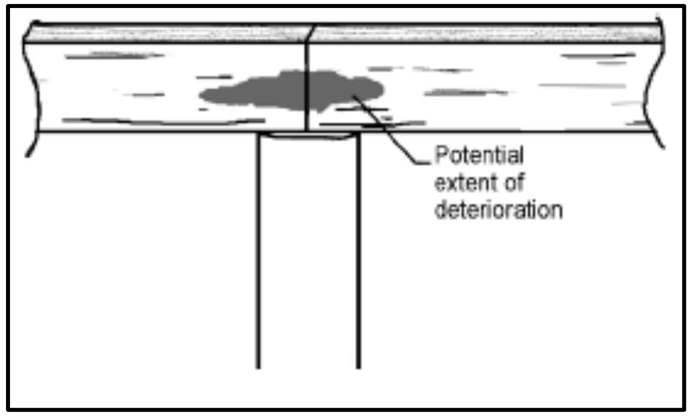

Figure 3.3. This line drawing shows interior deterioration that is often a precursor to significant localized collapse and failure shown in Figure 3.5.

Figure 3.4. Timber abutment cap showing visual evidence of localized failure demonstrated by longitudinal cracking. Photo courtesy of MnDOT.

Figure 3.5. A timber cap abutment has collapsed onto a timber piling as a result of decay and bearing loads. Photo courtesy of MnDOT.

Staining or Discoloration

Staining or discoloration of wood indicates that the wood has been subjected to water and potentially has high moisture content, making it susceptible to decay. Rust stains from connection hardware are also an indication of wetting. **Figure 3.6** shows an example of a timber element that clearly displays visual evidence of wetting and discoloration, including rust and deterioration of the fastener. The inspector used this information to focus additional, more detailed, inspection techniques in this area, enabling them to identify significant internal decay and deterioration zones. **Figure 3.7** also shows discoloration of bridge beams where water has come through bridge decking. A bituminous wear layer often covers transverse nail-laminated timber bridge decking. Often this wear layer may develop cracks or other failures that allow water to infiltrate and absorb into the bridge superstructure.

Figure 3.6. The timber members were stained and discolored due to high levels of water. The hardware shows significant corrosion.

Figure 3.7. Water staining and discoloration caused by water that infiltrated through the bituminous wear layer and nail-laminated deck.

Insect or Animal Activity

Insect activity is often identified by the presence of holes, frass, and powder posting. For wood boring insects like carpenter ants, frass is defined as the mix of insect excrement and excavated wood material from timber members where they are active. The presence of insects may also indicate the presence of decay, as carpenter ants often create tunnels and nests in decay cavities. **Figure 3.8** shows a timber abutment cap that has significant deterioration and is infested with carpenter ants. The abutment brace clearly shows frass that has fallen from the abutment cap where they are nesting. Carpenter ants deposit sawdust in gallery openings, trapping moisture and increasing the rate of decay of an element. In addition to insects, birds often nest under bridge decks, where the nests may trap moisture against a timber element that can potentially increase the moisture content resulting in localized decay. **Figure 3.9** shows a nest of young birds under a bridge deck.

Figure 3.8. A timber abutment cap that has been initially deteriorated by decay. Carpenter ants are nesting in the cap, with frass being deposited onto the cross bracing member.

Figure 3.9. Nesting birds are often found under timber bridges and their nests can trap and hold moisture against timber beams and bracing.

Plant or Moss Growth

Plant or moss growth in splits and cracks, or soil accumulation on the structure, indicates that adjacent wood has been at a relatively high moisture content for a sustained period and may sustain growth of decay fungi. **Figure 3.10** shows a timber deck with moss growth on the surface, while **Figure 3.11** shows a bridge wing wall cap that has substantial plant growth covering its surface (left image) and the plants removed showing severe decay (right image). These photos illustrate the importance of ongoing maintenance activities to remove dirt accumulation and plant growth from timber elements.

Figure 3.10. Moss growing on the surface of a nail laminated timber deck supported by steel beams along the curb/scupper zone.

Figure 3.11. A wing wall timber abutment has substantial plant growth on the cap surface. Once removed, visual and probing inspection showed that 75% of the cap cross-section had been severely decayed. This will eventually result in damage to the wing wall pile elements.

Check and Splits

Timber members are susceptible to drying and weathering, which often result in surface and deep surface checks, ring shake, end checks, and through splits. Checks and splits in members can indicate a weakened member, and also create an entry for moisture to enter the element. **Figure 3.12** shows side-by-side examples of ring shake, small end checks and severe splits. If a check or split develops to a sufficient depth, the inner untreated wood is susceptible to moisture and decay fungi. This will create conditions that can result in severe decay and premature deterioration of a timber bridge element. Railing posts, and abutment cap ends are typically the most common location to observe lumber checking or splitting. In rail posts, overtightening of bolts during construction can contribute their occurrence.

Figure 3.12. Timber railing posts showing various types of deterioration. From left to right, the posts show ring shake, small end checks, and severe through splits.

Severe splits in timber abutment caps often lead to substantial decay and should be thoroughly evaluated, especially when multiple spans are butted together over the support, or when the wood deck does not shelter the cap beam effectively. **Figures 3.13 and 3.14** show splits in abutment caps leading to deterioration. In **Figure 3.13**, the horizontal split has provided an opportunity for moisture to infiltrate from an open timber deck, resulting in severe decay.

Figure 3.13. A long horizontal split provides an opportunity for moisture passing through the timber deck to enter the abutment cap, leading to substantial decay.

In **Figure 3.14**, a severe through split in an abutment cap provides an opportunity for moisture to absorb into the element, resulting in conditions that allow for potential decay as well as deterioration of the surrounding steel elements such as the CIP bearing plate.

Figure 3.14. Visual assessment of a pier cap split. The split allows moisture from the deck to enter the member beyond the protective layer of preservative treated wood, resulting in increased likelihood of future decay and allows for deterioration of hardware such as the CIP bearing plate that supports this element.

Weathering or Impact Damage

Frequently, weathering and aging of bridge elements has an impact on the performance and durability of timber bridges. This occurs with both timber and non-timber materials like bituminous or other wear layers. **Figure 3.15** shows a bituminous wearing course that has been placed over a slab span, spike-laminated timber bridge. As noted in this picture of the beginning of the bridge, deterioration and reflective cracking frequently occur above the timber abutment where the approach roadway meets the bridge panels, supported by the abutment. This similar situation also occurs at the end of the bridge. **Figure 3.16** shows potholes or other substantial cracking damage of a bituminous wearing course. This damage creates ponding locations and allows the water to enter the bridge superstructure, creating conditions that may cause decay and or other types of deterioration like splits and checks in the timber superstructure or substructure.

Figure 3.15. Transverse cracking that occurs over the beginning of bridge abutment.

Figure 3.17 shows an exposed timber deck on the surface of a bridge where the wear layer has been completely removed. This creates an entry point for moisture infiltration into the timber decking, beams, abutments and piers.

Figure 3.16. Cracking and deterioration of bituminous wear layers create opportunities for water to pond on the deck and seep into the superstructure elements creating decay potential.

Figure 3.17. The bituminous wear layer has deteriorated exposing structural timber decking to moisture and potential deterioration.

Other natural weathering damage occurs to timber piles exposed to water and materials flowing down the river or stream. Freeze and thaw cycles, along with ice impact or crushing can damage timber piles, often at or near the waterline. Members in the mud zone, (+/- 2 ft of normal water level) have ideal conditions (oxygen, moisture) to promote decay. **Figure 3.18** shows two examples of shell damage to timber pile. This can affect the structural performance both through loss of cross-section and the removal of the preservative treatment.

Figure 3.18. Shell damage to timber piling at or near the water line, often caused by freeze thaw cycles, ice damage or flotsam floating down the river.

Additional damage to timber bridge components can be caused by impact from vehicle traffic. Snowplows can create damage to timber curb and railings during winter months, as the curb is hidden by snow. Floating objects, such as trees and logs, can also damage timber substructure during high flow rates associated with heavy rain events or seasons. **Figure 3.19** shows examples of impact damage to timber curbs.

Figure 3.19. The timber curbs shown have significant damage from a snowplow or other vehicle exposing untreated wood to high levels of moisture.

Miscellaneous Conditions

During visual inspections of timber bridge components, there are other significant conditions that need to be further explored using the full combination of inspection and assessment techniques. These conditions can include the rotation of timber piers and abutments caused by the loss of fill behind the backwall or by some other mechanism. Misalignment of caps and piles will not effectively transfer vehicle loads to the ground, causing piles to be overstressed in bending and compression. A second significant condition is the build-up of road materials like gravel or sand that hold moisture in

Figure 3.20. Rotation of timber pilings and pile caps in an abutment (left) and timber pier (right).

contact with structural timber elements. **Figure 3.20** shows significant rotation of timber abutment walls and piers. **Figure 3.21** shows gravel buildup and wet sand on top of the timber abutment cap, while **Figure 3.22** shows significant sand and gravel around timber beams. Both conditions were caused by vehicle traffic, road graders or snowplows carrying the material onto the bridge where it fell through the deck. **Figure 3.23** shows timber pile in contact with concrete footing, holding high levels of moisture capable of creating decay and deterioration.

Figure 3.21. Sand and gravel are shown on top of the timber abutment cap as deposited through vehicle traffic or road maintenance through a timber deck.

Figure 3.22. Sand and gravel are covering the timber abutment cap and the longitudinal timber beams, holding moisture against these elements.

Figure 3.23. Timber piling in direct contact with concrete footing, creating high moisture content conditions.

Chapter 4 Sounding, Probing, and Moisture Content Techniques

Simple mechanical tests are frequently used for in-service inspection of wood elements in timber bridges. For example, hammer sounding and probing is used in combination with visual inspection to conduct an initial assessment of the condition of a member. The underlying premise for such tests is that degraded wood is relatively soft and might sound hollow, with low resistance to penetration.

Sounding and Probing

Figure 4.1. A hammer pick is an effective tool for initial assessments of timber bridge elements.

One of the most commonly used techniques for detecting deterioration is to hit the surface of a member with a hammer or other object. Based on the sound quality or surface condition, an inspector can identify areas of concern for further investigation using advanced tools like a stress wave timer or resistance microdrill. Deteriorated areas typically have a hollow or dull sound that may indicate internal decay. Care must be taken to not confuse the sound associated with high moisture content pile with decay. A pick hammer commonly used by geologists is recommended for use in timber bridges because it allows inspectors to combine the use of sound and the pick end to probe the element. **Figure 4.1** shows a hammer pick being used to inspect a timber piling (left) and timber deck (right).

Figure 4.2. An awl is used to assess the depth and presence of decay in a horizontal split.

Probing with a moderately pointed tool, such as an awl or knife, locates decay near the wood surface as indicated by excessive softness or a lack of resistance to probe penetration and the breakage pattern of the splinters. A brash break indicates decayed wood. A splintered break reveals sound wood. Although probing is a simple inspection method, experience is required to interpret results. Care must be taken to differentiate between decay and water-softened wood that may be sound but somewhat softer than dry wood. It is also sometimes difficult to assess damage in soft-textured woods such as Douglas fir. **Figure 4.2** shows an awl probe inserted into a split to assess decay that is visible on the railing end. Probes can also be used to assess the depth of splits and checks. Flat bladed probes like pocket knives or calibrated feeler gauges are recommended for use in this process. This is also important to understand the impact of checks and cracks in other advanced techniques such as stress wave inspection. **Figure 4.3** shows the use of probes to assess the depth of checks and cracks in timber bridge elements.

Moisture Content Inspection

Moisture meters can effectively be used in conducting inspections of timber bridge elements. It is well documented that the presence of moisture is required for decay to occur in timber. Typically, moisture contents in timber less than 20% will not allow decay to occur in wood. However, as the moisture increases above 20%, the potential for decay to occur increases.

Figure 4.3. Probes are used to assess the depth of cracks, checks and through splits in timber bridge elements.

Serious decay occurs only when the moisture content of untreated wood is above 28-30%. This occurs when dry wood is exposed to direct wetting through rain, moisture infiltration or contact with ground water or bodies of water. Wood decay fungi will not affect wood that is fully saturated with water but without oxygen. Timber piles should be carefully inspected near the water line since rivers and streams have varying water levels throughout the year and from year to year. **Figure 4.4** shows the use of moisture meters with long pins (up to 3 inches long) assessing the moisture content of timber abutment caps. Pin style moisture meters determine the electrical resistance between two pins that are driven into the member. The presence of salts in CCA and ACQ will interfere with the results, making them unreliable.

Figure 4.4. A pin style moisture meter is used to determine moisture content of timber elements.

Chapter 5 Stress Wave Timing Techniques

Principles

Stress wave timing is an effective method for locating and defining areas of decay in timber bridges. Stress wave propagation in wood is a dynamic process that is directly related to the physical and mechanical properties of wood. In general, stress waves travel faster in sound and high quality wood than in deteriorated and low quality wood. By measuring wave transmission time through a timber bridge beam, pile cap or piling in the transverse direction, the internal condition of the structural element can be fairly accurately evaluated. As an introduction, a photograph and schematic of the stress wave concept for detecting decay in a timber piling are shown in **Figure 5.1**. A stress wave is induced by striking the timber member with an impact device instrumented with an accelerometer that emits a start signal to a timer. Alternately, an ultrasonic pulse creates a stress wave in the member. A second accelerometer, held in contact with the other side of the member, senses the leading edge of the propagating stress wave and sends a stop signal to the timer. The elapsed time for the stress wave between the accelerometers is displayed on the timer. This measured time, when converted to a transmission time on a per length basis (or wave propagation speed), can be used as a predictor of the physical conditions inside the timber bridge member.

The velocity at which a stress wave travels in a member is solely dependent upon the properties of the member. All commercially available timing units, if calibrated and operated according to manufacturer's recommendations, yield comparable results.

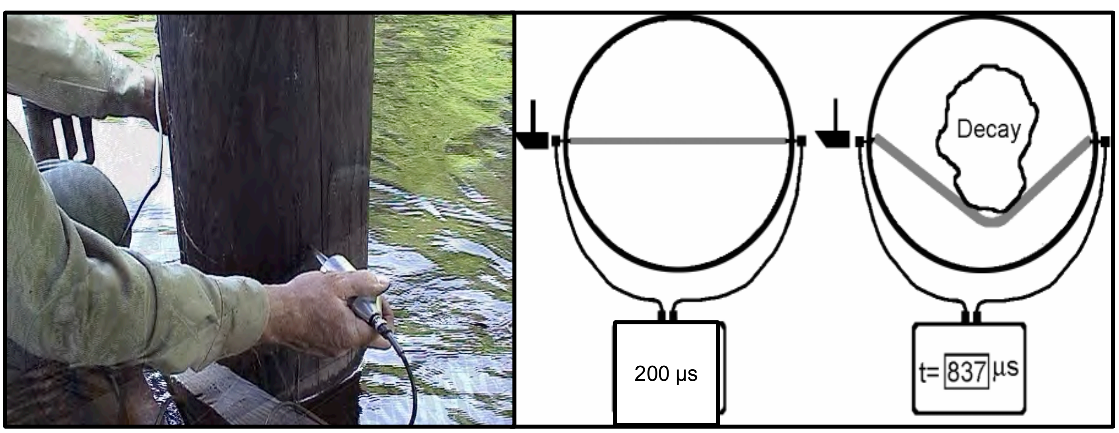

Figure 5.1 A stress wave timer is used to inspect timber bridge elements to identify the presence of internal decay that is not visible.

Measurement of Stress Wave Transmission Times

The most common technique used to measure stress wave transmission time utilizes simple time-of-flight-type measurement systems shown as a photograph in **Figure 5.2** and illustrated in **Figure 5.3**. With these systems, a mechanical or ultrasonic impact is used to impart a wave into the member. Sensors are placed at two points on the member and used to detect passage of the wave. The time required for the wave to travel between the sensors is measured by detecting the leading edge of the stress wave pulses.

Figure 5.2. A stress wave timer is used to determine the level of decay in a timber piling.

Stress wave timing is especially useful on thick timbers or glulam timbers (≥89 mm (3.5 in.)) where hammer sounding is not effective. However, access to both sides of the member is required to employ this technique. The speed of wave propagation varies with grain direction. Hammering the side of a timber member will cause a sound wave across or transverse to the wood cells (perpendicular to grain). The speed of sound across the grain is about one-fifth to one-third of the longitudinal value (Forest Products Laboratory 1999).

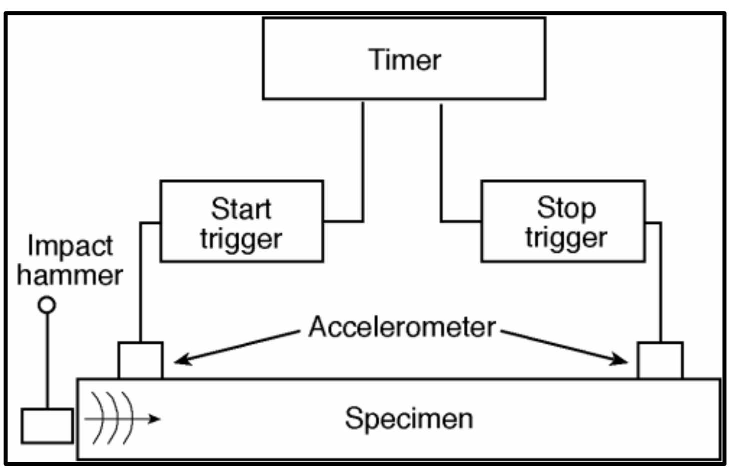

Figure 5.3. Technique used to measure stress wave transmission time in bridge members. The time is usually reported as microseconds per foot (μs/ft).

There are three key points to consider when using stress wave measurement systems:

1. The sensors must be in line with each other.
2. Spike or probe style accelerometers should be inserted at equivalent depths in the timber element being inspected. If using accelerometers, the inspector must make sure that the base of the accelerometer should directly face an approaching compressive wave. Simply turning the accelerometer so that its base faces away from the approaching compressive wave changes the characteristics of the waveform and provides an erroneous reading.
3. Consistent force should be applied when using impact style stress wave timers. Inconsistent striking will result in variability of the testing data during testing. The operator should use the impact hammers provided by the equipment supplier or find one of similar size and weight.

The field test set-up for time-of-flight measurement can vary based on the types of material tested and the locations of the sensors in the material. When using these techniques, consult and closely follow manufacturer's directions. Appendix B shows specific guidelines for using a commercial stress wave timer.

Interpretation of Stress Wave Readings

Stress wave transmission times are shortest along the grain (parallel to fiber) and longest across the grain (perpendicular to fiber). For common timber bridge species such as Douglas fir and southern yellow pine at dry conditions, the stress wave transmission time is approximately 60 μs/ft (197 μs/m) parallel to grain, but ranges from 150 to 300 μs/ft (492 to 984 μs/m) in the perpendicular or cross-grain direction.

Treatment with waterborne salts has almost no effect on stress wave transmission time. Treatment with oil-borne preservatives increases the transmission time by about 10-40 percent more than that of untreated wood (Ross et al 1999). Round southern yellow pine poles are usually penetrated to about 2.5 to 5.0 in. (64 to 127 mm), except at their ends where treatment fully penetrates the wood. Although these data illustrate the effect oil-borne treatments have on transmission time, these values should not be used to estimate level of preservative penetration.

The presence of deterioration from decay can greatly affect stress wave transmission time in wood, especially in the transverse direction. Transmission times for decayed wood are much greater than that for nondecayed wood. For example, transmission time for nondegraded Douglas fir is approximately 200 μs/ft (494 μs/m), whereas severely degraded members exhibit values as high as 975 μs/ft (3200 μs/m) or greater. A 50-100% increase in time indicates moderately decayed wood and an increase of over 100% may indicate severe deterioration.

Table 5.1 shows information that provides guidance on interpreting stress wave times and the potential level of decay for the two primary species used in timber bridges. These guidelines are useful in interpreting readings that show a higher transit time than those for sound wood. Voids and checks will not transmit stress waves, however the stress wave often travels around the split resulting in a longer transmit time than in solid wood. Based on the direction and length of the stress wave path in the wood, moisture content of the wood, and whether or not preservative treatment is present, the velocity and travel time for sound wood can be determined. For the transverse direction, the annual ring orientation and the existence of seasoning checks and splits should be recorded and considered when evaluating the data. When suspected decay is located, it is recommended that the inspector verify the amount and determine the effective cross-section through techniques like resistance drilling or coring.

Table 5.1. Stress wave transmission times in the transverse direction (perpendicular to the grain) for various levels of deterioration using the Fakopp Microsecond Timer.

Species	Stress Wave Transmission Time (μs/ft)			
	Sound Wood	Moderate Decay[1]	Severe Decay[2]	Splits
Douglas-fir (beams)	130-250	300-500	500+	300-700+
Southern yellow pine (pilings)	130-250	300-400	500+	300-700+

[1]Moderate decay is defined as cross-section loss of 10-30% of the cross-section width or 10-20% of the cross-section area.
[2]Severe decay is defined as cross-section loss of greater than 30% of the cross-section width or greater than 25% of the cross-section area.

Field Considerations and Use of Stress Wave Methods

Figure 5.4 outlines the general procedure used with stress wave timing methods for field inspection. Before venturing into the field, it is useful to estimate stress wave transmission time for the size of the members to be inspected. A second approach is to identify material on site that is confirmed using drilling or coring to be sound and use it as a control set of time data.

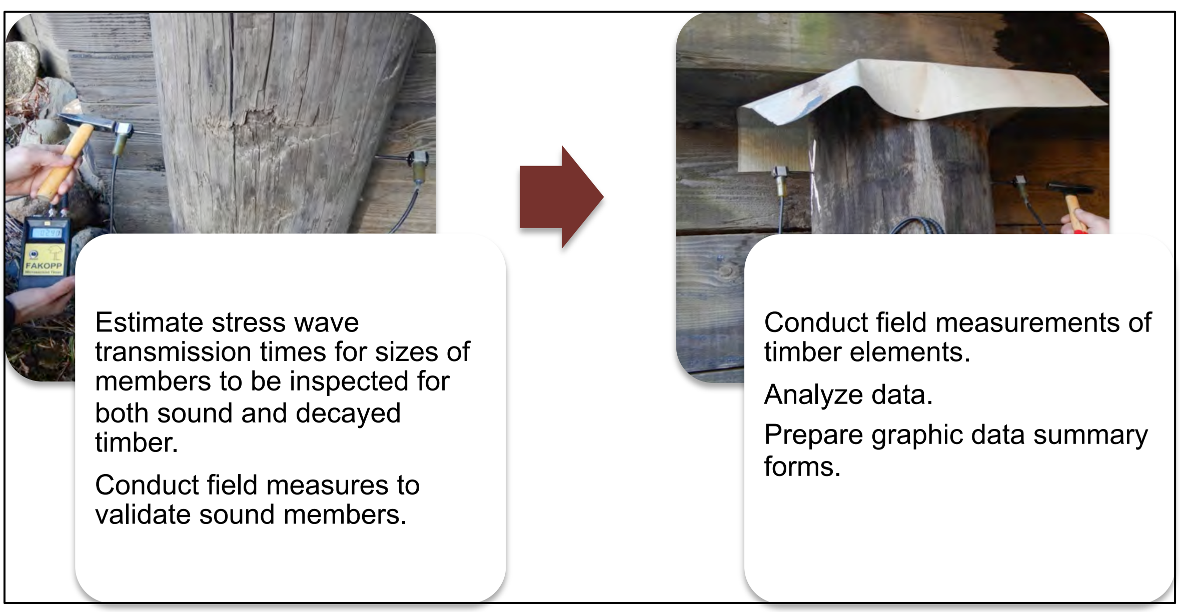

Figure 5.4. General procedure used to prepare and use stress wave timing methods for timber bridge inspection.

Preceding sections provided information on various factors that affect transmission time in wood. This information can be summarized, as a starting point, by simply using a baseline transmission time of 250 μs/ft. Transmission times, on a per length basis, less than this would indicate sound material. Conversely, transmission time greater than this value would indicate potentially degraded material. It is critical to confirm decay determined from the use of a stress wave timer with other techniques such as microdrilling.

Field Data Form

An example of a standardized graphic field data form is shown in **Figure 5.5.** Key items to include on this form are structure number, location, inspector(s), weather conditions, and date of inspection. Further details should include dimensions of members and the locations that data was collected. Full-size and additional field forms are included in Appendix C.

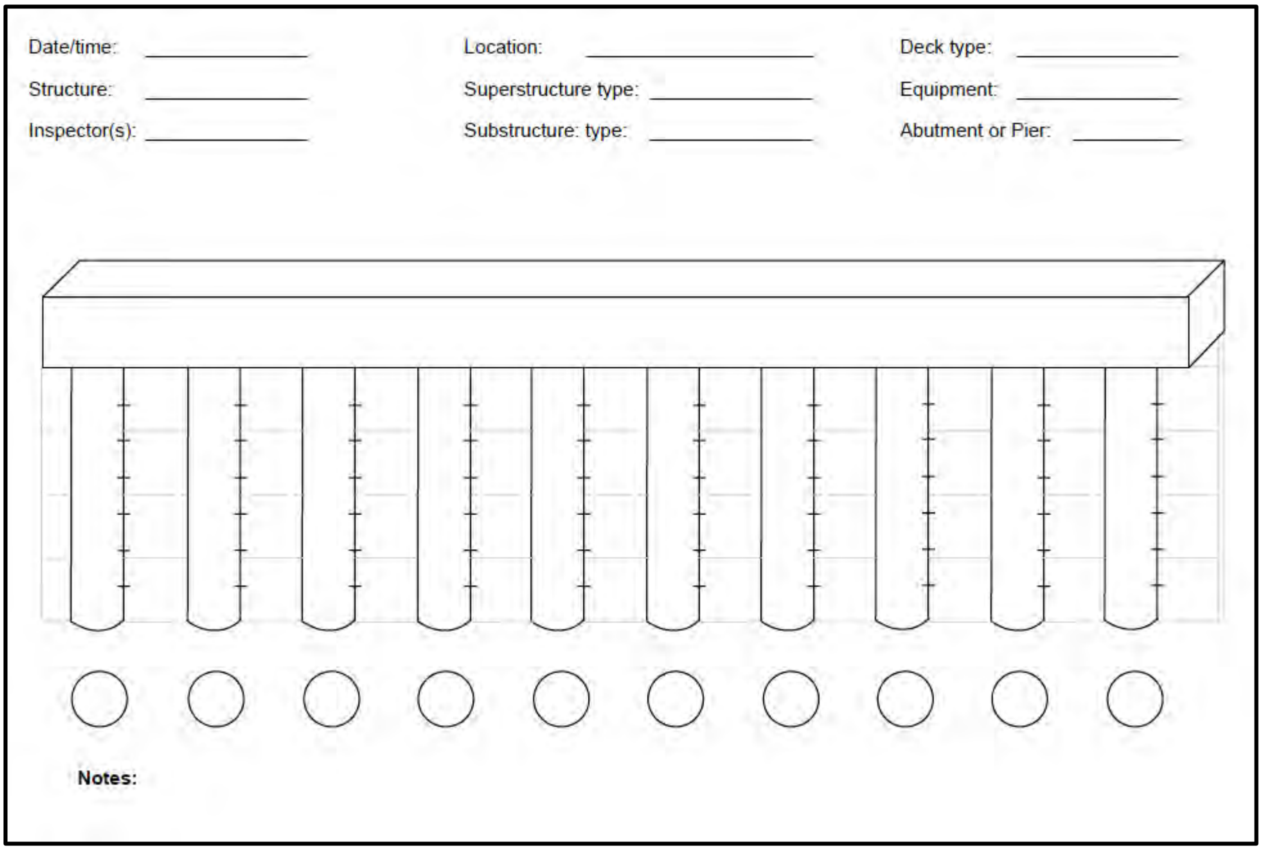

Figure 5.5. Typical field data acquisition form used for timber abutments, piers, and caps.

Field Measurements

Field use should be conducted using the instructions provided by equipment manufacturers. In the field, extra batteries, cables, and sensors are helpful. Testing should be conducted in areas of the member that are highly susceptible to degradation, especially in the vicinity of connections, bearing supports and ground or mud zones.

Baseline values provided serve as a starting point in the inspection. It is important to conduct the test at several points at varying distances away from the suspect area. In a sound member, little deviation is observed in transmission times. If a significant difference in values is observed, the member should be considered suspect.

Data Analysis and Summary Form

When data have been gathered, it is useful to present them in an easy to read manner. **Figure 5.6** illustrates various stress wave data for a timber abutment cap. From these notes, the presence and extent of degradation can readily be seen.

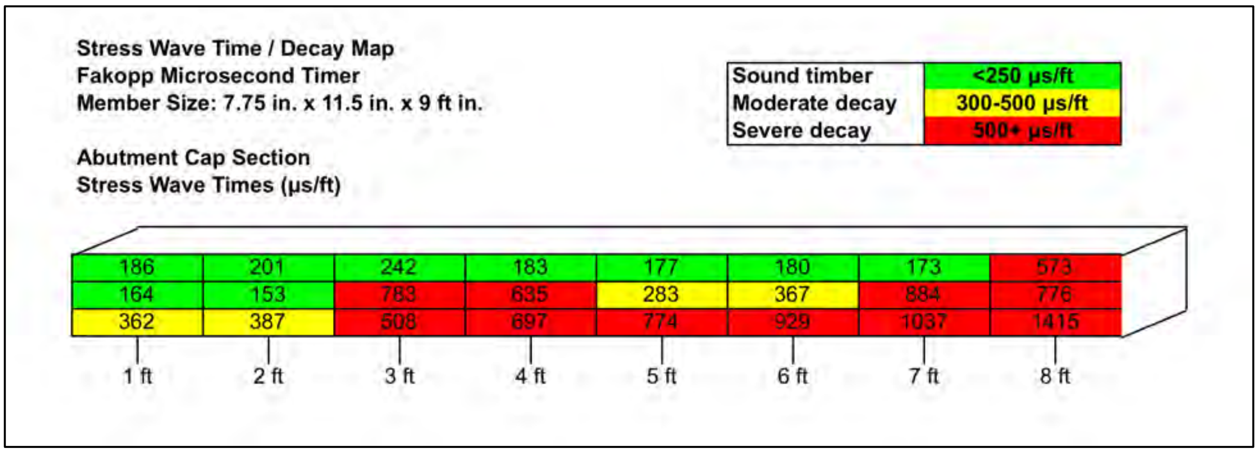

Figure 5.6. Example of a detailed data set from a timber abutment cap showing stress wave times and the level of decay present as confirmed through resistance drilling.

Commercial Equipment

There are several companies that produce stress wave timing equipment that is suitable for inspecting timber bridges. Additional detail for these companies and their equipment is shown in Appendix A.

FAKOPP Microsecond Meter
FAKOPP Enterprise
Agfalva, Hungary
Telephone: +36 99 33 00 99
Website: www.fakopp.com

Metriguard Model 239A Stress Wave Timer
Metriguard, Inc.
Pullman, WA 99163 USA
Telephone: (509) 332-7526
Website: www.metriguard.com

Sylvatest Trio
Concept Bois Technologie
Saint-Sulpice, Switzerland
Telephone: +41 21 694 04 04
Website: www.cbs-cbt.com

Chapter 6 Drilling and Coring Techniques

Drilling

Drilling and coring are the most common methods used to detect internal deterioration in wood members. Both techniques are used to detect the presence of voids and to determine the thickness of the residual shell when voids are present. Drilling is usually done with an electrical power drill or hand-crank drill equipped with a 3/8 to 3/4-in. diameter bit. Power drilling is faster, but hand drilling allows the inspector to monitor drilling resistance and may be more beneficial in detecting pockets of deterioration. In general, the inspector drills into the member in question, noting zones where drilling becomes easier and observing drill shavings for evidence of decay. The presence of common wood defects, such as knots, resin pockets, and abnormal grain, should be anticipated while drilling and should not be confused with decay. If decay is detected, remedial treatment such as copper naphthenate can be added to the wood through the inspection hole. Copper naphthenate is available for purchase on-line or at local building materials centers. The inspection hole is probed with a bent wire or a thickness gauge to measure shell thickness. Since these holes are typically ¼ to ½ in. diameter, they should be plugged with a wood dowel section that has been soaked in a preservative.

Coring

Coring with an increment borer (often used for determining the age of a tree) also provides information on the presence of decay pockets and other voids. The resultant solid wood core can be carefully examined for evidence of decay. In addition, the core can be used to obtain a measure of the depth of preservative penetration. **Figure 6.1** shows an increment core tool and the extracted core. It is also possible to determine the wood species from the core. Typically, coring should be conducted on a horizontal plane. To prevent moisture and insect entry, a bored-out core hole should be filled with a copper naphthenate treated wood plug.

Figure 6.1. An increment core can be used to conduct inspections of timber bridge elements. This image shows an extracted core from an in-service timber pile ready for examination.

Resistance Micro-Drilling

Another drilling technique that has been commercially developed is the resistance micro-drill system. Developed in the late 1980s, this system was originally developed for use by arborists and tree care professionals to assess tree rings, evaluate the condition of urban trees, locate voids and characterize decay. This technology is now being utilized to identify and quantify decay, voids, and termite galleries in wood beams, columns, poles, and piles. This technique is now the preferred drilling and coring technique for timber elements. **Figure 6.2** shows a resistance micro-drill being used to assess the level of decay in a pile.

Figure 6.2. A resistance microdrill is the preferred drilling inspection technique for timber bridge elements.

There are several machine types available from different manufacturers. They operate under the same general principle of measuring the electrical power consumption of a needle rotation motor. This value is proportional to the mechanical torque at the needle and mainly depends on wood density (Rinn et al. 1990). The purpose of the equipment is to identify areas in timber elements that have low density that is decay or deterioration. The resistance micro-drill equipment measures the resistance of wood members to a 0.6 in. (1.5 mm) drill bit with a 0.18 in. (3.0 mm) head that passes through them. Bits are typically 13.8-17.8 in. (350-450 mm) long. This flat tipped drill bit travels through the member at a defined movement rate and generates information that allows an inspector to determine the exact location and extent of the damaged area. **Figure 6.3** shows several drill bit ends that are used in resistance drills. While the unit is usually drilled into a member in a perpendicular direction to the surface, it is also possible to drill into

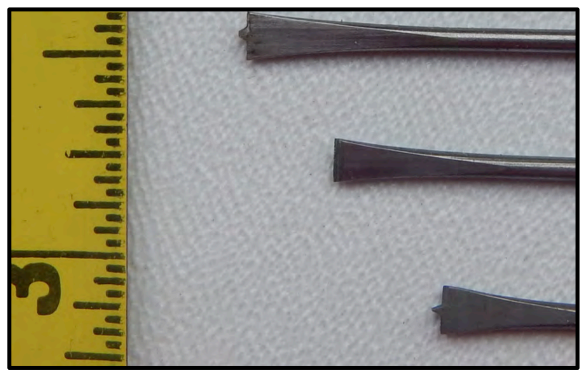

Figure 6.3. Close-up of the flat tipped resistance drill bits used to inspect timber materials.

Figure 6.4. Drilling can take place at an angle to assess the area below ground line.

members at an angle, as shown in **Figure 6.4.** However, the location of the void is slightly changed by the angle of the drilling.

Resistance micro-drills collect the data electronically and can also product a chart or printout showing the relative resistance over its drilling path. Modern tools are also promoting the ability to view the data wirelessly on a tablet computer or hand-held mobile phone in real-time. Areas of sound wood have varying levels of resistance depending on the density of the species and voids show no resistance. The inspector can determine areas of low, mild, and high levels of decay with this tool, and quantify the level of decay in the cross-section. **Figure 6.5** shows the use of a timber abutment cap being assessed with a resistance microdrill and the resulting chart image showing minimal drilling resistance that indicates the majority of the cap is decayed. **Figure 6.6** shows a commercial model that has an electronic display that can be reviewed in the field and then further processed using a computer in the office for archival into bridge inspection files. It is recommended that all holes be filled after drilling, especially if there is no decay present. This can be accomplished by injecting a small amount of silicone sealant or marine adhesive into the small opening as shown in **Figure 6.7.**

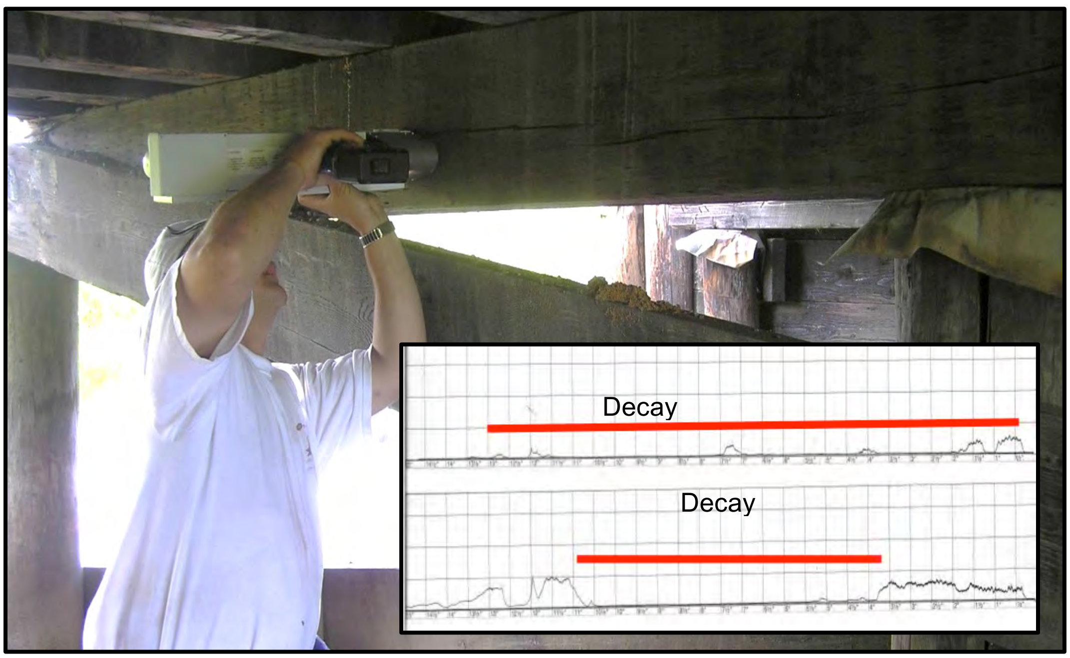

Figure 6.5. Resistance microdrilling showing significant decay in the bridge pile cap. The inlay shows the paper chart readout from a commercial drilling unit.

Figure 6.6. Electronic display on a resistance drill.

Figure 6.7. Silicone is used to fill the small drilling hole.

Interpreting Drilling Data Charts

Review of the charts or printouts should be conducted in the field and notes taken to ensure understanding of the testing location. It is recommended that notes be taken on a graphical data chart. Care should be exercised to ensure that low profiles from intact but soft, low density wood (such as Douglas fir) are not misinterpreted as decay. It is also known that the very center of softwood species near the pith will have low resistance and lack the defined growth rings visible in the outer sections. It is also important to understand the type of wood that is being drilled. Sound wood from many hardwood species may have high levels of resistance over 50%, while sound wood from softwood conifers may have low levels of resistance in the range of 15-50+%, depending on it's inherent density. It is important to evaluate the levels of decay across the full dimension, as some species have low resistance values, but are not decayed. Further, each piece of commercial equipment provides different scales and may have different resistance levels. **Table 6.1** shows a general assessment rating index that can provide support for the bridge inspector in evaluating the resistance data collected during testing. An example electronic drilling chart for a southern yellow pine pile and a Douglas fir pile cap is shown in **Figures 6.8 and 6.9,** respectively.

Table 6.1. General assessment of resistance drilling data for Douglas fir and southern yellow pine bridge members.

Drilling Resistance	Decay Level	Comments
0%	Severe	Decay resulting in an internal void
5-15%	Moderate	Often adjacent to the internal void areas.
20+%	Low to None	Sound material will have resistance that is often consistent across the full width.

Note: This data must be carefully interpreted since there are differences between species and commercial equipment.

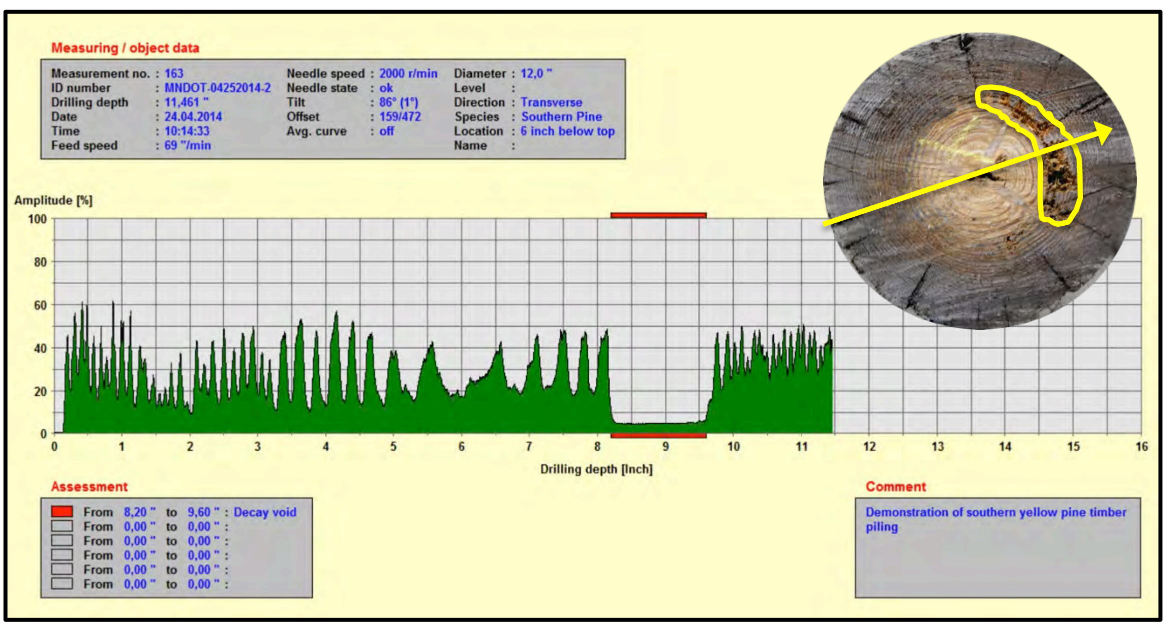

Figure 6.8. Electronic view of a southern yellow pine timber piling showing a decay pocket between 8 and 10 in. of the drilling profile.

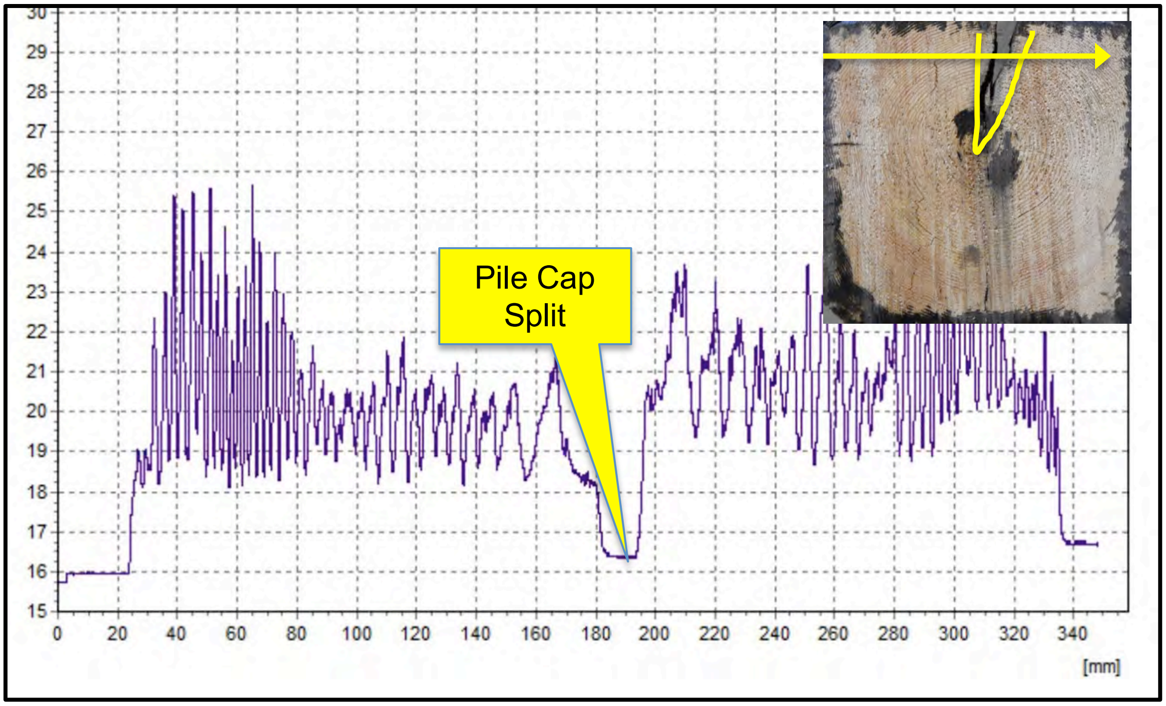

Figure 6.9. Electronic resistance chart of a Douglas fir pile cap showing a large crack between 180 and 200 mm (7.0 and 7.9 in) along the drilling path.

Commercial Equipment

There are several companies that produce stress wave timing equipment that is suitable for inspecting timber bridges. Details are shown in Appendix A.

Increment Borers
Forestry Suppliers Inc.
Jackson, MS 39284-8397 USA
Telephone: (800) 647-5368
Website: www.forestry-suppliers.com

Ben Meadows Company
Janesville WI USA 53547-5277
Telephone: (608) 743-8001
Fax: (608) 743-8007
Website: www.benmeadows.com

Resistance Microdrills

IML-RESI PD- and F-Series
IML North America, LLC
Moultonborough, NH 03254 USA
Telephone: 603-253-4600
Website: www.iml-na.com

Resistograph 4- and 5-Series
RINNTECH, Inc.
St. Charles, IL 60174, USA
Telephone: (630) 377-2477
Website: www.rinntech.de

Digital microProbe
Sibtec Scientific
Sibert Technology Limited
2a Merrow Business Centre, Guildford
Surrey GU4 7WA England
Telephone: +44 1483 440 724
Fax: +44 1483 440 727
Website: www.sibtec.com

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Chapter 7 Condition Assessment

A bridge inspection includes examining the structure, evaluating the physical condition of the structure, and reporting the observations and evaluations on the bridge inspection report. **The information presented in this chapter is not meant to replace, but only to supplement the guidance, procedures and protocols specified in the most recent MnDOT Bridge Inspection Field Manual shown, as shown in Figure 7.1 (MnDOT 2013).** Further, users of this information are encouraged to follow MnDOT bridge inspection best practices (MnDOT 2013).

Figure 7.1. 2013 MnDOT Bridge Inspection Field Manual.

MnDOT Bridge Inspection Field Manual

The Minnesota Department of Transportation Bridge Office has developed and uses a Bridge Inspection Field Manual that serves as a field guide for the inspection and condition rating of in-service bridges and culverts in Minnesota. The most recent Bridge Inspection Field Manual can be downloaded at the MnDOT Bridge website at: http://www.dot.state.mn.us/bridge/inspection.html. This manual provides detailed information and guidance for the National Bridge Inventory (NBI) condition ratings and structural element condition ratings; two separate condition rating systems that MnDOT uses for bridges and culverts.

NBI Condition Ratings

NBI condition ratings describe the general overall condition of a bridge. This numerical (0-9) rating system was developed by the Federal Highway Administration in the 1970's to improve safety of our Nation's bridges (FHWA 2014). The NBI condition ratings are used to calculate the Bridge Sufficiency Rating, which determines funding eligibility and priority for bridge replacement and rehabilitation.

Structural Element Condition Ratings

Structural element condition ratings divide a bridge into separate components that are rated individually based upon the severity and extent of deterioration. This rating system was developed by the American Association of State Highway and Transportation Officials (AASHTO), and is outlined in the AASHTO Manual for Bridge Element Inspection (AASHTO 2013). Structural element condition ratings provide input data for a bridge management system which can be used to identify present maintenance needs, and is intended to provide cost-effective options for long-range bridge maintenance and improvement programs (using computer projections of future deterioration).

Advanced Timber Bridge Inspection Field Manual

The manual presented here is intended to serve as a field guide for the inspection and condition rating of in-service timber bridges in Minnesota. The goal of the manual is to provide information on advanced inspection techniques and equipment that are available to conduct reliable inspections of timber bridges. Inspectors are encouraged to conduct inspections using a combination of assessment techniques, as outlined in **Figure 7.2.** While all three stages are recommended, many inspectors are only using visual/physical and resistance micro-drilling inspections.

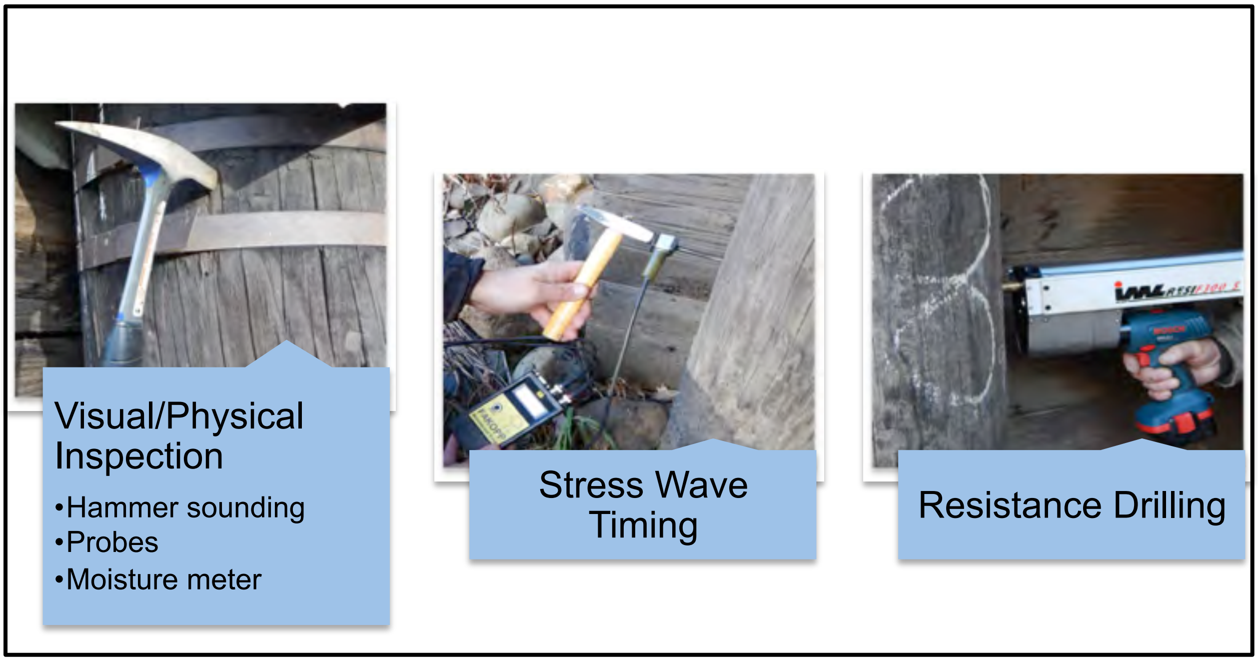


Figure 7.2. Detailed timber bridge inspections utilize visual inspection coupled with stress wave timing and resistance microdrilling.

The inspection team should also have appropriate inspection equipment as detailed in Chapter 2 of this manual. This includes:

- Personal safety equipment (gloves, hardhat, boots, ladder, safety harness)
- Personal inspection equipment (high rubber or hip boots, waders, boat)
- Hammer sounding device with a pick end
- Awl or other flat bladed probe
- Feeler gauges
- Tape measures
- Chalk for marking areas
- Moisture meter
- Stress wave timer
- Resistance microdrill
- Durable equipment cases
- Documentation supplies (notebooks, inspection forms, digital camera)
- Cell phone or radio for emergency communication

Timber Bridge Inspection Checklist

The following inspection checklist has been developed for the inspector with reference to timber bridges. Detailed notes and sketches should be created to document location of visible damage/deterioration, moisture accumulation, and data points for nondestructive evaluation (NDE) investigations such as stress wave timing and resistance microdrilling. The following checklist may prove useful for inspectors.

- ✓ Assess site specific safety hazards, place warning signs, and select safety gear.
- ✓ **Complete** all bridge specific data sections on the required inspection paperwork.
- ✓ **Print, review and bring previous inspection reports** to reference during the on-site inspection.
- ✓ **Wearing surface** type description (lumber, bituminous, running planks, gravel).
- ✓ **Preservative treatment** type used on superstructure members.
- ✓ **Significant checking, horizontal shear cracks, or split members** that are checked through thickness using a probe.
- ✓ **Dirt & debris** accumulation (or plant growth).
- ✓ **Sunken faces** or depressions.
- ✓ **Deterioration** at or near wood/wood and wood/concrete interfaces.
- ✓ **Corrosion** evidence of metal fasteners.
- ✓ **Loose connectors** or fasteners.
- ✓ **Crushing** evidence at abutment caps or under bearing plates.
- ✓ **Untreated wood** exposed by damage or deterioration.
- ✓ **Insect activity** (termites-white mud shelter tubes; carpenter bees or beetles-small holes; carpenter ants-saw dust piles on ground or underlying members).
- ✓ **Failed members.**
- ✓ **Fire damaged members.**
- ✓ **Integrity** of sub-superstructure bearing uniformity and note any deficiencies.
- ✓ **Condition** of (bridge ends) transition roadway to bridge. (Is there cracking in the pavement?)
- ✓ **Traffic observations** while at bridge site**.**
- ✓ **NDE moisture content** readings (target wet spots or bridge abutment regions).
- ✓ **NDE stress wave timer** readings (when warranted) to determine boundaries of internal decay.
- ✓ **NDE resistance microdrilling** to determine severity of internal decay (percent sound wood).
- ✓ **Element-level condition assessment** completed to determine the overall condition and safety of the primary load carrying members.
- ✓ **NBI condition ratings** are assigned to each timber bridge component (deck, superstructure, substructure).

Timber Element Inspection

A systematic approach should be used to complete an inspection of all bridge elements. The order of the inspection may vary based on inspector preference or bridge type, but efforts should be made to develop a consistent inspection strategy to increase efficiency and reduce possible errors. One suggested order of inspection depending on the presence of specific members is:

Topside

1) **Deck Inspection**
   a) Deck and wearing surface
   b) Slab and wearing surface
   c) Railing and curb

Bottomside

2) **Superstructure Inspection**
   a) Timber girder beam (solid sawn or glulam)
   b) Timber truss or arch
   c) Timber floor beam with secondary bracing
   d) Steel beams (when a timber deck is present)
3) **Substructure Inspection**
   a) Timber column
   b) Trestle (framed timber support)
   c) Abutment (timber planks)
   d) Timber pile (abutment, pier)
   e) Timber pier cap (abutment, pier, bracing)

For each of the required MnDOT Structural Elements, a checklist of inspection techniques and considerations has been developed. Specific definitions for AASHTO Condition State Definitions should be utilized as published by AASHTO (2013) and MnDOT (2014). Those criteria should be used in combination with the timber bridge inspection checklist provided in this manual.

Detailed Element Description and Inspection Techniques

In the followings sections, several timber elements have been combined into main categories including timber deck and slabs, timber railings, timber superstructure and timber substructure, based on guidance from the MnDOT Bridge Office (Wilson 2014).

Timber Decks and Slabs

These elements describe the component that is transferring load from the vehicle to the bridge (AASHTO 2013, MnDOT 2014). **Table 7.1** provides specific information on timber deck and slab element types and recommended inspection techniques and equipment. **Table 7.2** provides specific information on the defect types and appropriate condition states.

Table 7.1. Timber deck and slab element, inspection and defect information.

Timber Deck & Slab Elements	
# 31: Timber Deck (square ft - SF) **# 54: Timber Slab (SF)**	These elements describe the condition of timber decks or slabs. This includes timber plank decks, nail laminated decks, glulam timber deck panels, and nail or spike laminated timber slabs. There may be a bituminous, gravel, or timber wearing surface present as a wearing surface. It should be rated using element #510 (Wearing Surface).
Inspection Techniques and Equipment	1. Visual inspection 2. Hammer sounding with pick hammer 3. Awl and flat depth probes 4. Moisture meter of exposed wood with suspected high moisture content 5. Stress wave timing inspection 6. Resistance microdrill of decayed areas
Timber Plank Decks Plank decks are comprised of transverse timber planks or square timbers (wide dimension in the horizontal plane). The planks are typically clipped to the top flange of steel beams, and nailed (or bolted) to timber or glulam beams. Timber plank decks are used primarily on low-volume roads or on pedestrian bridges. Due to large live load deflections, they are not generally suitable for bituminous overlays. Longitudinal timber running planks are sometimes added under each wheel track.	

Transverse Nail-Laminated Timber Decks

Nailed-laminated timber decks consist of transverse timbers (wide dimension in the vertical position) that are nailed or spiked to each adjacent timber. These are often installed in pre-nailed sections, with overlap joints between adjacent sections. Nailed-laminated decks may have a bituminous overlay, timber running planks, or a gravel wearing surface. Gravel may build up over time, increasing the dead load. The inspector should note the depth of the bituminous and gravel to determine if a new load rating is needed.

Glulam Timber Decks

Glulam decks are similar to nail-laminated decks, except the individual timbers are bonded together with a waterproof structural adhesive. The panels are typically around 4 ft. wide, and are installed transversely across the deck. Glulam timber decks are often used on temporary bridges (with a bituminous overlay). When used in new construction, they may have timber wearing planks.

Longitudinal Nail-Laminated Timber Slabs

Nail-laminated slabs have timbers that span longitudinally, and serve as the primary superstructure element. Timber slabs usually have a bituminous or gravel wearing surface. *Timber slabs typically have a transverse stiffener beam at the center of each span that distributes load and deflection across the width of the slab. Transverse stiffener beams should be rated using element #156 (Timber Floorbeam).*

Table 7.2. Condition state definitions for timber deck and slab elements.

Timber Deck & Slab Elements				
# 31: Timber Deck (Square ft (SF)) # 54: Timber Slab (SF)				
Actions and Defects	**Condition States**			
	1	**2**	**3**	**4**
	Good	**Fair**	**Poor**	**Severe**
Structural Review	Structural review is not required	AZAAZAAA	Structural review is not required **or** Structural review has determined that strength or serviceability has not been impacted	Condition warrants structural review **or** Structural review has determined that the defects impact strength or serviceability.
Repairs	No repairs are present	Existing repair in sound condition	Repairs are recommended **or** Existing repair is deteriorated.	Immediate repairs are required (full-depth failures present or imminent).
Decay/Section Loss, or Fire Damage	None	Affects less than 10% of the deck or slab thickness No crushing or sagging.	Affects 10% or more of the member but does not warrant structural review. Minor crushing or sagging.	The condition warrants a structural review. Significant crushing or sagging.
Shake, Check, or Split	Penetrating less than 5% of the member thickness	Penetrates 5% - 50% of the thickness of the member and not in a tension zone.	Penetrates more than 50% of the thickness of the member or more than 5% of the member thickness in a tension zone.	Penetrates through entire member or more than 25% of the member thickness in a tension zone.
Crack or Fracture (Timber, Glulam)	None	Crack or partial fracture that has been arrested	Crack or partial fracture that has not been arrested	Severe crack or fractured member
Delamination (Glulam)	None	Minor	Significant	Severe
Weathering or Abrasion (Timber, Glulam)	None or no measurable section loss	Section loss less than 10% of the member thickness	Section loss 10% or more of the member but does not warrant structural review. Minor crushing or sagging.	The condition warrants a structural review.
Connection or Misalignment	Primary deck or slab components are properly aligned and securely connected.	Some fasteners may be loose, but primary deck or slab components are properly aligned.	Some fasteners may be broken or missing. Primary deck or slab components may be loose or misaligned.	Primary deck or slab components may be severely misaligned or missing.

Assessment Considerations
The use of inspection equipment can provide additional information to the definitions provided by AASHTO and MnDOT. A pick hammer can be used to assess surface quality and possible decay. Feeler gages and awls may be used to assess the extent of cracks, checks, splits and delamination. A moisture meter can detect members or areas with high levels of moisture. It is important to assess the presence of decay using hammer picks, stress wave timers and resistance microdrills to determine the actual cross-section and location of both sound and deteriorated material. Chapter 5 provided detailed information about the use of stress wave timers for identifying areas of decay. **Table 5.1** should be consulted when assessing the collected data. Chapter 6 provides detailed information about interpreting resistance drill data from a variety of different resistance drill models. **Table 6.1** should be consulted when assessing the collected data. **Figure 7.3** shows examples of damage to timber deck and slab elements.

Elements rated CS 3 have the potential to reduce the load rating of the bridge and should be recommended for structural evaluation, particularly if the element is a primary load-carrying member.

Elements rated CS 4 will likely reduce the load capacity or serviceability of the bridge and structural evaluation should be required. Elements that are rated CS 4 and are primary load-carrying members often will lead to a load posting on the bridge unless repaired or replaced.

Figure 7.3. Deterioration of timber decks and slabs.

Timber Bridge Railing
This element describes bridge railing constructed from wood materials (AASHTO 2013, MnDOT 2014). **Table 7.3** provides specific information on timber railing components and recommended inspection techniques and equipment. **Table 7.4** provides specific information on the defect types and appropriate condition states.

Table 7.3. Timber bridge railing element, inspection and defect information.

Bridge Railing	
# 332: Timber Bridge Railing (Lineal ft (LF))	This element applies to all types and shapes of timber railing. This includes railings constructed entirely of timber, or railings in which the primary horizontal members are timber. Included in this element are posts, blocking, or curbs constructed of metal, concrete, timber, or any other material. Refer to the other railing elements for appropriate defect condition language to rate these sections.
Inspection Techniques and Equipment	1. Visual inspection 2. Hammer sounding with pick hammer 3. Awl and flat depth probes 4. Moisture meter of exposed wood 5. Stress wave timing inspection 6. Resistance microdrill
Timber Railing Vertical Posts Railing posts are usually comprised of solid timber members. The posts are usually fastened to the bridge using a combination of bolts or other fasteners. The typical design includes a block member and a vertical post. Most railing posts have been preservative treated.	

Timber Railing Horizontal railing may be comprised of solid sawn or glulam timbers. It is typically one or more sections of material spanning the full length of the bridge. Most railing members have been preservative treated.	
Timber Curb Horizontal curbing may be comprised of solid sawn or glulam timbers. It is typically one or more sections of material spanning the full length of the bridge. It typically includes a scupper opening to allow water to drain off the surface of the bridge deck. Most curb members have been preservative treated.	

Table 7.4. Condition state definitions for timber railing.

Bridge Railing				
# 332: Timber Bridge Railing (SF/ft²) - MnDOT Rail Type Codes #06, 26, 38, 50, 55, or 56.				
Actions and Defects	**Condition States**			
	1	**2**	**3**	**4**
	Good	**Fair**	**Poor**	**Severe**
Structural Review	Structural review is not required.	Structural review is not required.	A structural review has determined that the strength or serviceability has not been impacted.	Condition warrants structural review **or** Structural review has determined that the defects impact strength or serviceability.
Repairs	No repairs are present.	Existing repair in sound condition.	Repairs are recommended (structural review is not required) **or** Existing repair is deteriorated.	Immediate repairs are required (full-depth failures present or imminent).
Connection	Connection is in-place and functioning as intended.	Loose fasteners or pack rust without distortion, but the connection is in-place and functioning as intended.	Missing bolts, rivets, or fasteners; broken welds; or pack rust with distortion. Components may be misaligned.	The condition warrants a structural review to determine the effect on strength or serviceability of the bridge railing **or** A structural review has been completed and the defects impact strength or serviceability of the bridge railing.
Misalignment	All components are properly aligned.	All components are properly aligned.	Components may be misaligned.	
Decay/ Section Loss, Fire Damage, or Abrasion/ Wear	None.	Affects less than 10% of the member cross-section.	Affects 10% or more of the member cross-section.	
Check/Shake	Penetrating <5% of member thickness regardless of location.	Penetrates 5% - 50% of the member thickness; not in a tension zone.	Penetrates more than 50% of the member thickness more than 5% of the member thickness in a tension zone.	
Split, Crack or Delamination	None	Length less than the member depth or arrested with effective actions.	Length equal to or greater than the member. Crack that is not arrested.	
Impact Damage	Superficial damage	Impact damage that does not require repair	Impact damage that may require repair.	

Assessment Considerations
The use of inspection equipment can provide additional information to the definitions provided by AASHTO and MnDOT. Special attention should be focused on the steel connections, and looking for evidence of decay in timber adjacent to the connections. A pick hammer can be used to assess surface quality and possible decay. Feeler gages and awls may be used to assess the extent of cracks, checks, splits and delamination. A moisture meter can detect members or areas with high levels of moisture. It is important to assess the presence of decay using hammer picks, stress wave timers and resistance microdrills to determine the actual cross-section and location of both sound and deteriorated material. Chapter 5 provided detailed information about the use of stress wave timers for identifying areas of decay. **Table 5.1** should be consulted when assessing the collected data. Chapter 6 provides detailed information about interpreting resistance drill data from a variety of different resistance drill models. **Table 6.1** should be consulted when assessing the collected data. **Figure 7.4** shows examples of damage to timber railing elements.

Figure 7.4. Examples of deterioration of timber railing components.

Timber Bridge Superstructure
Superstructure elements transfer load from the decks into the substructure. This element describes timber girder or beams, timber stringers, timber trusses or arches, and timber floorbeams (AASHTO 2013, MnDOT 2014). **Table 7.5** provides specific information on timber superstructure types and recommended inspection techniques and equipment. **Table 7.6** provides specific information on the defect types and appropriate condition states.

Table 7.5. Timber superstructure elements, inspection and defect information.

Timber Superstructure Elements	
#54 Timber Slab (see Table 7.1) **# 111: Timber Girder or Beam (Lineal feet - LF)** **# 117: Timber Stringer (LF)** **# 135: Timber Truss (LF)** **# 146: Timber Arch (LF)** **# 156: Timber Floorbeam (LF)**	These elements apply to timber superstructure members of any type or shape - this includes sawn or glulam timber members. Connections on timber elements will typically include steel components (bolts, nuts, washers, connection plates).
Inspection Techniques and Equipment	1. Visual inspection 2. Hammer sounding with pick hammer 3. Awl and flat depth probes 4. Moisture meter of exposed wood 5. Stress wave timing inspection 6. Resistance microdrill
# 111: Timber Girder or Beam **# 117: Timber Stringer** A longitudinal beam typically comprised of solid sawn or glulam members that support the bridge deck. Solid sawn members are often preservative treated Douglas fir. Glulam members are comprised of face laminated structural lumber and are preservative treated.	

#135: Timber Truss
#146: Timber Arch
Timber trusses are jointed structures that have an open web configuration so that the frame is divided into a series of triangles with members primarily stressed in an axial orientation. Arches typically have a curved shape.

 # 156: Timber Floorbeam
Timber floorbeams are located in a transverse direction to the bridge and support the deck or other components of the deck system. In spike or dowel laminated deck systems, they are attached to the bottom of individual panels, providing connection and distribution of loading.

Table 7.6. Condition state definitions for timber superstructure.

Timber Superstructure Elements				
# 111: Timber Girder or Beam (LF) # 117: Timber Stringer (LF)			# 135: Timber Truss # 146 Timber Arch (LF) # 156: Timber Floorbeam (LF)	
Actions and Defects	**Condition States**			
	1	**2**	**3**	**4**
	Good	**Fair**	**Poor**	**Severe**
Structural Review	Structural review is not required.	Structural review is not required.	Structural review is not required **or** Structural review has determined that strength or serviceability has not been impacted.	Condition warrants structural review **or** Structural review has determined that the defects impact strength or serviceability.
Repairs	No repairs are present.	Existing repair in sound condition.	Repairs are recommended **or** Existing repair unsound.	Immediate repairs are required.
Connection (Steel)	Connection in-place and functioning as intended	Loose fasteners, but connection is in-place and functioning as intended	Missing bolts, rivets, or fasteners; broken welds; or pack rust with distortion	Connection has failed (or failure is eminent)
Misalignment	None	Slightly misaligned	Significantly misaligned	Severely misaligned
Decay/ Section Loss, Fire Damage	None.	Affects less than 10% of the member cross-section. No crushing or sagging.	Affects 10% or more of the member but does not warrant structural review. Minor crushing or sagging.	The condition warrants a structural review. Significant crushing or sagging.
Check/Shake or Split	Penetrating <5% of member thickness.	Penetrates 5% - 50% of the member thickness; not in a tension zone.	Penetrates more than 50% of the member thickness or > 5% of the member thickness in a tension zone.	Penetrates through entire member or more than 25% of the member thickness in a tension zone.
Crack or Fracture (Timber, Glulam)	None	Crack or partial fracture that has been arrested	Crack or partial fracture that has not been arrested	Severe crack or fractured member.
Delamination (Glulam)	None	Minor	Significant	Severe
Weathering or Abrasion	None or no measurable section loss.	Section loss less than 10% of the member thickness	Section loss 10% or more of the member thickness but does not warrant structural review.	The condition warrants a structural review.

Assessment Considerations
The use of inspection equipment can provide additional information to the definitions provided by AASHTO and MnDOT. Special attention should be focused on the steel connections, and looking for evidence of decay in timber adjacent to the connections. A pick hammer can be used to assess surface quality and possible decay. Feeler gages and awls may be used to assess the extent of cracks, checks, splits and delamination. A moisture meter can establish high levels of moisture. It is important to assess the presence of decay using hammer picks, stress wave timers and resistance microdrills to determine the actual cross-section and location of both sound and deteriorated material. Chapter 5 provided detailed information about the use of stress wave timers for identifying areas of decay. **Table 5.1** should be consulted when assessing the collected data. Chapter 6 provides detailed information about interpreting resistance drill data from a variety of different resistance drill models. **Table 6.1** should be consulted when assessing the collected data. **Figure 7.5** shows examples of damage to timber superstructure elements.

Elements rated CS 3 have the potential to reduce the load rating of the bridge and should be recommended for structural evaluation, particularly if the element is a primary load-carrying member.

Elements rated CS 4 will likely reduce the load capacity or serviceability of the bridge and structural evaluation should be required. Elements that are rated CS 4 and are primary load-carrying members often will lead to a load posting on the bridge unless repaired or replaced.

Decay/Section Loss

Checks and Horizontal Sheer Failures

Internal Decay/Section Loss

Decay/Section Loss

Figure 7.5. Examples of deterioration of timber superstructure elements.

Timber Bridge Substructure
Substructure elements transmit the load from the superstructure into the ground. These elements describe columns, piles, pile caps, pier/bent caps, pier walls, and abutments (AASHTO 2013, MnDOT 2014). **Table 7.7** provides specific information on timber substructure types and recommended inspection techniques and equipment. **Table 7.8** provides specific information on the defect types and appropriate condition states.

Table 7.7. Timber substructure elements, inspection and defect information.

Timber Substructure Elements	
# 206 Timber Column **# 208 Timber Trestle** **# 216 Abutment** **# 228 Pile** **# 235 Pier Cap**	These elements apply to timber substructure members of any type or shape. This includes sawn or glulam timber members. Connections on timber elements will typically include steel components. If impact damage is present, element #890 (Impact Damage) must be added and rated. If settlement is evident, element #891 (Settlement) must be added and rated. If scour is present, element #892 (Scour) must be added and rated.
Inspection Techniques and Equipment	1. Visual inspection 2. Hammer sounding with pick hammer 3. Awl and flat depth probes 4. Moisture meter of exposed wood 5. Stress wave timing inspection 6. Resistance microdrill
# 206: Timber Column This is a general term that applies to a member resisting compressive stress and having a considerable length in compression as compared to its transverse dimensions. These members are typically solid sawn and preservative treated. A column differs from a piling as it is supported by a footing.	

# 208: Timber Trestle A bridge structure with framed timber supports that consist of beam or truss spans supported by bents, which are typically timber. These members are preservative treated.	
# 216: Timber Abutment Timber abutments include the sheet material retaining the embankment, integral wing walls, and abutment extensions. These are typically constructed of solid sawn, preservative treated members. Pilings and caps would be rated separately.	
# 228: Timber Pile These elements are typically pole-like members that are driven into the earth through soil material to provide a secure foundation for bridges built on soft, wet or submerged sites. Timber piles are often southern yellow pine members that are preservative treated. Areas to be inspected may be above and/or below the water line.	

# 235: Timber Pier Cap A sawn or glulam member placed horizontally on an abutment or pier to distribute and transfer load to piles or columns. Solid sawn members are typically preservative treated Douglas fir or southern yellow pine.	

Table 7.8. Condition state definitions for timber substructure.

Timber Substructure Elements				
# 206 Timber Column # 208 Timber Trestle		# 216 Abutment # 228 Pile # 235 Pier Cap		
Actions and Defects	**Condition States**			
	1	**2**	**3**	**4**
	Good	**Fair**	**Poor**	**Severe**
Structural Review	Structural review is not required.	Structural review is not required.	Structural review is not required **or** Structural review has determined that strength or serviceability has not been impacted.	Condition warrants structural review **or** Structural review has determined that the defects impact strength or serviceability.
Repairs	No repairs are present.	Existing repair in sound condition.	Repairs are recommended **or** Existing repair unsound.	Immediate repairs are required.
Connection (Steel)	Connection in-place and functioning as intended.	Loose fasteners, connection is in-place and functioning as intended.	Missing fasteners; broken welds; or pack rust with distortion. Connection is distressed.	Connection has failed (or failure is eminent).
Misalignment	None	Slightly misaligned.	Significantly misaligned.	Severely misaligned.
Decay/ Section Loss, Fire Damage	None.	Affects <10% of the member cross-section. No crushing or sagging.	Affects 40%* or more of the member cross-section, but does not warrant structural review. Minor crushing or sagging.	The condition warrants a structural review. Significant crushing or sagging.
Check/Shake or Split	Penetrates less than 5% of member thickness.	Penetrates 5% - 50% of the member thickness; not in a tension zone.	Penetrates more than 50% of the member thickness or >5% of the member thickness in a tension zone.	Penetrates through entire member or more than 25% of the member thickness in a tension zone.
Crack or Fracture (Timber)	None.	Crack or partial fracture that has been arrested.	Crack or partial fracture that has not been arrested.	Severe crack or fractured member.
Settlement	None.	Within tolerable limits or arrested (no distress)	Exceeds tolerable limits.	Stability of element has been reduced.
Scour	None	Within tolerable limits or counter-measures installed	Exceeds tolerable limits but less than critical scour limits	Exceeds the critical scour limits

*Specified by MnDOT

Assessment Considerations
The use of inspection equipment can provide additional information to the definitions provided by AASHTO and MnDOT. Special attention should be focused on the steel connections, and looking for evidence of decay in timber adjacent to the connections. A pick hammer can be used to assess surface quality and possible decay. Feeler gages and awls may be used to assess the extent of cracks, checks, splits and delamination. A moisture meter can establish high levels of moisture. It is important to assess the presence of decay using hammer picks, stress wave timers and resistance microdrills to determine the actual cross-section and location of both sound and deteriorated material. Chapter 5 provided detailed information about the use of stress wave timers for identifying areas of decay. **Table 5.1** should be consulted when assessing the collected data. Chapter 6 provides detailed information about interpreting resistance drill data from a variety of different resistance drill models. **Table 6.1** should be consulted when assessing the collected data. **Figure 7.6 and 7.7** shows examples of damage to timber substructure elements.

Elements rated CS 3 have the potential to reduce the load rating of the bridge and should be recommended for structural evaluation.

Elements rated CS 4 will likely reduce the load capacity or serviceability of the bridge and structural evaluation should be required. Elements that are rated CS 4 and are primary load-carrying members often will lead to a load posting on the bridge unless repaired or replaced.

Decay or deterioration in timber substructures can potentially control the load rating of the bridge, so elements rated CS 3 are strongly recommended for a revised load rating analysis. Because of the variability of timber substructures, such as cap dimensions, pile diameter and pile spacing, decay or deterioration can have a large impact on the capacity of the bridge depending on whether it occurs in an exterior or interior pile, the pile cap, or any combination therein.

Figure 7.6. Examples of deterioration of timber substructure elements.

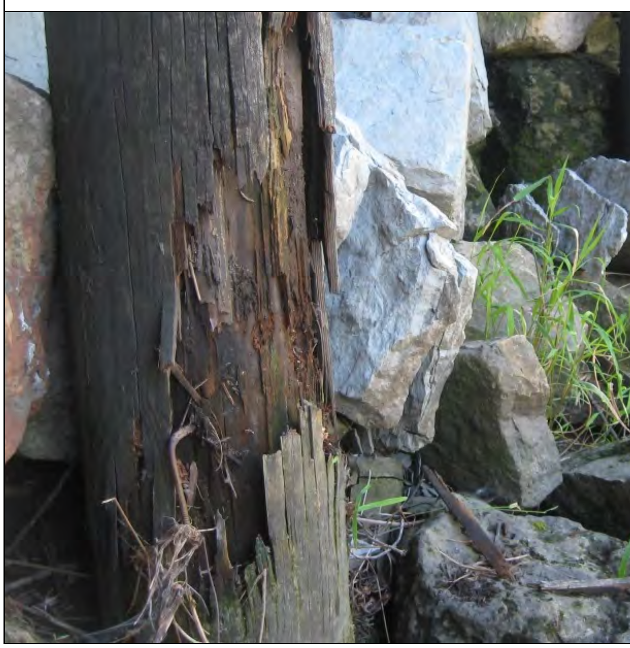
Severe Checks and Splits	Severe Decay and Crushing
	
Decay/Section Loss	**Decay/Section Loss**
	

Figure 7.7. Examples of deterioration of timber substructure elements.

Chapter 8 Integration of Results into SIMS

Overview

The National Bridge Inspection Standards (NBIS) requires bridge inventory and inspection data to be maintained for all structures over 20 feet face to face of abutments on roads maintained by public agencies that are open to the public. The data is collected to insure public safety and to provide information that helps to determine federal funding for replacement and rehabilitation of bridges. The MnDOT database for this information is called the Structural Information Management System (SIMS). It is an online application used for entering, submitting and managing all bridge inspection information.

MnDOT utilizes SIMS Collector as an easy to use software package designed to assist bridge inspectors with completing and submitting inspection reports. Inspectors are able to generate complete, standard reports that are concise and readily available on command. With countless tools and enhancements available through the software, such as multiple picture uploads, the inspection reports will be more accurate, thorough, reliable, and readily available. This software allows inspectors to start and even complete inspection reports while in the field using a laptop/tablet computer or on the other hand, use the application at their desk to review, revise, or submit the report for approval. Overall, the inspection process is streamlined, more efficient and very effective for all personnel responsible for inspecting and managing bridges (MnDOT 2014). Detailed information on using SIMS Collector, Manager and Laptop versions is available at MnDOT's Bridges and Structures website portal located at: http://www.dot.state.mn.us/bridge/bridgereports/.

Integration of Timber Bridge Inspection Results

Improved inspection techniques are available for assessing the quality and condition state for timber bridge elements as outlined in this manual. However, it is important for inspectors to capture this information for further review and assessment and as a means to monitor changes over time. SIMS can be used to collect and record this information. Specific recommendations for integrating this manual into SIMS includes:

1. Update key structure information on bridge materials and types
2. Provide detail on inspection techniques and results into element notes
3. Upload additional pictures and field data forms
4. Utilize updated reports in future inspections

Update Key Structure Information on Bridge Materials and Types

There is a lack of clarity in many of the inspection reports as to the style and type of bridge materials. Historical database information should be reviewed on site and updated to include specific type of bridge decking material (timber plank, nail-laminated deck, glulam decking) and the type of beam (glulam or solid sawn timber) or slab bridge style present. Updates should also be made to reflect any element changes that are present.

Provide Detail on Inspection Techniques and Results into Element Notes
Audit reviews of timber bridge inspections often report a lack of detailed information recorded in the notes section for each element. When entering the data into the report, the descriptions should be as detailed as possible. It is important that future review of the inspection report will result in the ability to fully understand what has been accomplished during the inspection and the results noted. This should include information on the inspection technique used, the results obtained and interpretation of the results. The goal is to explain what inspection tools/methods were used, findings, locations of findings, and the use of additional pictures to support the descriptions.

The following example provides two different descriptions for bridge element bridge element # 55, timber slab with bituminous overlay (Note: AASHTO 2013 changes this to element # 54.). The improved note provides significantly more detail than the original note.

Timber Slab with Bituminous Overlay

<u>Original Note</u>
[2013] Timber is in good condition but overlay is cracking and potholes are starting.

<u>Improved Note</u>
[2013] Significant deterioration evidenced as cracking and potholing in bituminous wear layer in transverse direction at both bridge abutments and at the piers. There are also longitudinal cracking present, most likely at joints for deck panels. Water infiltration is occurring at these locations, as evidenced by visual staining of the underside and water dripping though the deck. Hammer sounding and pick inspection did not identify any decay present. One area that sounded affected was drilled with IML resistance drill. No decay noted using drill in these locations. Water infiltration through deck is also causing high moisture and cracking in pier 1 and pier 2 caps. This moisture is leading to severe corrosion of CIP bearing plates.

Upload Additional Pictures and Field Data Forms
Inspectors are encouraged to take additional pictures during the inspection process and upload them for each element. The following pictures are recommended:
beginning and end of bridge from roadway, upstream and downstream profiles, wear layer, railings, superstructure and substructure. Specific attention and photographs should be taken of any deterioration noted for any timber element or any modification or repair that has been completed. It is recommended that electronic files be established for each bridge and that any pictures uploaded into SIMS have detailed descriptions added for future reference. These pictures can be printed in the report or accessed by the bridge manager during final review, offering addition information and visual evidence of the bridge elements and condition.

New field forms have been developed and are located in Appendix C. These forms have been created for use with stress wave timers and resistance microdrills. The forms allow the inspector to note element or bridge dimensions, inspection locations, data from a stress wave timer, file information for resistance drilling results, and space for detailed field notes to be taken by the inspection team. These forms can be further modified by the bridge owner to reflect additional needs or information. These forms can be uploaded as pictures or scanned and uploaded as files. This information can then be easily accessed and used by the bridge manager during final review, offering additional information and visual evidence of the bridge elements and condition.

Utilize Updated Reports in Future Inspections
As noted, pictures and data forms that are generated during bridge inspections can be uploaded into SIMS and attached to each element. Further, these images and file can be printed in the future and brought to the bridge inspection for review. This important information will allow the inspector to clearly identify where previous testing was completed and the inspection results. The information can also be further accessed during office review and processing of inspection results.

Sample Bridge Inspection Report

A sample bridge inspection report was created to provide a case study example of integrating the procedures and methods described in this manual into SIMS. MnDOT provided test site access to the lead author. The following sample report was created using the principles outlined to improve the description of the bridge members, to provide additional detail in the notes section, and to use additional photos and data forms during the inspection. Bridge 69529 (St. Louis County, MN) was selected as a case study. This bridge was constructed in 1981 and is considered a timber slab span, with the panels manufactured by Wheeler Consolidated. The bridge is constructed from Douglas fir lumber that had been creosote treated. Southern yellow pine timber pilings were located on each abutment and CIP piling was used for the piers. A UMD project inspection team completed the inspection during 2013. In the report, notes designated with [2013] were created by the UMD team. The inspection consisted of a visual inspection with a hammer pick. Nondestructive timber inspection equipment used included a moisture meter, a Fakopp microsecond timer, and an IML F300 resistance drill. Digital pictures were taken of the bridge and detailed descriptions were used as captions. Inspection forms were used to collect the data from the stress wave timer and resistance microdrill. These forms were scanned, converted into PDF format and uploaded to SIMS.

The notes in the report identify that the bituminous wearing layer was deteriorated with transverse and longitudinal cracking and potholes. This damage allowed water to penetrate through the wear layer into and through the timber slab. Further, deck drainage resulted in a lot of water being drained onto pier caps that were outside of the bridge drip line. This resulted in high moisture content and severe cracking in the cap member. Stress wave timing and resistance drilling did not indicate the presence of decay, but the required moisture conditions are present that could result in future decay and deterioration in both the slab and the cap members.

2013 ROUTINE
BRIDGE INSPECTION REPORT

BRIDGE # 69529
CSAH 52 over DITCH

DISTRICT: District 1 **COUNTY:** St. Louis **CITY/TOWNSHIP:** KELSEY

Date(s) of Inspection: 11/18/2013
Equipment Used:

Owner: County Highway Agency

Inspected By: Brashaw, Brian

Report Written By: Brian Brashaw
Report Reviewed By:
Final Report Date:

MnDOT Bridge Office
3485 Hadley Avenue North
Oakdale, MN 55128

MnDOT Structure Inventory Report

Bridge ID: 69529 CSAH 52 over DITCH Date: 11/19/2013

GENERAL

Agency Br. No. 221
District District 1
Maint. Area Crew
County 069 - St. Louis
City
Township 69037 - KELSEY
Desc. Loc. 0.2 MI W OF JCT CSAH 7
Sect., Twp., Range 10 - 054N - 18W
Latitude Deg 47 Min 10 Sec 6.3
Longitude Deg 92 Min 36 Sec 15.7
Custodian 02 - County Highway Agency
Owner 02 - County Highway Agency
BMU Agreement
Year Built 1981
MN Year Reconstructed
FHWA Year Reconstructed
MN Temporary Status
Bridge Plan Location 3 - COUNTY
Date Opened to Traffic
On-Off System 0 - OFF
Legislative District 05B

STRUCTURE

Service On 1 - Highway
Service Under 5 - Waterway
Main Span Type
7 - Timber 09 - Slab Span
Main Span Detail
Appr. Span Type

Appr. Span Detail
Skew 20 R
Culvert Type
Barrel Length ft.
Cantilever ID

NUMBER OF SPANS

MAIN: 3 APPR: 0 TOTAL: 3
Main Span Length 23.0 ft.
Structure Length 58.0 ft.
Deck Width (Out-to-Out) 34.0 ft.
Deck Material 8 - Wood or Timber
Wear Surf Type 6 - Bituminous
Wear Surf Install Year
Wear Course/Fill Depth 0.25 ft.
Deck Membrane 0 - None
Deck Rebars N - Not Applicable (no deck)
Deck Rebars Install Year
Structure Area (Out-to-Out) 1972 sq. ft.
Roadway Area (Curb-to-Curb) 1851 sq. ft.
Sidewalk Width Lt 0.00 ft. Rt 0.00 ft.
Curb Height Lt 1.00 ft. Rt 1.00 ft.
Rail Type Lt 06 Rt 06

ROADWAY

Bridge Match ID (TIS) 0
Roadway O/U Key Route On Structure
Route Sys 04 - CSAH Number 52
Roadway Name or Description
CSAH 52
Level of Service 1 - MAINLINE
Roadway Type 2 - 2-way traffic
Control Section (TH Only)
Reference Point 009+00.770
Detour Length 7.0 mi
Lanes On 2 Under 0
ADT 95 Year 2008
HCADT 0 ADTT 0 %
Functional Class 08 - Rural - Minor Collector

RDWY DIMENSIONS

	NB-EB		SB-WB	
If Divided				
Roadway Width	32.00	ft.		ft.
Vertical Clearance		ft.		ft.
Max. Vert. Clear.		ft.		ft.
Horizontal Clear.		ft.		ft.
Lateral Clearance		ft.		ft.

Appr. Surface Width 32.0 ft.
Bridge Roadway Width 32.0 ft.
Median Width On Bridge ft.

MISC. BRIDGE DATA

Structure Flared 0 - No flare
Parallel Structure N - No parallel structure
Field Conn. ID
Abutment Foundation 2 - TIMBER
(Material/Type) 4 - PILE BENT
Pier Foundation 8 - CIP
(Material/Type) 4 - PILE BENT
Historic Status 5 - Not eligible

PAINT

Year Painted
Unsound Paint %
Painted Area sq. ft.
Primer Type
Finish Type

BRIDGE SIGNS

Posted Load 0 - Not Required
Traffic 0 - Not Required
Horizontal 1 - Object Markers
Vertical N - Not Applicable

INSPECTION

Userkey 109
Unofficial Structurally Deficient N
Unofficial Functionally Obsolete N
Unofficial Sufficiency Rating 100.0
Routine Inspection Date
Routine Inspection Frequency 24
Inspector Name MISC
Status A - Open

NBI CONDITION RATINGS

Deck 6 - Satisfactory Condition
Unsound Deck %
Superstructure 8 - Very Good Condition
Substructure 7 - Good Condition
Channel 8 - Banks are protected
Culvert N - Not Applicable

NBI APPRAISAL RATINGS

Structure Evaluation 7
Deck Geometry 8
Underclearances N
Water Adequacy 8 - Bridge Above Approache
Approach Alignment 8 - Equal to present desirabl

SAFETY FEATURES

Bridge Railing 0 - SUBSTANDARD
GR Transition 1 - MEETS STANDARDS
Appr. Guardrail 1 - MEETS STANDARDS
GR Termini 1 - MEETS STANDARDS

IN DEPTH INSP.

	Y/N	Freq	Date
Frac. Critical			
Underwater			
Pinned Asbly.			
Spec. Feat.			

WATERWAY

Drainage Area (sq. mi.) 48.0
Waterway Opening 204 sq. ft.
Navigation Control 0 - No nav. control on waterw
Pier Protection
Nav. Clr. (ft.) Vert. ft. Horiz. ft.
Nav. Vert. Lift Bridge Clear. (ft.)
MN Scour Code I - LOW RISK Year 1995

CAPACITY RATINGS

Design Load 5 - HS 20
Operating Rating 2 - AS HS 30.2
Inventory Rating 2 - AS HS 21.3
Posting VEH: SEMI: DBL:
Rating Date 12/1/1982
MnDOT Permit Codes
A: N - N/A
B: N - N/A
C: N - N/A

11/19/2013

Inspector: MISC

BRIDGE 69529 CSAH 52 OVER DITCH — ROUTINE INSP. DATE: 11/18/2013

County: St. Louis
Location: 0.2 MI W OF JCT CSAH 7
Length: 58.0 ft.

City:
Route: 04 - CSAH 52 Ref. Pt.: 009+00.770
Deck Width: 34.0 ft.

Township: 69037 - KELSEY
Control Section:
Rdwy. Area/ Pct. Unsnd: 1851 sq. ft. / %

Section: 10 Township: 054N Range: 18W Maint. Area:
Paint Area/ Pct. Unsnd: sq. ft. / %

Span Type: 7 - Wood or Timber 01 - Slab
Local Agency Bridge Nbr.: 221
Culvert: N/A

List:
Postings:

NBI Deck: 6 Super: 8 Sub: 7 Chan: 8 Culv: N

Open, Posted, Closed: A - Open

MN Scour Code: I - LOW RISK

Appraisal Ratings - Approach: 8 Waterway: 8

Required Bridge Signs - Load Posting: 0 - Not Required Traffic: 0 - Not Required

Horizntal: 1 - Object Markers Vertical: N - Not Applicable

Unofficial Structurally Deficient N

Unofficial Functionally Obsolete N

Unofficial Sufficiency Rating 100.0

Structure Unit:

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
055	Timber Slab with Bituminous (AC) Overlay	2	Routine	11/18/2013	1970 SF	0	1970	0	0	N/A
			Other	07/11/2012	1970 SF	0	1970	0	0	N/A
			Routine	04/21/2011	1970 SF	0	1970	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] Significant deterioration evidenced as cracking and potholing in bituminous wear layer in transverse direction at both bridge abutments and at the piers. There are also longitudinal cracking present, most likely at joints for deck panels. Water infiltration is occurring at these locations, as evidenced by visual staining of the underside and water dripping through the deck. Hammer sounding and pick inspection did not identify any decay present. One area that sounded affected was drilled with Resistance drill. No decay noted using drill in these locations. Water infiltration through deck is also causing high moisture and cracking in pier 1 and pier 2 caps. This moisture is then leading to severe corrosion of CIP plates.

CRACKS IN BITUMINOUS.
2012-Longitudinal and transverse cracks in bituminous w/ some minor potholes.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
156	Timber Floorbeam	2	Routine	11/18/2013	112 LF	112	0	0	0	N/A
			Other	07/11/2012	112 LF	112	0	0	0	N/A
			Routine	04/21/2011	112 LF	112	0	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] Element removed and replaced with transverse stiffener beam #415
2012-No deterioration noted.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
206	Timber Column	2	Routine	11/18/2013						
			Other	07/11/2012						
			Routine	04/21/2011	14 EA	9	5	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes:

Structure Unit:

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
216	Timber Abutment	2	Routine	11/18/2013	75 LF	65	10	0	0	N/A
			Other	07/11/2012	75 LF	65	10	0	0	N/A
			Routine	04/21/2011	75 LF	65	10	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] There was some indication of high moisture content on the EOB (east) between pilings 8 and 9. It had a very green tint but moisture content assessments were in the normal range of <16% based on a moisture meter at 1 and 2 inch depths. Hammer sounding indicated abutments in good condition.
2012-No additional deterioration noted.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
228	Timber Piling	2	Routine	11/18/2013	10 EA	10	0	0	0	N/A
			Other	07/11/2012						
			Routine	04/21/2011						

☐ Requires Monitoring ☐ Monitored

Notes: [2013] For abutments, Fakopp SWT was used to collect times at 6" above ground line and 6" below pile cap. See attached sketch and file for results. Pile number 11 had SWT of 450 microseconds (12" dia.). A resist drill test was completed (drill #7) showed no deterioration. All other piling times were in normal range of 180-250 microseconds/ft of transverse time.
2012-No deterioration noted.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
235	Timber Pier Cap	2	Routine	11/18/2013	151 LF	151	0	0	0	N/A
			Other	07/11/2012	151 LF	151	0	0	0	N/A
			Routine	04/21/2011	151 LF	151	0	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] Timber pier cap showed significant visual vertical cracking caused by water infiltration at cap ends and excess weathering. Fakopp SWT were >500 microseconds for pier 1 along almost complete length. See attached sketch file. Resistance drilling completed (files 3-6) showed no evidence of decay but the presence of vertical crack causing high SWT. Significant moisture problems in in pier 1 showed MC >25%. Visual water dripping through deck and into the exposed end from the deck. Pier 2 showed normal SWT (180-250 microseconds/ft transverse). Some evidence of vertical through crack on south end pier 2.

2012-Minor checking in both pier caps.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
332	Timber Bridge Railing	2	Routine	11/18/2013	115 LF	115	0	0	N/A	N/A
			Other	07/11/2012	115 LF	115	0	0	N/A	N/A
			Routine	04/21/2011	115 LF	115	0	0	N/A	N/A

☐ Requires Monitoring ☐ Monitored

Notes: Laminated Timber Rail w/ Wood posts.
[2013] - Hammer sounding and SWT timing were within normal conditions and no deterioration was noted.
2012-No deterioration noted.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
~~357~~	~~Pack Rust Smart Flag~~	~~2~~	~~Routine~~	~~11/18/2013~~	~~1 EA~~	~~1~~	~~0~~	~~0~~	~~0~~	~~N/A~~
			Other	07/11/2012	1 EA	1	0	0	0	N/A
			Routine	04/21/2011	1 EA	1	0	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes: 2012-Pack rust developing between the CIP piling and the plate the piling are attached to on the pier caps.

Structure Unit:

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
382	Cast-In-Place (CIP) Piling	2	Routine	11/18/2013	12 EA	0	12	0	0	N/A
			Other	07/11/2012	12 EA	0	12	0	0	N/A
			Routine	04/21/2011	12 EA	0	12	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] Minor corrosion near the pier cap, but significant corrosion and deterioration to the bearing plates on top of CIP in contact with high moisture content pier 1. Pier 2 showed much less corrosion of CIP cap plates.
SOME PILE CAPS STARTING TO RUST.
2012-Minor corrosion near the pier cap.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
386	Timber Wingwall	2	Routine	11/18/2013	4 EA	4	0	0	0	N/A
			Other	07/11/2012	4 EA	4	0	0	0	N/A
			Routine	04/21/2011	4 EA	4	0	0	0	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] NW cap showed severe decay in pile. NE cap 50% decayed as it was almost fully covered by vegetation. SW Wing pile showed decay.

NE WING CAP DAMAGED.
SE WING CAP BURIED.
SW WING PILE ROTTED.
2012-Covered with brush.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
407	Bituminous Approach Roadway	2	Routine	11/18/2013	2 EA	0	0	1	1	N/A
			Other	07/11/2012	2 EA	0	0	1	1	N/A
			Routine	04/21/2011	2 EA	0	0	1	1	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] Settlement behind each abutment and visual evidence of longitduinal and transverse ccracking present causing potential water infiltration.

Settlement behind Abuts.
2012-Longitudinal and horizontal cracking in both approach roadways.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
415	Timber Transverse Stiffener Beam (Timber Slabs)	2	Routine	11/18/2013	112 LF	112	0	0	0	N/A
			Other	07/11/2012						
			Routine	04/21/2011						

☐ Requires Monitoring ☐ Monitored

Notes: [2013] Stiffener beams inspected using hammer sounding and stress wave timer. No damage noted and SWT within normal requirements of 180-250 microseconds/ft of transverse time.

Structure Unit:

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
964	Critical Finding Smart Flag	2	Routine	11/18/2013	1 EA	1	0	N/A	N/A	N/A
			Other	07/11/2012	1 EA	1	0	N/A	N/A	N/A
			Routine	04/21/2011	1 EA	1	0	N/A	N/A	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] No critical findings during this inspection.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
981	Signing	2	Routine	11/18/2013	1 EA	1	0	0	0	0
			Other	07/11/2012	1 EA	1	0	0	0	0
			Routine	04/21/2011	1 EA	1	0	0	0	0

☐ Requires Monitoring ☐ Monitored

Notes: DELINEATORS.
2012-All signs in place.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
982	Approach Guardrail	2	Routine	11/18/2013	1 EA	1	0	0	N/A	N/A
			Other	07/11/2012	1 EA	1	0	0	N/A	N/A
			Routine	04/21/2011	1 EA	1	0	0	N/A	N/A

☐ Requires Monitoring ☐ Monitored

Notes: Flex Beam w/ 2-ET 2000 and 2-wraps south.
2012-No deterioration noted.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
985	Slopes & Slope Protection	2	Routine	11/18/2013	1 EA	0	1	0	N/A	N/A
			Other	07/11/2012	1 EA	0	1	0	N/A	N/A
			Routine	04/21/2011	1 EA	0	1	0	N/A	N/A

☐ Requires Monitoring ☐ Monitored

Notes: SOME EROSION BOTH SIDES UNDER BRIDGE, MOSTLY WEST.
2012-No additional deterioration noted.

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
986	Curb & Sidewalk	2	Routine	11/18/2013	1 EA	1	0	0	N/A	N/A
			Other	07/11/2012	1 EA	1	0	0	N/A	N/A
			Routine	04/21/2011	1 EA	1	0	0	N/A	N/A

☐ Requires Monitoring ☐ Monitored

Notes: [2013] Hammer sounding and stress wave timing showed excellent condition for most of the timber curb and railing. Significant sand and gravel buildup and drainage areas are also located directly above pier caps. Poor design as it allows significant water to drain from bridge onto pier cap.
2012-No deterioration noted.

General Notes: [2013] The bridge is in satisfactory condition. There is an accumulation of sand/gravel along curbs along with vegetation growing on the wing walls. The is cracking through the bituminous, especially over the area with pilings below. The railing is 6.5" by 10.5", the curb is timber glulam that is 5.5" by 11.5", and the rail supports are 8.5" by 11" timber. The guardrail is steel and the deck has 3" by 10" boards. The stress wave timer and resistance drill confirmed that Pile cap B has splits along its length due to water dripping onto it through cracks in bituminous, although no decay was noted. The pilings were only timber at the abutments, and stress wave timing along with moisture contents showed no areas of possible decay. There is also significant rust at the tops of the CIP pilings at the pile cap plates. Abutment walls are in good condition, one area between pilings 8 and 9 has a green tint and has vegetation growing at the base but moisture content readings there are normal. The wing walls, most notably the upstream EOB one, have vegetation growth and deterioration. The bridge has 3 spans, 2 pile

Structure Unit:

ELEM NBR	ELEMENT NAME	ENV	REPORT TYPE	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5

caps at the abutments and 2 over the steel pilings, and in between each piling set is a timber spreader beam.

SLC District 5
Inspected by: [2013] BB, BV, etc....
[2013] Enter any gen. inspection notes you want to say.

7/11/2012 - Post 2012 Flood Inspection by JRM and RRC from TKDA.

58. Deck NBI: Significant deterioration to bituminous wearing layer causing water infiltration

36A. Brdg Railings NBI:

36B. Transitions NBI:

36C. Appr Guardrail NBI:

36D. Appr Guardrail Terminal NBI:

59. Superstructure NBI: Structural timber slab in good condition. Water infiltration noted along bituminous cracking and potholing.

60. Substructure NBI: Some deterioration in pier 1 and pier 2 caps. Pilings in good condition.

61. Channel NBI:

62. Culvert NBI:

71. Waterway Adeq NBI:

72. Appr Roadway Alignment NBI:

Inventory Notes:

Inspector's Signature

Reviewer's Signature

Pictures

Photo 1 - S. profile

Photo 2 - Deck - Pot hole above Pier 2 with longitudinal cracking

Photo 3 - Bituminous east end before abutment

Photo 4 - N. deck-scupper 3" sand on deck

Pictures

Photo 5 - SW corner of bridge showing vegetation and gravel/sand near curb. Deterioration noted.

Photo 6 - Pier 1 - North End - Through split extending 80% of full length of cap. SWT over 500 but R drill showed only crack with no decay

Pictures

Photo 7 - Pier 1 - South End - Through split extending 36"

Photo 8 - Span 1 - Moisture pen. through deck.

Photo 9 - Pier 2 - South end - Through split continuing 24 inches into cap.

Photo 10 - Pier 2 North end - Through split extending 14" into cap.

Pictures

Photo 11 - W. Abut. Pile 3

Photo 12 - High moisture abutment wall between piles 8 and 9. Moisture content over >25% but no decay present.

Photo 13 - Pier 1 -CIP cap plate rusting with section loss.

Photo 14 - E abut - Pile 11 - Sound condition

Photo 15 - Wing wall - NE

Photo 16 - Wing wall - NE

Pictures

Photo 17 - Wing wall with significant vegetation

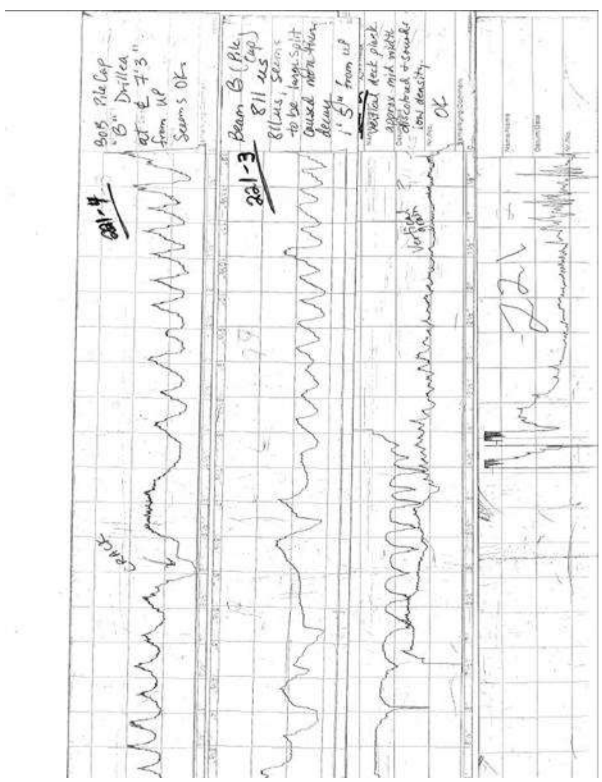


Photo 18 - Resistance drill data

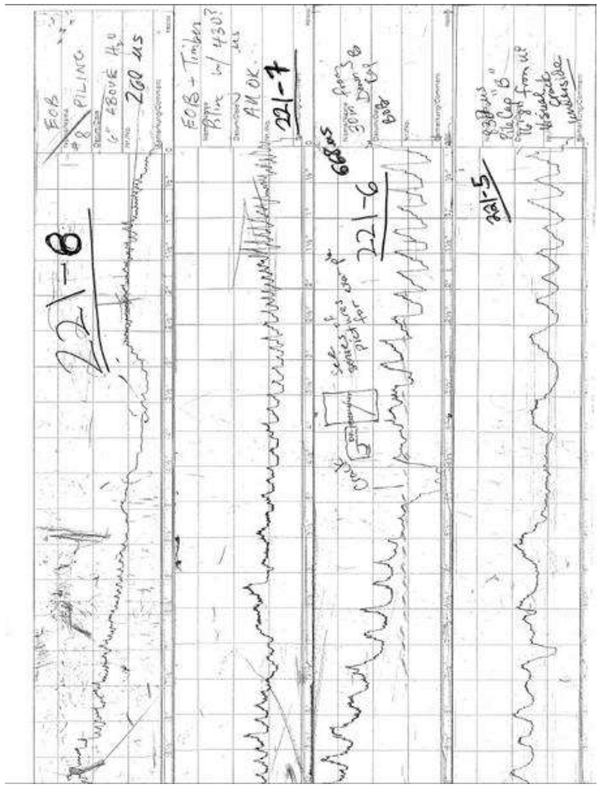


Photo 19 - Resistance drill data

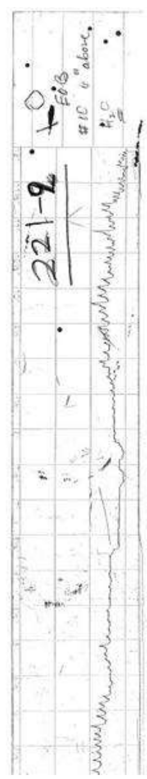


Photo 20 - Resistance drill data


1. Picture 115.jpg


2. Picture 061.jpg


3. Picture 062.jpg


4. Picture 014.jpg


5. Picture 016.jpg


6. Picture 035.jpg


7. Picture 076.jpg


8. Picture 033.jpg


9. Picture 036.jpg


10. Picture 046.jpg


11. Picture 024.jpg


12. Picture 095.jpg


13. Picture 047.jpg


14. Picture 105.jpg


15. Picture 066.jpg


16. Picture 070.jpg


17. Picture 068.jpg

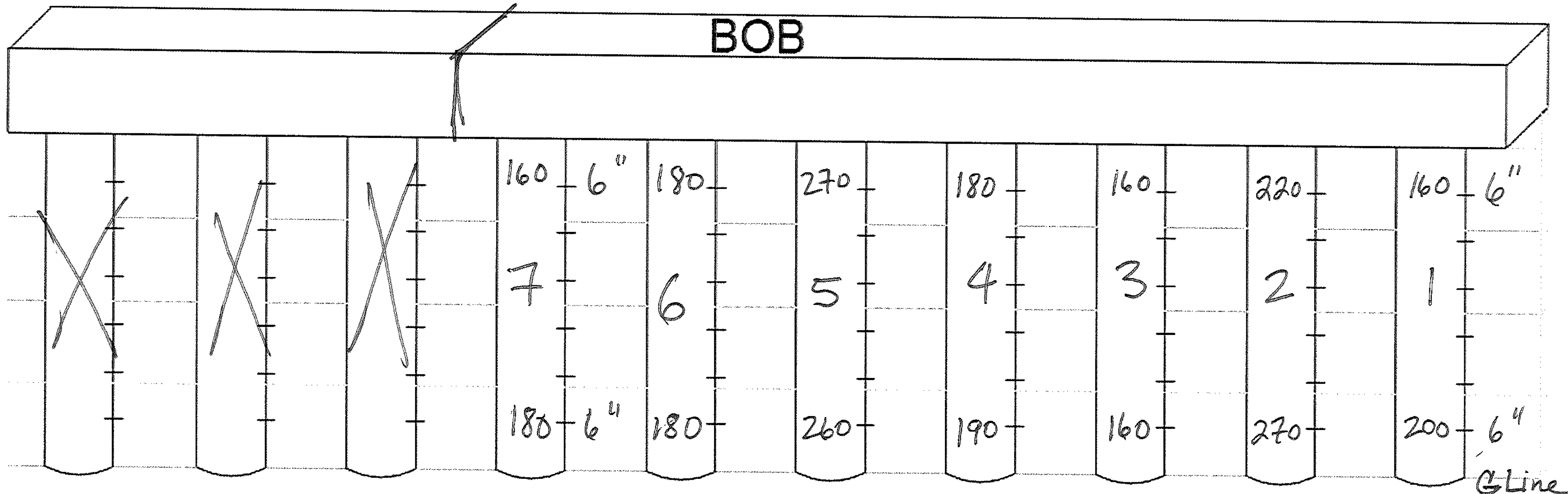

18. 5.JPG


19. 6.JPG

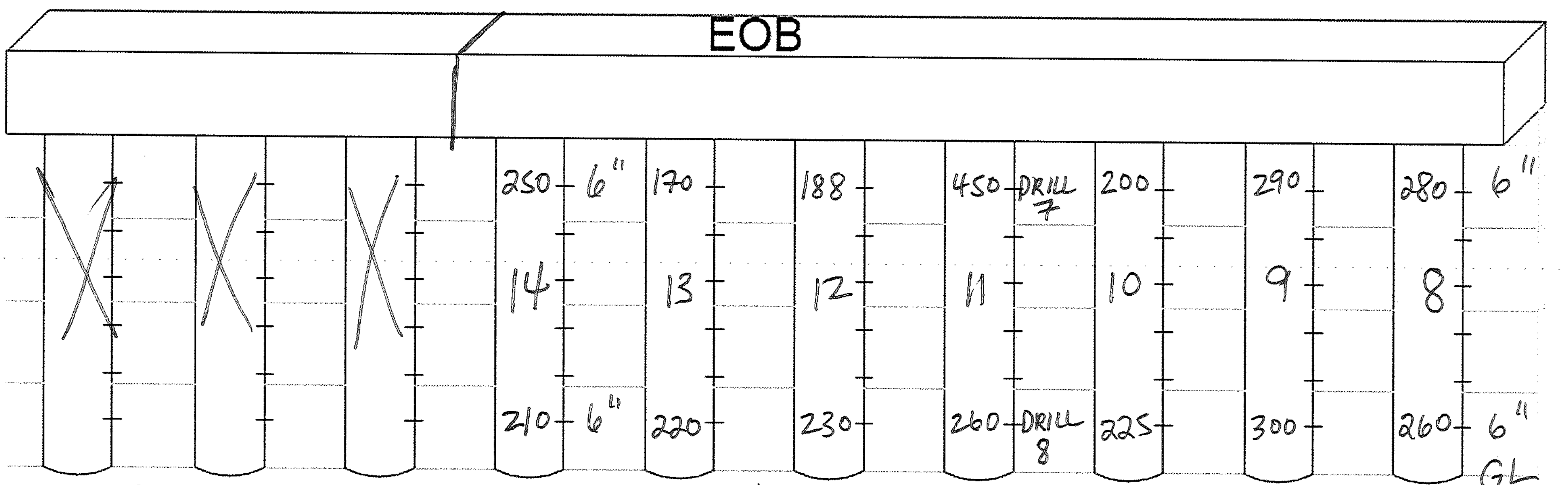

20. 7.JPG

← FLOW

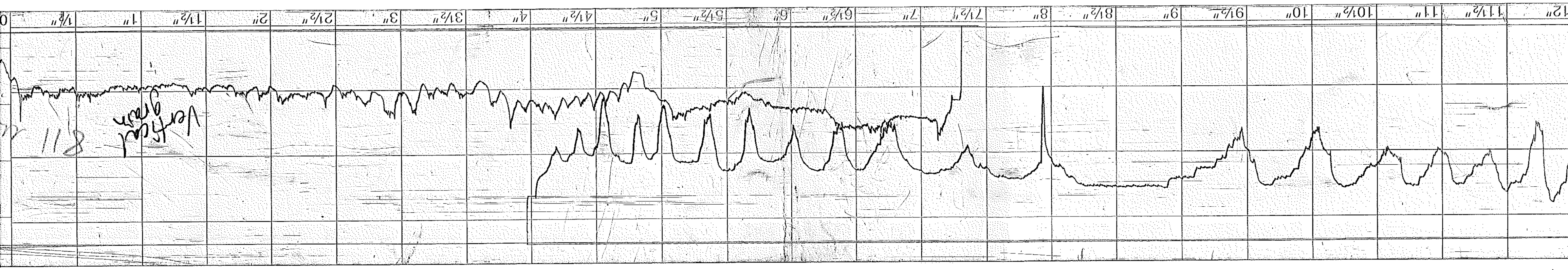
Date: 6/18/13 Inspector: BKB Bridge: 221



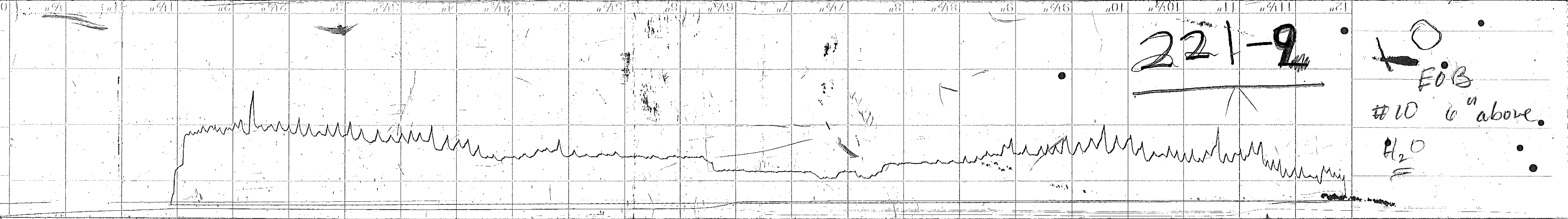
Notes: Timber pilings. Minimal surface checking. Stress wave timer shows good condition on all pilings. Full cross-section sound.

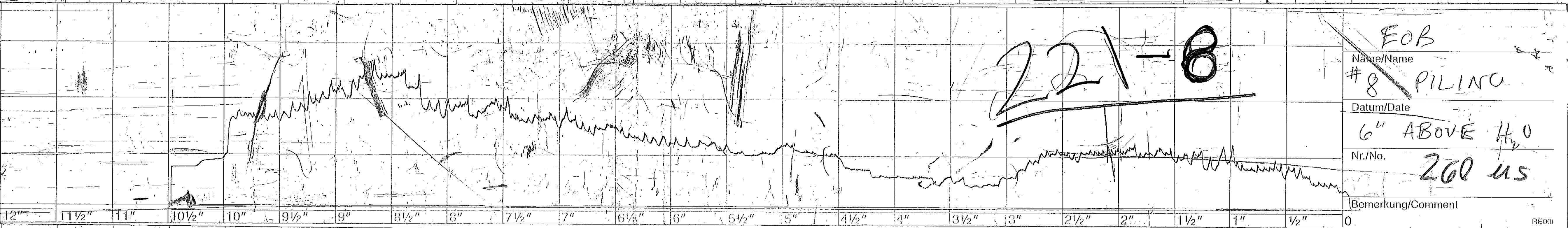


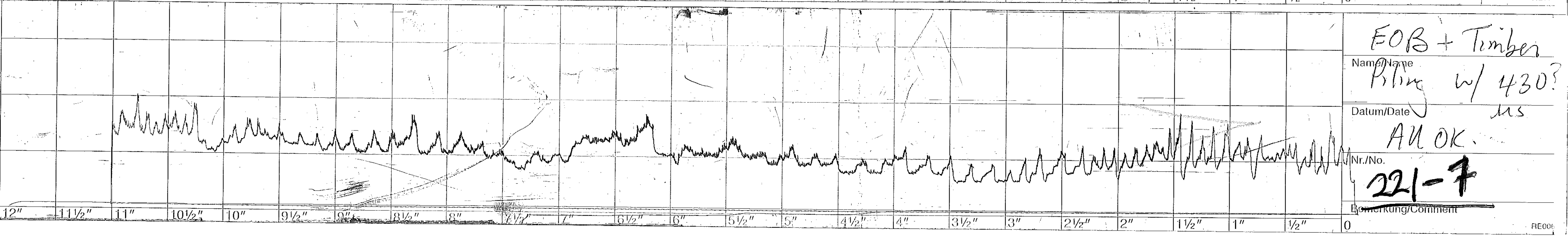
Notes: Timber pilings. Minimal surface checking. Stress wave timer on pile 11 affected by vertical crack/split. Resistance drill @ 460 µs on pile 11 showed good condition.



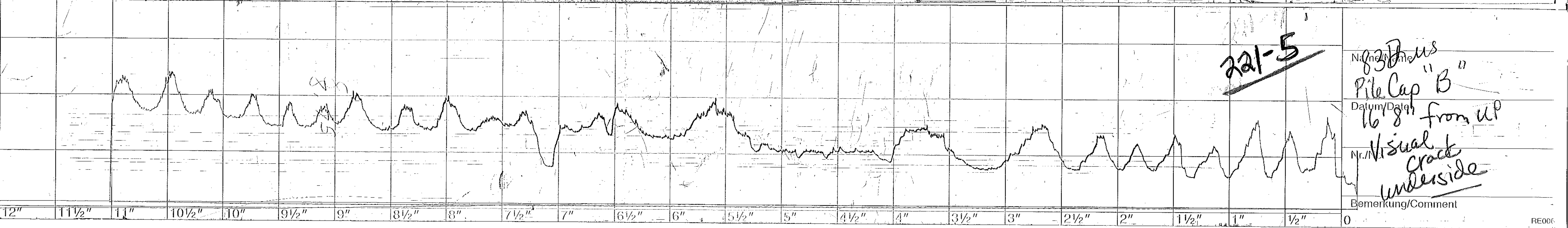
Bridge ~~221~~-1
Deck Board
5th in from UP (BOB)
Sounded a bit soft
Looks OK here w/
Drill, Drilled vertical
≈10 deep beam


221-9
EOB
#10 6" above
H_2O

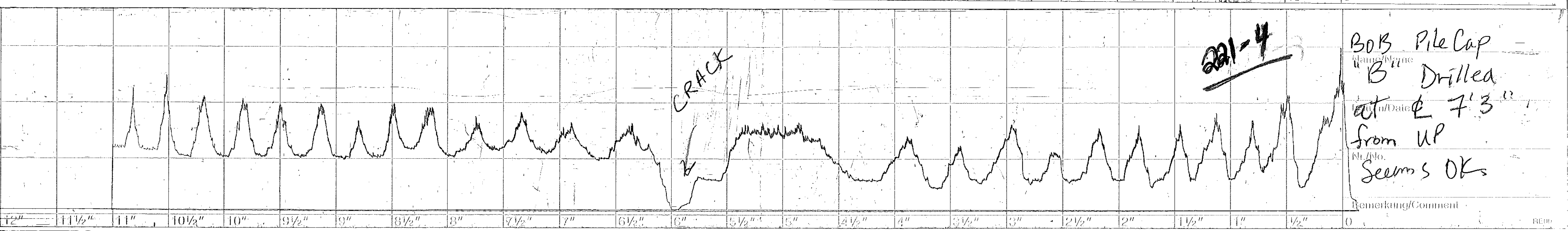

221-8
EOB
Name/Name
#8 PILING
Datum/Date
6" ABOVE H_2O
Nr./No.
260 us
Bemerkung/Comment
12" 11½" 11" 10½" 10" 9½" 9" 8½" 8" 7½" 7" 6½" 6" 5½" 5" 4½" 4" 3½" 3" 2½" 2" 1½" 1" ½" 0


EOB + Timber
Name/Name
Piling w/ 430? us
Datum/Date
All OK.
Nr./No.
221-7
Bemerkung/Comment
12" 11½" 11" 10½" 10" 9½" 9" 8½" 8" 7½" 7" 6½" 6" 5½" 5" 4½" 4" 3½" 3" 2½" 2" 1½" 1" ½" 0

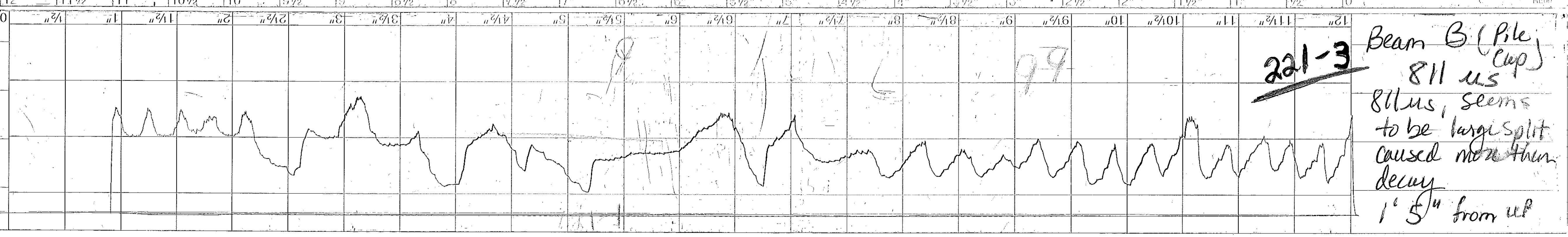
Crack
See series of pictures for example
221-6
668 us
Name/Name
30 in from Down S Cap B
Datum/Date
BOB
Nr./No.
Bemerkung/Comment



221-5
837 us
Pile Cap "B"
16'8" from UP
Visual crack underside
Bemerkung/Comment

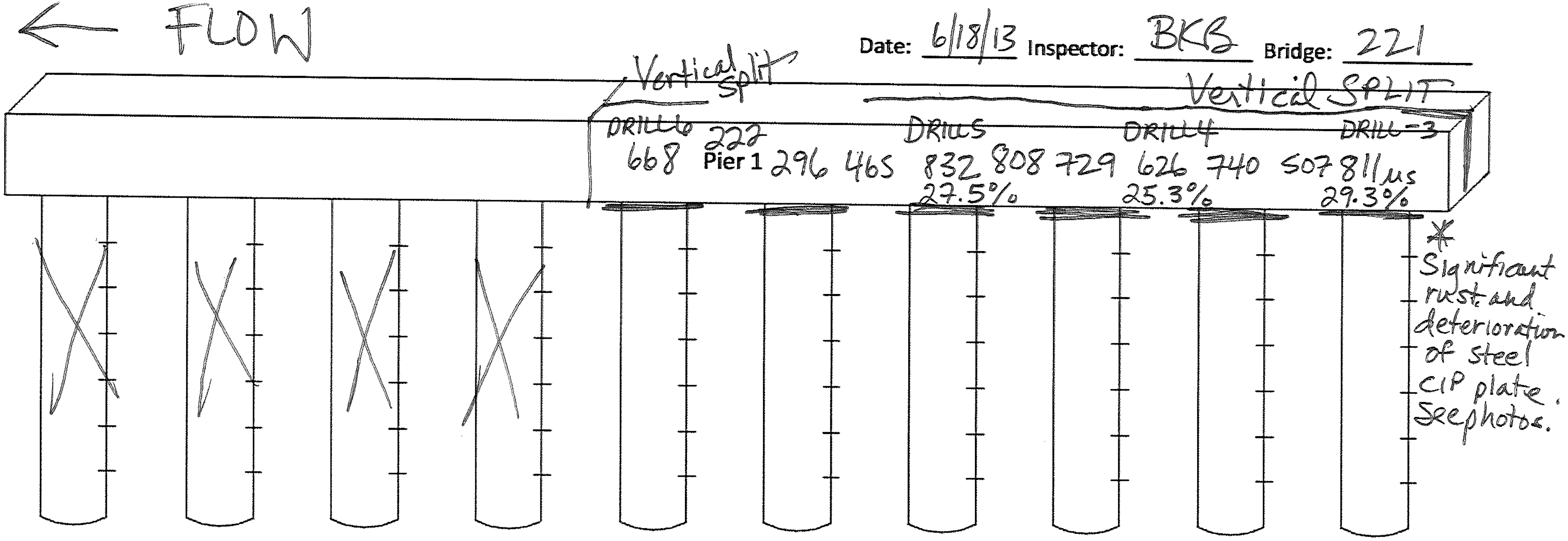


CRACK
221-4
BOB Pile Cap "B" Drilled at ℄ 7'3" from UP
Seems OK
Bemerkung/Comment

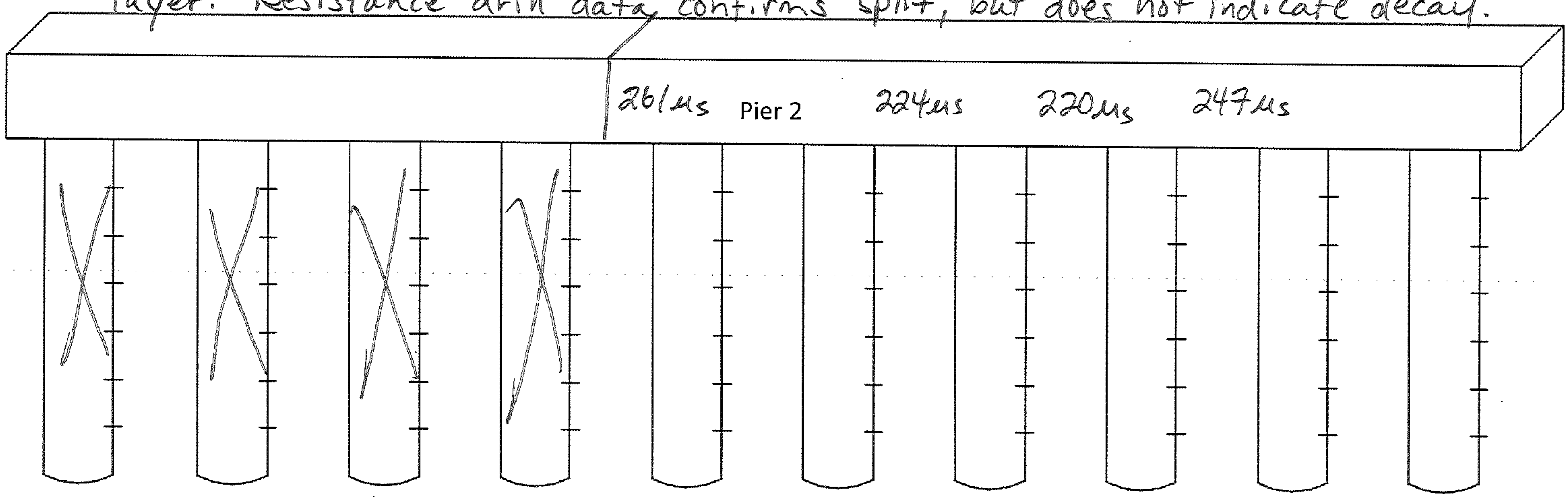


221-3
Beam B (Pile Cap)
811 us
811us, seems to be large split caused more than decay
1' 5" from UP

Date: 6/18/13 Inspector: BKB Bridge: 221



Notes: All pilings CIP. Through splits are present on both the upstream and downstream pier cap. Mcontent measures are above 25% MC. Moisture is entering splits from ends and through deteriorated bituminous wear layer. Resistance drill data confirms split, but does not indicate decay.

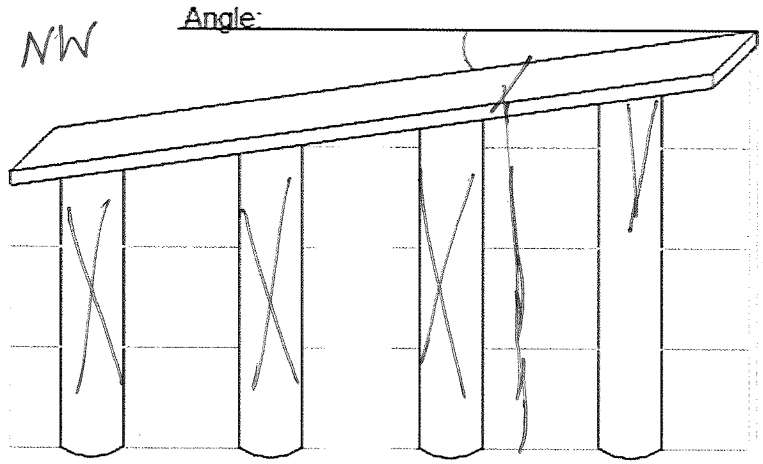


Notes: All pilings CIP.

Date: 6/18/13 Inspector: BKB Bridge: 221

BOB

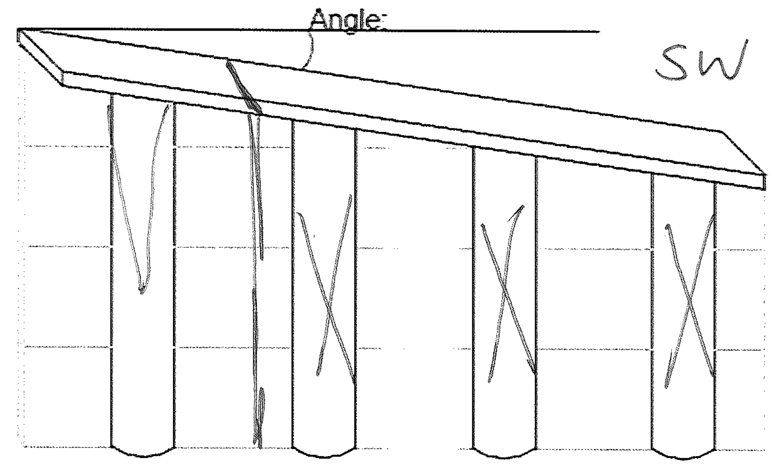
Angle:



☒ Upstream ☐ Downstream

Notes: Slight visual deterioration in piling.

Angle:

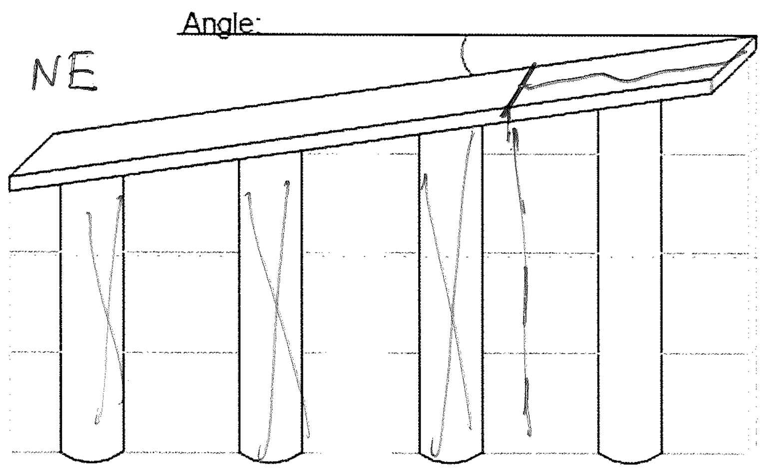


☐ Upstream ☒ Downstream

Notes: Severe decay in piling. Visual.

EOB

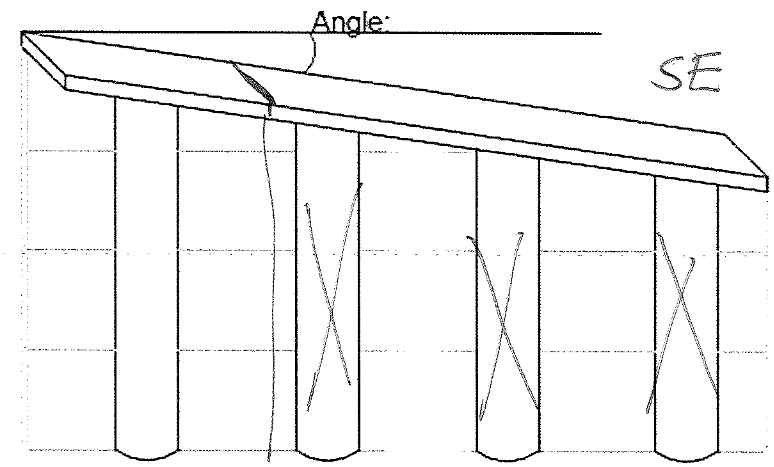
Angle:



☒ Upstream ☐ Downstream

Notes: 50 % of cap is decayed due to significant plant growth noted through hammer sounding & probe pick

Angle:



☐ Upstream ☒ Downstream

Notes: Cap fully covered by deterioration potential future decay.

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Appendix A - Commercial Equipment Suppliers

Stress Wave Timing

The following types of commercial equipment are available and recommended to measure stress wave transmission times in wood. The manufacturer, methods of operation, key considerations, and specifications for this equipment are also given.

FAKOPP Microsecond Meter
FAKOPP Enterprise
Fenyo Str. 26, H -9423 Agfalva, Hungary
Telephone: +36 99 33 00 99; Fax: +36 99 33 00 99
Website: www.fakopp.com; Email: office@fakopp.com

Method of Operation
This equipment is battery operated and designed for field applications. Needles attached to accelerometers are used as mediators. A hammer is used to tap the start sensor to generate a stress wave into a wood member. The two sensors pick up the start and stop signal and the wave transmission time is displayed on a LCD screen.

Specifications
Power requirements: 9-V battery
Resolution: ±1 μs
Dimension: 4.5 by 8 by 15 cm (1.77 by 3.23 by 5.90 in.)
Weight: 347 g (0.76 lb.)

Metriguard Model 239A Stress Wave Timer
Metriguard, Inc.
2465 NE Hopkins Court, Pullman, WA 99163 USA
Telephone: (509) 332-7526; Fax: (509) 332-0485
Website: www.metriguard.com; Email: sales@metriguard.com

Method of Operation
A mechanical stress wave is impact induced in a member by a hammer or other means and is detected with accelerometers at two points along the propagation path. The timer starts when the wave front arrives at the first accelerometer. The timer stops when the wave front arrives at the second accelerometer and displays the propagation time between accelerometers in microseconds.

Specifications
Power requirements: 9-V battery
Resolution: ±1 μs
Dimensions: 23 by 15 by 20 cm (9 by 6 by 8 in.)
Weight: 5.4 kg (12 lb.) (including hammer and accelerometers)

Sylvatest Trio
Concept Bois Technologie
Jordils Park Rue des Jordils 40, 1025 Saint-Sulpice, Switzerland
Telephone: +41 21 694 04 04

Fax: +41 21 694 04 05
Website: www.cbs-cbt.com; Email: info@cbt-cbt.com

Method of Operation
The Sylvatest unit utilizes an ultrasonic pulse generator to impart a stress wave into a member. Two transducers are placed a fixed distance apart on a member. A transmitting transducer imparts a wave into the member, and a receiving transmitter is triggered upon sensing of the wave. The time it takes the wave to pass between the two transducers is then coupled with various additional information, such as wood species, path length, and geometry (round or square section), to compute modulus of elasticity. This unit also measures damping characteristics of the member.

Specifications
Tranducer: 22 kilohertz (kHz)
Power requirements: rechargeable batteries
Dimensions: 20 by 10 by 5 cm (8 by 4 by 2.0 in.)
Weight: 1400 g (3.1 lb.) (instrument with 2 transducers)

Increment Corers

The following types of commercial equipment are available and recommended to obtain increment cores in timber bridge elements.

Forestry Suppliers Inc.
205 West Rankin Street
P.O. Box 8397
Jackson, MS 39284-8397 USA
Telephone: (800) 647-5368; Fax: 800-543-4203
Website: www.forestry-suppliers.com

Ben Meadows Company
PO Box 5277
Janesville WI USA 53547-5277
Telephone: (608) 743-8001
Fax: (608) 743-8007
Website: www.benmeadows.com

Resistance Microdrills

The following types of commercial equipment are available and recommended to obtain resistance drilling data in timber bridge elements.

IML-RESI PD- and F-Series
IML North America, LLC
Moultonborough, NH 03254 USA
Telephone: 603-253-4600
Website: www.iml-na.com

PD Series

Method of Operation

The PD Series utilizes a thin drilling needle with an integrated drilling system to determine the internal quality of the material. It has an electronic digital data acquisition package with an optional software package.

Specifications

Drilling depths: 200 mm to 1000 mm (7.9 in. to 39.4 in.)
Energy source: Lithium-ion rechargeable battery
Data: Electronic data storage, optional: Bluetooth printer
Resolution: 0.02 mm/300 mm
Feed speed: 5 feed rates, freely adjustable from 15- to 250 cm/min (5.9- to 98 in/min)
Rotation speeds: 5 rotation speed levels, freely adjustable from a minimum of 1500 rpm to a maximum of 5000 rpm

F-Series

Method of Operation

The F-Series utilizes a thin drilling needle with a cordless drill drive unit to determine the internal quality of the material. It can document measurement results directly on site through the recording of the measurement curve on weatherproof wax paper strips.

Specifications

Drilling depths: 150 mm to 500 mm (5.9- to 19.7 in.)
Energy source: Lithium-ion rechargeable battery
Data: Measurement record on wax paper strips, optional: Electronic measurement data storage
Versions: Standard Version, reinforced S- and SX-Version
Feed speed: 2 stages up to 150 cm/min (59.0 in/min)
Sensitivity: 2 adjustable stages for hard and soft wood

Resistograph 4- and 5-Series

RINNTECH, Inc.
St. Charles, IL 60174, USA
Telephone: (630) 377-2477
Website: www.rinntech.de

Resistograph 4-Series

Method of Operation

The RINNtech 4-Series is a drill resistance measuring unit that is electronically controlled. The penetration resistance of a fine drill needle into a timber member is measured and recorded. The quality of the wood can be assessed through examination of the resulting charts.

Specifications

Drill weight: 4 kg
Drilling depths: 30 or 44 cm (11.8 to 17.3 in.)

Energy source: Standard battery pack 24 Volts x 7.2 Ah = 172 Vah for up to 100 drills
Data: Electronic data collection and simultaneous chart printout in scale 1:1 on scratch-resistant thermal paper rolls
Resolution: 0.1 mm (0.004 in.)
Feed speed: Automatic feedrate adjustment for all kinds of wood

Digital microProbe
Sibtec Scientific
Sibert Technology Limited
2a Merrow Business Centre, Guildford
Surrey GU4 7WA England
Telephone: +44 1483 440 724
Fax: +44 1483 440 727
Website: www.sibtec.com

Method of Operation
The DmP is a lightweight, battery powered portable tool that uses a 1 mm diameter probe to penetration timber up to 1 meter deep. The tool measures the resistance to penetration of the probe and downloads the resulting data in digital form for analysis. The difference between probing harder or softer wood can be "felt" because of the varying resistance of different types of wood.

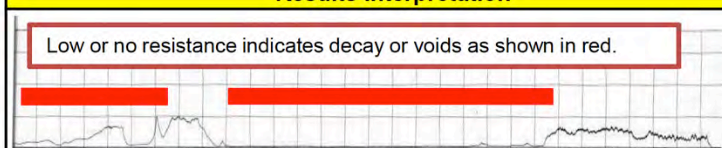
Specifications
Drilling probe diameter: tip 0.7 mm (1.7 in), 0.9 mm shaft (0.4 in)
Drilling probes depth: Any length up to 1000 mm (39 in.)
Drilling probe rotation: 7000 per minute
Power source: 12 V rechargeable battery
Standard battery: 3.2 Ah (approximately 100 drillings per charge)
Charger: 240V or 110V
Weight: 2.2 kg (4.8 lbs)

Appendix B - Operating Procedures For Stress Wave Timer, Resistance Microdrills

Standard Operating Procedure	IML RESISTANCE F300 DRILL		
Organization:	UMD/NRRI	**PPE:**	Gloves, safety glasses
Approved:		**Tools:**	Resistance drill, batteries and case w/accessories.
Document #:	2013-2.1		

No.	Procedure	Key Points
1	Insert battery.	Install rechargeable battery into drill base. Replace or recharge to ensure consistent drilling.
2	Select sensitivity setting.	Press the setting wheel and turn until the bolt catches. Setting 1 is for softwood species.
3	Install wax paper.	Open top cover. Bend the paper and slide into slot by lifting stylus. Close cover when complete.
4	Select drilling location.	Conduct drilling based on visual or stress wave inspection. Typical areas of concern: Piling - Test just above water line and 6-12 inches below cap. 45° attachment could be used at water line. Cap - Test at end, moving toward center of bridge. Test at midline.
5	Drill into member.	Select forward on drill. Pull trigger and drill at a relatively consistent speed. Monitor the depth and results during drilling.
6	Remove drill.	Switch drill to reverse. Pull trigger while gently pulling bit back out of wood. Observe the tip for sharpness. Bit should last 100+ drillings.
7	Fill drilling hole with silicone.	If the piling is sound, fill hole with a small amount of silicone to prevent new moisture infiltration.
8	Record data into notebook.	Drilling location and data should be entered onto data form. Notes should be added on paper strip.
9	Repeat at next location.	If decay is noted, test further in either the length (CAP, GIRDER) or height (PILING). Remove wax paper. If using electronic collection, note file no.
10	Turn off unit.	Remove battery and put into case.

Results Interpretation



Low or no resistance indicates decay or voids as shown in red.

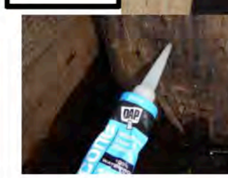
VISUAL PROCEDURES

Insert charged battery into drill.

Select sensitivity setting of 1 for softwood bridge elements.

Insert paper into top by sliding into slots and under stylus.

Visually inspect drill tip after each drill.



Silicone should be used to fill the tiny hole.

Resistance drilling can be used independently or to confirm stress wave testing results.

Vertical testing can be completed on timber caps or slab span members.

A 45° attachement allows for inspection below the water or ground line. Silicone should be used to fill the hole.

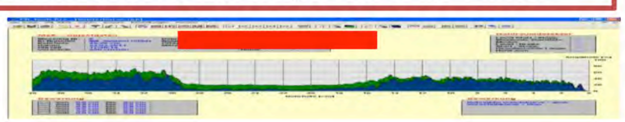
Standard Operating Procedure	IML PD Series

Organization:	UMD/NRRI	**PPE:**	Gloves, safety glasses
Approved:		**Tools:**	Resistance drill, batteries and case w/accessories.
Document #:	2014-5		

No.	Procedure	Key Points
1	Insert battery.	Install rechargeable battery into drill . Replace or recharge to ensure consistent drilling.
2	Turn on the unit.	Press the navigation knob to turn the unit on. The main menu will be displayed.
3	Select settings in the main menu	Enter the ID Settings using the navagation knob. Apply the data by pressing OK or cancel.
4	Select drilling location.	Conduct drilling based on visual or stress wave inspection. Typical areas of concern: Piling - Test just above water line and 6-12 inches below cap. 45° attachment could be used at water line. Cap - Test at end, moving toward center of bridge. Test at midline.
5	View profile screen.	Turn the navigation knob to select the graph symbol to view the profile
6	Drill into member.	Press the unit firmly against the member, making sure to compress the adapter sleeve. Push the red button briefly to start drilling.
7	Finish the drilling test.	Once the drill has gone completely through or to the desired depth, it will auto reverse.
8	Fill drilling hole with silicone.	If piling is sound, fill hole with small amount of silicone to prevent moisture uptake.
9	Repeat at next location.	If decay is noted, test further in either the length (CAP, GIRDER) or height (PILING). If using electronic collection, note file number.
10	Turn off unit.	Remove battery and put into case.

Results Interpretation

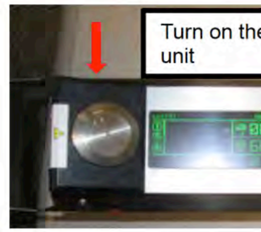
Low or no resistance indicates decay or voids as shown in red.



VISUAL PROCEDURES

IML PD and Case

Install battery by sliding it forward



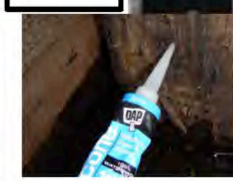
Turn on the unit

Main menu allows changes to made

Press the red button to start drilling

Visually inspect drill tip after each drill.

Press the drill firmly against the member , and press the start trigger, hold firmly until the drill reverses the bit out



Silicone Should be used to fill the tiny hole.

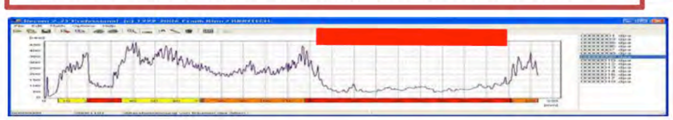
Standard Operating Procedure	RINNtech R5420 Drill

Organization:	UMD/NRRI	**PPE:**	Gloves, Safety glasses
Approved:		**Tools:**	Resistance drill, batteries and case w/accessories.
Document #:	2013-2.1		

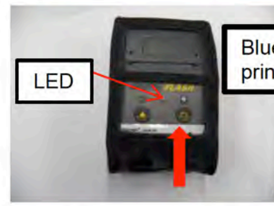
No.	Procedure	Key Points
1	Turn on unit.	Turn on the unit by pressing the rocker switch located near the handle.
2	Turn on printer.	Turn it on by pressing the button on the right. It is connected when the LED is flashing
3	Select drilling location.	Locate areas of potential decay or according to testing plan.
4	Start drilling.	Pull the red switch back towards the handle. It is not necessary to hold the switch. Press in opposite direction to stop the drill. Press it once more to reverse the drill. It will reverse automatically when the full drilling depth is reached.
5	Store data.	The unit beeps twice when the drill profile is stored. A constant beep means an error has occurred.
6	Remove drill.	Press the drilling switch in the opposite direction. The drill will auto reverse when it has used its full drilling length.
7	Fill drilling hole with silicone.	If the piling is sound, fill hole with a small amount of silicone to prevent moisture uptake.
8	Record data in notebook.	Drilling location and data should be entered onto data form.
9	Repeat at next location.	If decay is noted, test further in either the length (CAP, GIRDER) or height (PILING).
10	Turn off unit.	Put all items into the case.

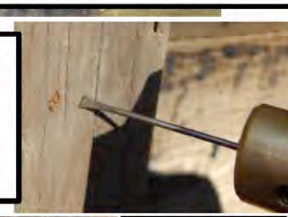
Results Interpretation

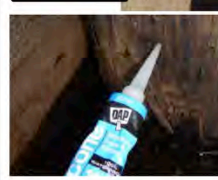
Low or no resistance indicates decay or voids as shown in red.



VISUAL PROCEDURES







Turn on the unit by pressing the switch on the underside.

Remove the paper from printer and record the drilling location on the end of the chart. Store in a dry location.

Standard Operating Procedure	FAKOPP STRESS WAVE TIMER

Organization:	UMD/NRRI	PPE:	Gloves, safety glasses
Approved:		Tools:	Fakopp, hammer, data forms, batteries, strap
Document #:	2013-1.1		

No.	Procedure	Key Points
1	Connect cables to unit.	Note color of cable ends, start probe is red, stop is black.
2	Turn on unit.	Hold reset button down while turning on for auto reset after each tap. Make sure battery is acceptable.
3	Select appropriate location for testing.	PILINGS - at or below water line (if waterproof probes) and 6-12 inches below cap. CAP - Start at cap end, move toward center of bridge testing at midline.
4	Insert probe into wood specimen using the small hammer.	The probes have sharp points. Make sure they are directly across from each other at center of element and that they are in the same horizontal plane. The probes should be inserted 3/8 - 1/2 in. and firm.
5	Tap start sensor with crisp tap of light force.	Use hammer to take 3-5 readings. If they are not consistent, readjust sensor and retry. Reading should be within ± 5 microseconds (μs). Do not hit the probe too hard causing it to penetrate further.
6	Remove and reinsert at 90°.	If there is no visual deterioration and results normal, it may not be necessary to test at 90°.
7	Record data into notebook.	Data should be entered onto data form.
8	Continue testing member.	If decay is noted, test further in either the length (CAP, GIRDER) or height (PILING)
9	Confirm decay depth with resistance drill.	Continue testing according to project plan.
10	Turn off unit.	Remove cables and put into case.

Results Interpretation

Sound wood = 150-250 microseconds/ft (μs/ft)
Minor decay = 250-350 μs/ft
Moderate decay = 400 - 700 μs/ft
Severe decay = >700 μs/ft
Caution must be exercised with significant checks, cracks/splits as their presence can affect time readings.

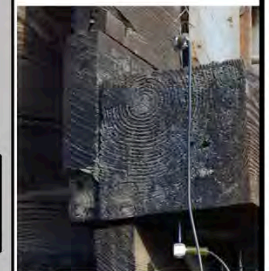
VISUAL PROCEDURES

Fakopp should be stored with all parts in durable case.

Hold down reset button when turning on.

Red/Start

Insert probes across from each other in same plane.



Cap testing can be done in either the vertical or transverse direction. Start at midline near ends or areas of concern.

Typical areas of concern are below the cap, at water line and slightly below water line. Waterproof transducers are available.

Standard Operating Procedure	Moisture Meter		
Organization:	UMD/NRRI	**PPE:**	Gloves, safety glasses
Approved:		**Tools:**	Moisture meter, slide hammers, spare pins
Document #:	2014-2		

No.	Procedure	Key Points
1	Turn on unit.	Press the "read" button, which is the rain drop symbol.
2	Connect slide hammer.	Select the proper slide hammer and connect it to the meter.
3	Check calibration.	Press the cal check button. It should read 12%.
4	Select species.	Select species from the chart on the back and enter it using the tree symbol. Typical species for pilings is Southern Yellow Pine and for girders, Douglas Fir is typical.
5	Enter temperature.	Select the temperature by using the thermometer button.
6	Install slide hammer into specimen.	Install so that the pins are in grain direction. Be careful not to break the pins.
7	Take reading.	Press the read button.
8	Continue testing member.	If high readings are found, further testing may be needed. Expand test area and/or use stresswave or resistance drilling equipment.
9	Confirm decay depth with resistance drill.	Continue testing according to project plan.
10	Turn off unit.	Remove cables and put into case.

Results Interpretation

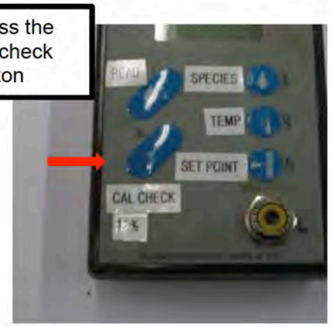
Normal moisture readings of exposed wood should be in the 8 - 16 % range. Readings over 20% may indicate presence of decay warranting additional inspection with the stresswave timing equipment or resistance microdrills.

VISUAL PROCEDURES

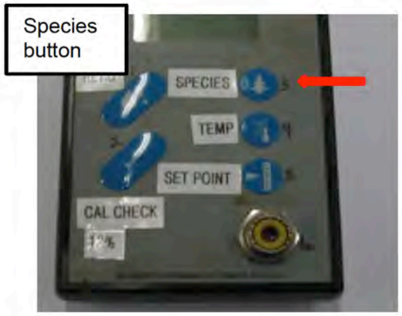
Turn on Delmhorst moisture meter

Meter and slide hammers

Press the cal check button



Species button

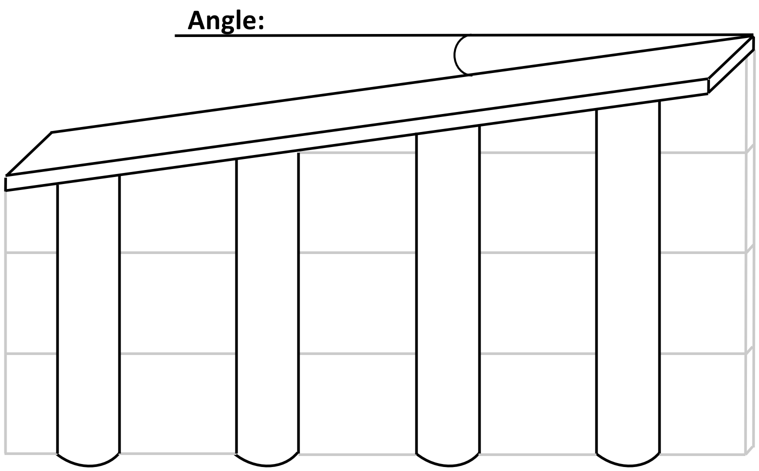


Use the Temp. button to select the testing temperature

Take reading and record on data sheet

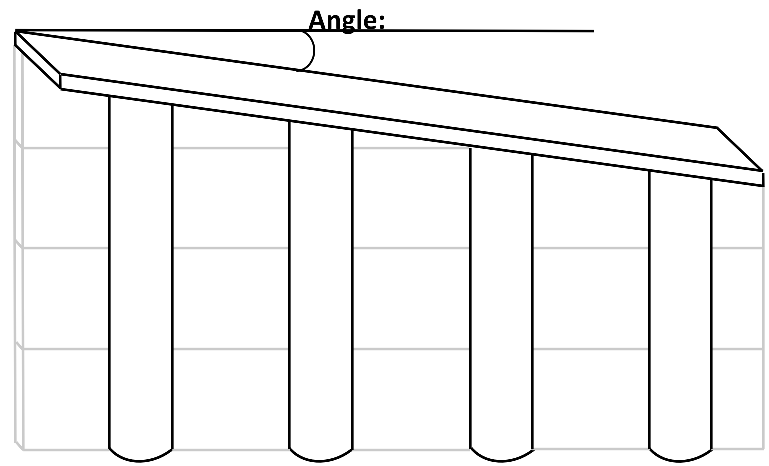
Appendix C - Example Data Forms

Date: Inspector: Bridge:

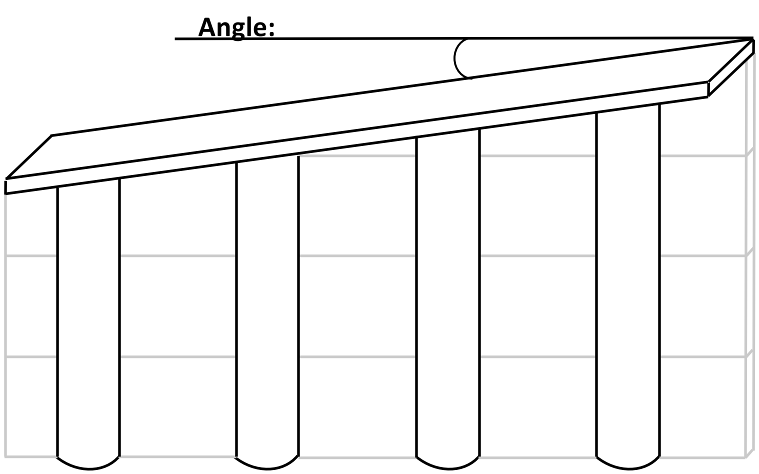


☐ Upstream ☐ Downstream

BOB

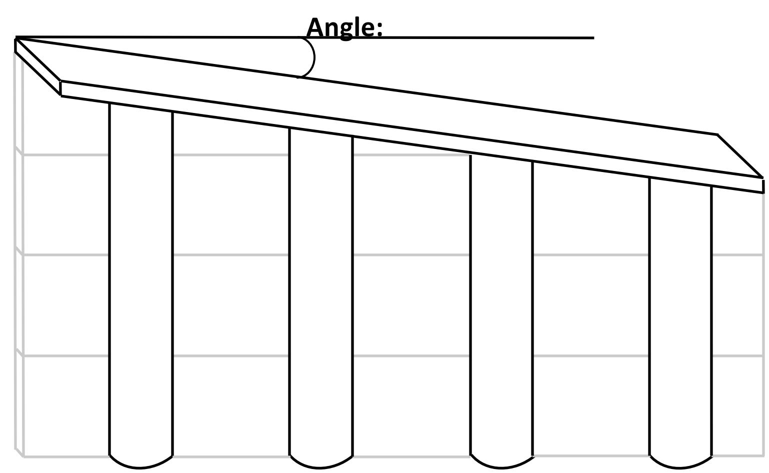


☐ Upstream ☐ Downstream



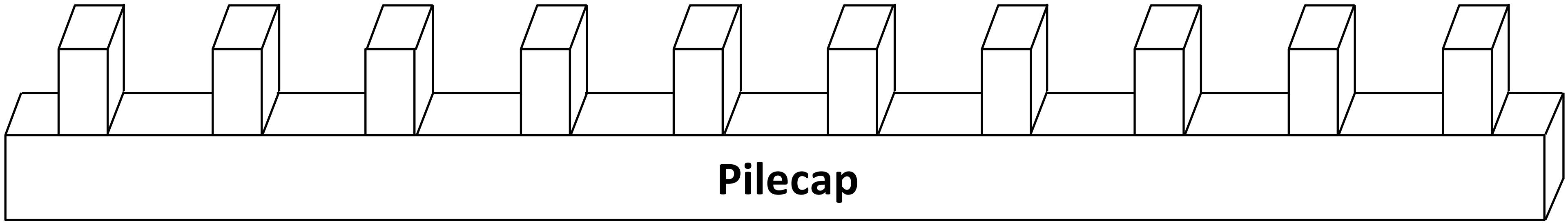
☐ Upstream ☐ Downstream

EOB

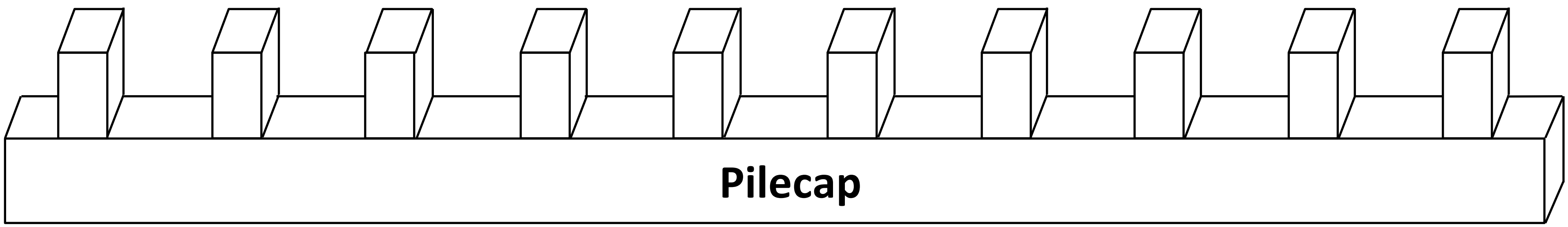


☐ Upstream ☐ Downstream

Date: Inspector: Bridge:



Notes:



Notes:

Date/time: ______________

Structure: ______________

Inspector(s): ______________

Location: ______________

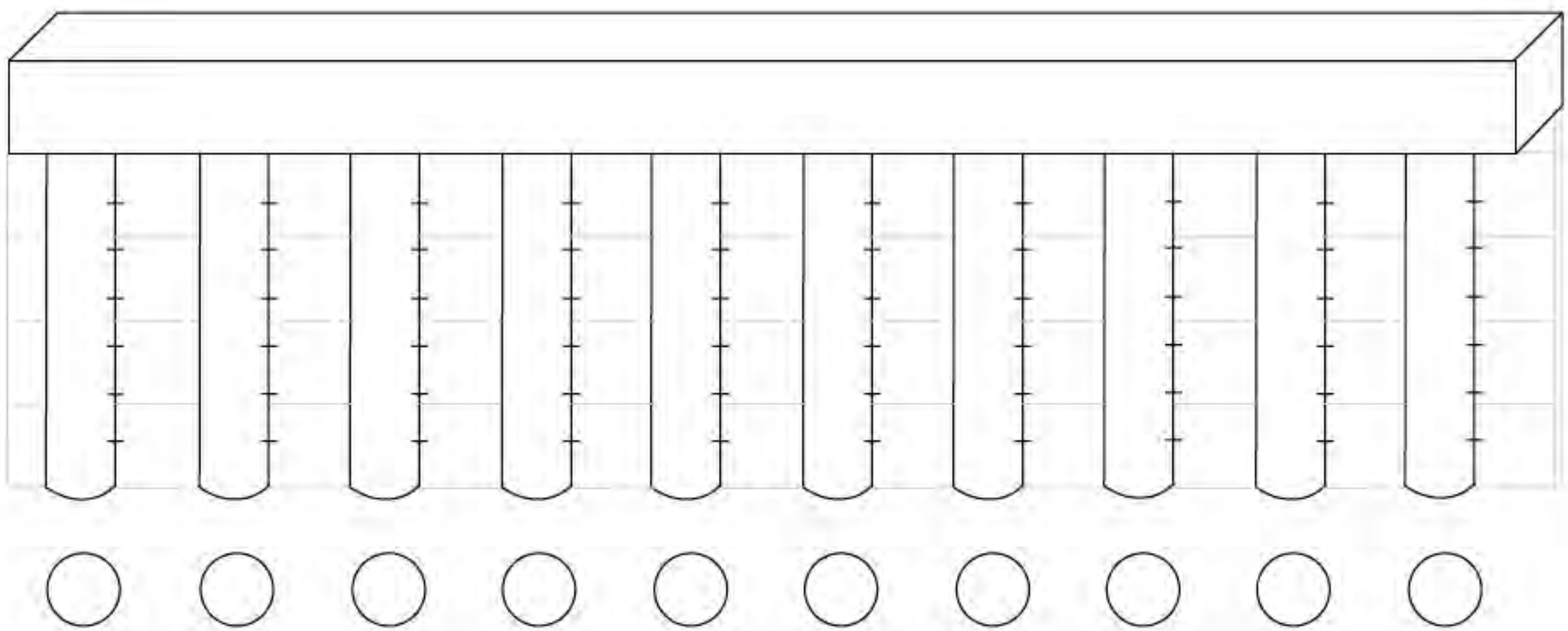
Superstructure type: ______________

Substructure: type: ______________

Deck type: ______________

Equipment: ______________

Abutment or Pier: __________



Notes: