Condition Rating Table: Corrugated Metal Barrel (See Appendix B Photographs)

Table 4.11.2-1—Corrugated Metal Barrel Condition State Definitions

	1 GOOD	2 FAIR	3 POOR	4 SEVERE
SURFACE DAMAGE	No dents or other localized damage.	Small dents or impact damage to pipe wall or end section with no wall breaches.	Large dents or impact damage to pipe wall or end section with localized wall breaches, no more than one corrugation over circumferential length of 6 in.	Dents or damage that warrant engineering evaluation. Through-wall holes greater than one corrugation over a length more than 6 in., allowing unimpeded soil infiltration.
CORROSION	Isolated areas of freckled rust.	Freckled rust, corrosion of pipe wall material. No loss of section, no through-wall penetration from corrosion.	Corrosion of pipe material and widespread section loss less than 10% of wall thickness. Localized deep pitting. Several holes less than or equal to 1 in. diameter. Penetration possible with hammer pick strike.	Widespread through-wall penetration. Invert missing in localized sections. Holes greater than 1 in. diameter or many smaller holes grouped closely.
ABRASION	No damage due to abrasion.	Small or local abrasion of wall or coating with no breaches in the coating exposing structural wall or signs of corrosion.	Widespread abrasion of protective coating with breaches exposing the pipe wall material and allowing through-wall penetration during inspection probing with a pick.	Abrasion has worn large holes through the metal pipe greater than one corrugation in length for more than 6 in. around the circumference.
SHAPE (CLOSED SHAPE)	Smooth curvature in barrel, deformation less than 5% of inside diameter.	Top half smooth. Minor bulges or flattening of bottom. Deformation 5%–10% of original inside diameter.	Significant distortions or flattening. Lower third may be kinked. Deformation greater than 10%–15% of original inside diameter. Visible out-of-roundness.	Extreme distortion throughout pipe, local areas of reverse curvature and kinks. Deformation greater than 15% of original inside diameter. Significant out-of-roundness.
SHAPE (OPEN SHAPE)	Smooth curvature, rise and span measurements within tolerance.	Refer to shape inspection requirements for specific structure type.	Refer to shape inspection requirements for specific structure type.	Refer to shape inspection requirements for specific structure type.

4.12 Masonry Barrel

Masonry barrels refer to structures constructed of individual masonry units made of stone, brick, or concrete block. Brick and concrete block structures are typically constructed with a layer of mortar placed between units. Masonry units are placed in wythes and courses. Course refers to the layer of units running horizontally. The number of courses determines the height of the wall. Wythes are the continuous vertical sections of the wall. The number of wythes determines the wall thickness. Stone masonry may be dry (no mortar), pointed (stones set in mortar), or cemented (stones set in concrete).

Masonry construction is most commonly found in culvert barrels and limited primarily to headwalls, wingwalls, inlet structures, and access structures (e.g., manholes), and older combined sewers. While new culverts are rarely constructed from masonry, a wide variety of masonry culverts are still in service. Stone culverts were constructed by skilled artisans, mostly before the 1940s. Some now have historic designations and are being preserved.

4.12.1—Purpose

The purpose of inspection of the masonry barrel is to identify distress or potential distress using common and distress indicators in the masonry units and mortar. Barrel shape can also be an indicator of structural distress, joint/mortar distress, or loss of backfill support.

4.12.2—What to Look For

Masonry culverts are generally arch shaped, pipe arch shaped, or box shaped. These structures may be supported on footings, or with closed bottoms. The walls, floors, and top of masonry culverts should be carefully inspected both visually and by tapping stones, bricks, or blocks and mortar with a geologist's rock hammer. The Inspector should note any apparent signs of distress.

Many masonry culverts are very old, some over 150 years old, and local development and changes in the surrounding land use may have increased the volume of storm water runoff that flows to the culvert. Hence, some may now be undersized for hydraulic capacity. When flow exceeds the culvert capacity, the culvert may overtop and suffer erosion and damage at the outlets. In addition, these historic structures may now carry heavier vehicle loads than existed at the time of their construction.

Typical items to inspect include the condition of the masonry units and mortar, movement or distortion, and weathering of the masonry.

Masonry Unit Distress — The individual stones, bricks, or blocks should be checked for displaced, cracked, broken, crushed, or missing units. For some types of masonry, surface deterioration or weathering can also be a problem and can cause spalling.

Figure 4.12.2-1—Missing Units in Masonry Barrel Wall with Cracked and Missing Mortar
(Photo courtesy of Ohio Department of Transportation)

Movement
Movement of individual or grouped masonry units may occur due to freeze–thaw action, vegetation growth, mortar deterioration, or stress. The Inspector should identify loose or dislodged units.

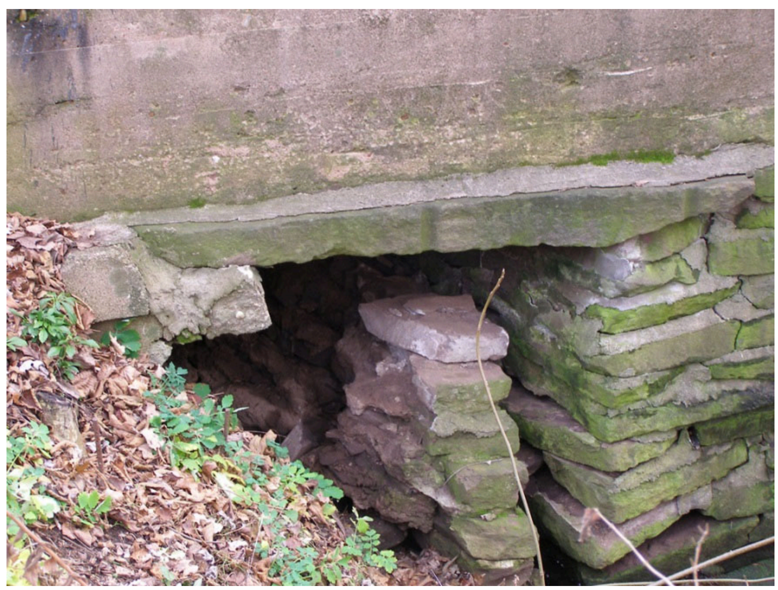

Figure 4.12.2-2—Structure Condition is Severe and Unstable Due to Movement of Foundation Wall
(Photo courtesy of Ohio Department of Transportation)

Shape
Masonry arches act primarily in compression. Racking, flattened curvature, bulges in walls, or other shape deformations may indicate unstable soil conditions. The vertical and horizontal alignment should be checked visually.

Cracking and Splitting
Cracking and splitting in masonry units are generally caused by tensile stress in the units. Cracking may be due to differential settlement or expansion of foundation soils, increased lateral earth pressure, shifting of units due to mortar deterioration, or impact damage. The Inspector should note the presence and location of cracked masonry units.

Freeze–Thaw Cycling

Expansion of frozen water trapped behind a masonry unit can cause movement of the unit. Under repeated cycling, and sometimes combined with other deterioration and erosion, units can become loose and dislodged.

Vegetation

Lichen and mosses growing on the face of units can create a moist environment which accelerates chemical weathering. Higher order vegetation and trees can also plant roots between units and dislodge masonry units. Vegetation should be removed from the units as part of regular maintenance.

Acid Weathering

Acidic rainwater and storm water runoff can dissolve the surface of the units. Weathering typically appears as roughened surface with discoloration when compared with unweathered counterparts. Sandstone, limestone, and marble are susceptible to acid attack.

Mortar Distress

In most masonry arch culverts, mortar is used to bond the masonry units together. The condition of the mortar should be checked to ensure that it is still holding strongly. It is particularly important to note cracked, deteriorated, or missing mortar especially if other deterioration is present such as loose or missing masonry units. The presence of dirt or vegetation between masonry units should be noted as these can be indicators of loss of backfill or erosion behind the structure. Water infiltration can also contribute to mortar distress in cold climates as freeze–thaw cycles break the mortar apart.

Figure 4.12.2-3—Missing Mortar between Masonry Units
(Photo courtesy of Ohio Department of Transportation)

Efflorescence and Staining

Water infiltration through walls or joints may be indicated by deposits caused by efflorescence (leaching of salts or chlorides) leaking through the mortar joints. Efflorescence and staining on its own are primarily cosmetic issues due to capillary action in porous materials; therefore, its presence alone cannot cause a severe rating. However, it can sometimes lead to spalling and deterioration and should be recorded and tracked during inspection.

Condition Rating Table: Masonry Barrel (See Appendix B Photographs)

Table 4.12.2-1—Masonry Barrel Condition State Definitions

	1 GOOD	2 FAIR	3 POOR	4 SEVERE
MASONRY UNITS AND MOVEMENT	No cracking, split, or missing masonry units. No displaced masonry units. No surface deterioration. No measurable cross sectional distortion.	Cracking of isolated individual units. Surface weathering or spalling. No movement of masonry units.	Split or cracked masonry units. Large areas of moderate spalling, scaling, or weathering. Pronounced movement or dislocation of masonry units but does not warrant engineering evaluation.	Widespread cracking, splitting, or crushing of masonry units or missing units. Large areas of heavy spalling, scaling, or weathering. Holes through structure wall. Significant movement of individual units. Visible movement or distortion of cross sectional shape, structure appears unstable.
MORTAR	Mortar is intact with no deterioration.	Localized cracked or missing mortar. Widespread areas of shallow mortar deterioration, possible minor water infiltration (no active flow) or exfiltration through joints.	Extensive missing mortar. Extensive mortar deterioration, small flow but no soil/fines, infiltration or exfiltration through joints. Vegetation sprouting from between units.	Missing mortar with backfill infiltration, possible voids in roadway.
EFFLORESCENCE	Localized areas of efflorescence less than 2 in^2.	Widespread areas of efflorescence without rust staining.	Heavy buildup of efflorescence with rust staining.	Cannot cause Severe rating.

4.13 Timber Barrels

Timber culverts are primarily inspected for material deterioration, called biotic degradation, and mechanical damage. Biotic degradation includes attack of the timber member by bacteria, fungi, insects, and marine borers. Bacteria and fungi degrade wood by breaking down constituents of the material that provide strength, also known as decay. Insects and marine borers degrade the strength of the structure by creating tunnels and cavities in the wood for shelter. Mechanical damage may be caused by abrasion creating marred or worn surfaces (from traffic, stream flow, or ice), impact damage (from vehicles, debris, or ice floes), long-term exposure to overload stresses, or fire.

4.13.1—Purpose

The purpose of the timber barrel inspection is to identify distressed connections, decay, structural overload distress, or other material deterioration to allow assignment of a condition rating.

4.13.2—What to Look For

Visual inspection is a cursory means to assess the structure for signs of actual or potential deterioration, noting areas for further investigation. Inspection of timber culverts should also check for signs of material deterioration at the surface (exterior) and interior of wood members. Material deterioration should be inspected by sounding the wood, probing, and possibly by pick testing.

Sounding Sounding the wood surface by striking it with a hammer or other object is used to detect interior deterioration based on the tonal quality of the strike sounds. A trained and experienced Inspector can typically interpret dull or hollow sounds that may indicate the presence of large interior voids or decay. Although sounding is widely used, it is often difficult to interpret because factors other than decay can contribute to variations in sound quality. In addition, sounding provides only a partial picture of the extent of decay present and will not detect wood in the incipient or intermediate stages of decay. Nevertheless, sounding still has its place in inspection and can quickly identify seriously decayed structures. When suspected advanced decay is encountered, it must be verified by other methods such as boring or coring. Boring involves drilling into the member with an electric drill. Inspection during boring includes noting depths where drilling becomes easier and inspecting shavings for signs of decay. Coring is the removal of a solid small diameter core for evaluation of decay.

Probing Probing is conducted with a pointed tool, such as an awl, screwdriver, pick, or knife, to identify decay near the wood surface. Degradation is indicated by excessive softness and reduced resistance to probe penetration. 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.

Pick Testing The pick test is used for detecting surface decay by driving a pointed pick, awl, or screwdriver into the wood to pry out a sliver. The wood break is examined to determine if the break is brash (decayed) or splintered (sound). Sound wood has a fibrous structure and splinters when broken across the grain. Decayed wood breaks abruptly across the grain or crumbles into small pieces. Several studies indicate that the pick test is reasonably reliable for detecting surface decay. This method is destructive and thus should not be conducted unless interior decay (Poor or worse condition rating) is suspected.

Interior deterioration is difficult to detect without the aid of sophisticated non-destructive techniques such as X-ray and sonic evaluation devices, or destructive methods such as coring or drilling. However, sounding with a hammer can be used to detect advanced interior decay. Additional information regarding agents of wood deterioration, and methods for detecting interior and exterior deterioration can be found in the United States Department of Agriculture Forest Service publication *Timber Bridges: Design, Construction, Inspection, and Maintenance*.

Connections

Connections must be checked for signs of potential capacity loss. Common issues with joints include deteriorated or missing bolts/fasteners, and local defects in the wood material at load transfer zones. Timber connections made with steel plates must also be checked for degradation. This includes surface rust and pack rust. Pack rust is a form of corrosion that occurs in metallic crevices and joints between the plate and the connected element. Pack rust can cause bulging and deterioration of the connection plate which can significantly reduce its structural capacity.

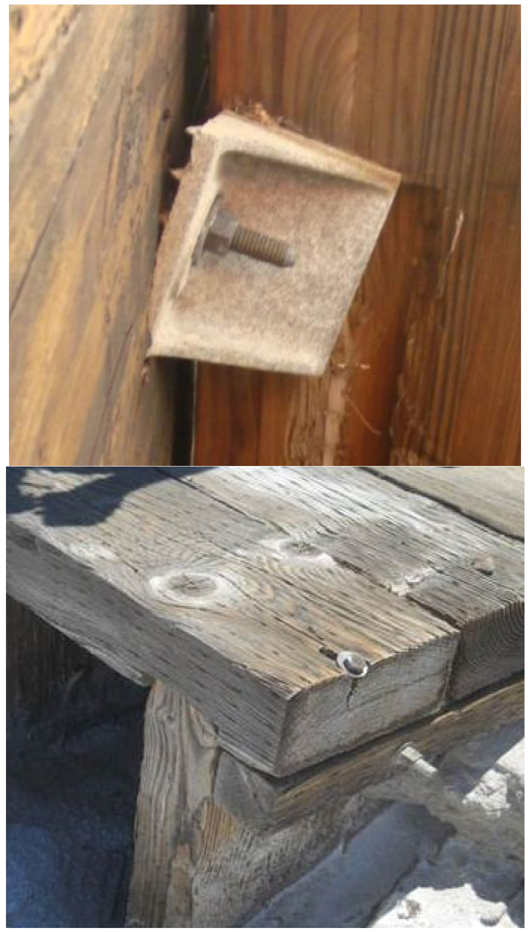

Figure 4.13.2-1—Connection Bent/Loose Possibly Due to Overload or Movement of Structure

(Photos courtesy of New York Department of Transportation (top) and Simpson Gumpertz & Heger, Inc. (bottom))

Missing Members

Missing members may be due to structural failure of the member or its connection, or impact from stream or ice flows. Other activities such as installation of utilities or structure modifications may remove a member in whole or part (i.e., notched or cored beam for utility conduit).

Figure 4.13.2-2—Connection Failure Causing Partial Collapse of Member and Missing Members Allowing Loss of Backfill
(Photo courtesy of Colorado Department of Transportation)

Decay

Visual inspection for decay requires good lighting and is suitable for detecting intermediate or advanced surface decay. It will not detect decay in the early stages, when control is most effective, nor will a visual inspection reveal internal decay. Consequently, visual inspection should never be the sole method employed. Decay indicators should be sounded and probed to assess the extent of decay. Some common decay indicators include fruiting bodies, sunken faces, staining or discoloration, insect activity, and fire damage.

Figure 4.13.2-3—Decay on Timber Culvert Member near Ground Level
(Photo courtesy of Simpson Gumpertz & Heger Inc.)

Fruiting Bodies

Fruiting bodies are the reproductive spores of fungi that form on the surface of wood. Fruiting bodies are found in a variety of shapes such as cap-and-stem mushrooms or shelf-like, antler-like, coral-like, cage-like, trumpet-shaped, or club-shaped fungi. Fruiting bodies provide positive indication of advanced fungal attack, but do not indicate the amount or extent of decay. Some species of fungi produce fruiting bodies after small amounts of internal decay have occurred, while others develop only after decay is extensive. Fruiting bodies almost certainly indicate serious decay problems when they are present.

Figure 4.13.2-4—Fruiting Bodies on Timber Culvert Members
(Photo courtesy of California Department of Transportation)

Sunken Faces
Sunken faces or localized surface depressions can indicate underlying decay. Sunken faces occur when a thin layer of intact or partially intact wood forms a depression over voids or pockets near the surface of the member.

Staining or Discoloration
Staining and discoloration are indicators of potential decay. Members with staining have been subjected to water and potentially high moisture contents and stained areas may mean conditions are suitable for decay. Rust stains on a member face may indicate wetting-induced deterioration of the connection hardware. These areas should be noted for future monitoring.

Figure 4.13.2-5—Staining and Sunken Faces on Timber Culvert Members
(Photo courtesy of Colorado Department of Transportation)

Insect Activity
Insects can bore into wood structures and weaken members. Insect activity is visually indicated by signs of holes in members, or the presence of powder. Typical insects that threaten wood culverts include ants, termites, beetles, worms, and marine borers.

Fire Damage
The extent of any charring and fire damage should be noted by the Inspector. Large wood members often retain structural strength after fire damage and an in-depth inspection by an Engineer is required to determine the residual capacity or to design for repair or replacement.

Figure 4.13.2-6—Fire Charring on Timber Culvert Members
(Photo courtesy of Colorado Department of Transportation)

Checks and Shakes

Checks
Checks are shrinkage cracks that occur along the radius of solid sawn timber, usually perpendicular through the growth rings. Checks can be seen along the face of members and are typically not a structural problem as they are accounted for in the engineering design values for strength. Severe checking at connections can weaken the ability of fasteners to carry load and should be flagged during inspections.

Figure 4.13.2-7—Checks in Timber Culvert Member
(Photo courtesy of Simpson Gumpertz & Heger Inc.)