1. Standard for Rail Transit Structure Inspection and Maintenance

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APTA Rail Transit Standards Fixed Structures Inspection and Maintenance Committee

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Abstract: This standard provides general requirements for the periodic inspection of safety critical components of rail transit structures, including bridges, tunnels, and ancillary structures, retaining walls, culverts, barrier (crash) walls, communication towers, and catenary structures. This standard defines the minimum means, methods, and frequency of inspection and maintenance activities, and the qualifications that rail transit employees or contractors must have to perform these procedures. This standard provides both a rating system for safety critical components and record keeping requirements.

Keywords: ancillary structures, barrier walls, bridges, catenary structures, communication towers, crash walls, culverts, inspection, maintenance, periodic inspection and maintenance, retaining walls, safety, structures, transit structures, tunnels
Introduction

(This introduction is not a part of APTA RT-FS-S-001-02, Standard for Rail Transit Structure Inspection and Maintenance.)

APTA rail transit safety standards represent an industry consensus on safety practices for rail transit systems to help achieve a high level of safety for passengers, employees, and the general public. This document was created by and for those parties concerned with its provisions; namely, rail transit systems (operating agencies), manufacturers, consultants, engineers, and general interest groups. This standard provides procedures for inspecting and maintaining rail transit structures.

APTA recommends this standard for:

– Individuals or organizations that inspect, maintain, and/or operate rail transit systems
– Individuals or organizations that contract with others for the inspection, maintenance, and/or operation of rail transit systems
– Individuals or organizations that influence how rail transit systems are inspected, maintained, and/or operated (including but not limited to consultants, designers, and contractors)

This standard intends to meet the following objectives:

– To ensure special life/safety equipment is operational and reliable
– To help rail transit systems incorporate safety considerations during the inspection and maintenance process
– To identify inspection criteria and maintenance standards that provide a high level of passenger and personnel safety

The application of any standards, practices, or guidelines contained herein is voluntary. In some cases, federal and/or state regulations govern portions of how a rail transit system operates. In such cases, the government regulations override any conflicting practices this document requires or recommends.
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Standard for Rail Transit Structure Inspection and Maintenance

1. Overview
This document establishes a standard for inspecting and maintaining rail transit system structures.

1.1 Scope
The scope of this standard includes all fixed facilities that support or carry loads. This includes bridges, tunnels and ancillary structures, retaining walls, barrier (crash) walls, communication towers and culverts.

This standard applies to rail transit systems that operate light rail or heavy rail systems. The standard does not apply to commuter railroads that operate on the general railroad system regulated by the Federal Railroad Administration (FRA).

1.2 Purpose
The purpose of this standard shall establish, through broad-based industry participation and consensus, minimum requirements for inspections and maintenance of rail transit system structures to ensure the safety of the traveling public and transit system employees and to ensure the continued performance of rail transit infrastructure. This standard includes a listing of all structure types to be inspected, the frequencies of such inspections and the qualifications of rail transit system employees or contractors who perform these inspection and maintenance activities.

1.3 Alternate practices
Individual rail transit systems may modify the practices in this standard to accommodate their specific equipment and mode of operation. APTA recognizes that some rail transit systems may have unique operating environments that make strict compliance with every provision of this standard impossible. As a result, certain rail transit systems may need to implement the standards and practices herein in ways that are more or less restrictive than this document prescribes. A rail transit system (RTS) may develop alternates to the APTA standards so long as the alternates are based on a safe operating history and are described and documented in the system’s safety program plan (or another document that is referenced in the system safety program plan).

Documentation of alternate practices shall:

a) Identify the specific APTA rail transit safety standard requirements that cannot be met
b) State why each of these requirements cannot be met

c) Describe the alternate methods used

d) Describe and substantiate how the alternate methods do not compromise safety and provide a level of safety equivalent to the practices in the APTA safety standard (operating histories or hazard analysis findings may be used to substantiate this claim).

2. References

This standard shall be used in conjunction with the most recent versions of the following publications:

23 CFR 650, Subpart C, National Highway Bridge Inspection Standards.
29 CFR, OSHA Standards.
29 CFR, OSHA Standards, Subpart T.
AASHTO Manual for Maintenance Inspection of Bridges, prepared by the Highway Subcommittee on Bridges and Structures for the American Association of State Highway and Transportation Officials.
ANSI/AWS D1.1.
ANSI/AWS D1.5.
AREMA Fatigue Standards.
AREMA Manual for Railway Engineering, Chapter 9, Part 1, Section 1.2.
AREMA Manual for Railway Engineering, Chapter 9, Part 1, Section 1.5.
FHWA Bridge Inspectors Training Manual 90.
FHWA Bridge Inspectors Training Manual 90, Chapter 17.
FHWA Inspection of Fracture Critical Bridge Members.
FHWA Manual for Moveable Bridge Inspection.
FHWA Manual on Uniform Traffic Control Devices.
3. Definitions and acronyms

For the purposes of this standard, the following definitions and acronyms apply:

3.1 Definitions

3.1.1 rail transit system (RTS): The organization or portion of an organization that operates rail transit service and related activities. Syn: operating agency, operating authority, transit agency, transit authority, transit system.

3.1.2 rail transit system engineer: A licensed professional engineer that is authorized by the rail transit system to exercise engineering judgment, make technical decisions with regard to the fixed transit guideway structures, and to direct qualified staff, engineering consultants, or other qualified specialists to perform work. The rail transit engineer does not have to be a direct employee of the owner.

3.1.3 fixed structure: A structure used by rail transit systems for the purpose of providing transit services.

3.1.4 owner: The legal entity that retains the right to construct and operate a transit system.

3.2 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of Highway Transportation Officials</td>
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<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
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<tr>
<td>APTA</td>
<td>American Public Transportation Association</td>
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<td>AREMA</td>
<td>American Railway Engineering and Maintenance Association</td>
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<tr>
<td>AWS</td>
<td>American Welding Society</td>
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<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
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<tr>
<td>FCM</td>
<td>fracture critical members</td>
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<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
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<tr>
<td>FRA</td>
<td>Federal Railroad Administration</td>
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<tr>
<td>NICET</td>
<td>National Institute of Certification in Engineering Technologies</td>
</tr>
<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
</tr>
<tr>
<td>RTS</td>
<td>rail transit system</td>
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</tbody>
</table>

4. Inspection practices

4.1 Inspection manual

Rail transit systems shall develop structural inspection manuals with the following sections:

a) Organization
   - Job descriptions
   - Qualifications
   - Responsibilities
b) Policies
   - Personnel
   - Inspection
   - Maintenance
   - Safety
   - Reports, plans and files

c) Coordination
   - Internal interfaces
   - External interfaces

d) Quality assurance/quality control

e) Inspection procedures

f) Planning and scheduling

g) Inventory

h) Inspection type

i) Documentation

Comment: Each RTS shall obtain inspection manuals used by the state or states they operate in. These are necessary for inspecting/documenting “highway” grade separations that cross the property that they may own/maintain.

**4.2 Condition ratings**

Each RTS shall establish a rating system pertaining to its structures which is both compatible with their maintenance planning and scheduling and with any outside agencies they must coordinate with. If they have a computerized maintenance system, the rating system must be structured to input into that system.

The inspectors must be trained to uniformly apply the rating system when performing the inspections. The rating system shall cover the structures and components listed in Sections 4.2.1-4.2.5.
4.2.1 Bridges

a) Substructure
   - Timber
   - Concrete
   - Masonry
   - Steel
   - Earth retention systems

b) Superstructure
   - Type
     1. Truss
     2. Multi girder
     3. Box girder
     4. Arches
     5. Slab
     6. Movable
     7. Rigid frame
     8. Suspension
     9. Cable stayed
   - Material
     1. Steel
     2. Timber
     3. Concrete
     4. Prestressed concrete
     5. Masonry
- Other
  1. Bearing
  2. Joints
  3. Coating system
  4. Special connections (pin-hangers)

  c) Decks
     - Materials
       1. Concrete
       2. Steel
       3. Timber
          - Parapets
          - Railings
          - Walkways
          - Appendages
       4. Drainage
       5. Lighting
       6. Utilities (hangers and connections)
       7. Noise suppression systems

4.2.2 Tunnels

  a) Materials
     - Steel
     - Concrete (cast in place)
     - Concrete (pre-cast)
     - Unlined
b) Special subsystems
   - Drainage
   - Floating slab
   - Wall penetrations (doors, pipe, etc.)
   - Ventilation shafts

4.2.3 Culverts
   a) Materials
      - Concrete (cast in place / pre-cast)
      - Metal
      - Masonry

4.2.4 Waterway
   a) Scour
   b) Channel protection

4.2.5 Ancillary structures

4.3 Load rating

Load ratings are not required as part of a scheduled inspection for guideway structures. However, a structural load rating shall be performed if any of the following conditions exists:

   a) Significant deterioration of the primary structural members is discovered during a visual inspection.

   b) Current live loads (axle weight or configuration) are substantially different from the original design live load.

   c) Undocumented structural modifications are discovered during inspection, which may potentially alter or inadvertently reduce the load carrying capacity of a guideway.

The rail transit system engineer will determine the need for, and will be in charge of any mandated load ratings. If a determination is made that load ratings are needed, then they shall be prepared using the latest version of the rail transit system’s design criteria. The completed load rating shall be referenced in the corresponding inspection report, and be disseminated according to established documentation procedures.
4.4 Fatigue

The objective of these requirements shall establish an inspection procedure that will mitigate the potential for fatigue-related failures. An analysis of each structure is required to determine fracture critical members (FCM). Per the National Bridge Inspection Standards, each RTS shall prepare a fracture critical member file for each bridge structure. These files shall become part of the structures permanent file.

The routine inspection of transit guideways shall include the following program of activities:

   a) The rail transit system’s engineer shall identify all of the fatigue sensitive details throughout the transit guideway. The identified details shall be classified as fatigue-sensitive based on AASHTO requirements, which includes an evaluation based on the actual stress range and estimated number of cycles that each detail has been subjected to. This inventory and classification of fatigue-sensitive details will require careful consideration, recognizing that some susceptible details may be excluded from the fatigue-sensitive classification because they are subjected to low levels of stress or a small number of cycles. Also, the fatigue-sensitive determination is time dependent, meaning that, as cycles accumulate; additional details may be reclassified as fatigue-sensitive.

   b) The rail transit system’s engineer shall also identify all of the fracture critical members, as defined by FHWA Inspection of Fracture Critical Bridge Members. If possible, this inventory shall establish which fracture critical members were fabricated in compliance with AASHTO’s applicable requirements.

   c) Using the compiled inventory of fatigue-sensitive detail and fracture critical members, the rail transit system’s engineer shall train Inspectors to examine these details and structural members for potential deficiencies. If special equipment or testing procedures are called for, then the Inspectors shall be trained to use this equipment, or the inspection program shall include provisions to retain the services of certified specialists to perform the work.

   d) At a minimum, the fatigue-sensitive details and fracture critical members shall be examined during each routine inspection of the guideway structure.

   e) The inspection findings for the fatigue-sensitive details and fracture critical members shall be included in the corresponding inspection reports, which shall be disseminated according to established documentation procedures.

Comment: AREMA fatigue standards may be utilized instead of AASHTO standards at the option of the RTS.

4.5 Seismic

The requirements for seismic inspection are presented using an incremental two-step approach
which, based on a rational assessment of seismic risk, shall accommodate the needs of each RTS.

Under the direction of the rail transit system’s engineer, each RTS shall perform an inventory in accordance with AREMA Chapter 9, Part 1, Section 1.5 to determine the degree to which all the transit guideway structures are susceptible to seismic loads.

This inventory shall be compiled in a report that is disseminated according to the established documentation procedures.

Following the determinations made during the existing structure inventory, each owner shall prepare “Post-Seismic Event Operation Guidelines” in accordance with AREMA Chapter 9, Section 1.2. Once completed, this self-contained manual shall be readily available to the rail transit system’s engineer, as well as operations and maintenance personnel, to be used as an immediate source of reference information.

4.6 Structural damage diagnosis techniques

The RTS shall have on staff, or contract for the services of qualified personnel who perform routine visual inspections of structural elements. In the event that structural damage or failures are found through visual examination, additional testing may be required.

4.6.1Routine testing

Inspection teams shall routinely use nondestructive testing such as thickness measurement instruments to help determine loss of section and dye penetrants to help locate and define cracks in steel. All testing shall be performed per industry standards.

4.6.2Additional testing

Destructive material testing may be required once a problem has been identified and further study may be needed to determine its severity and extent. The rail transit system’s engineer may direct destructive testing of structural components to predict or determine failure modes. Removing a sample of steel for lab tests to determine fatigue vulnerability or material properties would be an example of destructive testing. For concrete structures, destructive testing may include such tests as petrographic analysis or winsor probe testing.

Other types of tests may be include use of specialized equipment for ultrasonic or X-ray examination of steel members or weldments.
4.7 Underwater inspection

If applicable, each RTS shall perform underwater structural inspection at no more than 5-year intervals or more frequently as determined by a scour vulnerability analysis outlined by applicable FHWA publications. Underwater inspections involve visually or tactually inspecting all the exposed underwater components of each bridge, utilizing appropriate tools and methods. This includes but is not limited to abutments, piers, footings, piles, fender systems, and channel scour problems. This work shall be performed in conformance with applicable OSHA regulations, Subpart T and as described in the Bridge Inspectors Training Manual '90, Chapter 17 and the FHWA manual.

Underwater inspections shall be performed on any qualifying structure where the water depth around any of the substructure units is normally greater than 1 meter and inspection using hip boots is impossible or impractical because of water depth, current, soft bottom conditions, etc.

Underwater inspection reports shall contain pertinent information as required by FHWA Manual and the Bridge Inspectors Training Manual 90.

4.8 Inspection implementation

Before beginning the inspection, the inspection team shall study the structure file and as-built plans carefully to determine locations and level of criticality for the inspection. In addition, an assessment shall be made of the following: the potential for fatigue damage based upon the loading history, the fatigue prone details, records of damage and records of past repairs.

The inspection intensity is based on the criticality of the structural element. Certain fatigue-prone details on fracture critical members require a close up, hands on, visual examination. Inspectors shall understand the importance of redundancy in a structure. They shall take into account the age of the bridge and the material characteristics when it was constructed.

A hands-on inspection shall be performed on all fracture critical members. The inspection shall focuses on tension zones of fracture critical members and fracture critical connections. All details identified as “prone-to-cracking,” such as details with a potential for fatigue damage, shall be checked very closely. The inspector’s view shall be clear, unobstructed, well illuminated and within an arms length, of the structural member. The member shall be viewed from all sides and all angles. Additional light, magnification, and nondestructive testing equipment shall be used when needed.

Welded girders, insert plates, cover plate ends, and unground welds are susceptible to fatigue crack initiation. Reentrant corners and web gaps can also initiate fatigue cracks. Inspectors shall recognize problems caused by secondary stresses such as out-of-plane bending at diaphragm and floorbeam connections, particularly on skewed bridges. Other points of localized stress concentration and potential crack initiation are tack welds, intermittent nicks, scars, and holes with rough edges.
Special attention shall be given to truss spans. Inspectors shall safely position themselves on truss spans so that members and connections may be examined from all angles. If debris is present, the surface must be cleaned and scraped if necessary. Compression members shall be checked for buckling. Deformations, twisting or eccentricity is also to be documented. Tension members shall be checked for flaws, welding, tears, cracks or “necking down” of section. Each member and connection shall be checked for loose or missing bolts or rivets, for corrosion and section loss, and for collision damage. If a suspicious problem is identified, but its significance cannot be determined with the equipment at the disposal of the inspector, appropriate follow-up testing and consultation with the rail transit system engineer is required.

The following procedures shall be performed routinely, but may be adjusted based on special requirements.

a) Verify dimensions and member sizes using thickness gauges to determine if there is section loss due to corrosion. If a bridge has been repainted, corrosion-related section loss may not be obvious. Document deviations, modifications, or repairs with an estimate of their age.

b) Concrete elements shall be sounded and checked for cracks, scaling, spalling, or other deterioration that might indicate a loss in strength.

c) Check steel members for corrosion, cracking, or deformities with particular emphasis on locations prone to fatigue, brittle fracture, or stress corrosion. Perform dye penetrant tests at suspicious locations.

d) Concrete decks shall be inspected and sounded, top and bottom, to identify delamination and moisture penetration.

e) Check devices that facilitate movement to ensure that they are functioning properly.

f) Bearings and deck joints are also to be checked. Document opening or position relative to ambient temperature. This data shall be used to identify excessive movement or frozen bearings.

g) Substructure units shall be sounded and checked for settlement. Probe foundations for scour and undermining.

Inspector safety is an important consideration. Procedures shall be carefully planned for each project. Inspectors shall be familiar with, and follow, OSHA regulations related to fall protection, underwater safety, confined space restrictions, and exposure to toxic materials around bridges such as creosote and bird droppings.

Each RTS shall establish policies to address routine maintenance needs identified in the inspection process.

Each RTS shall establish emergency procedures to respond to the finding of critical conditions during routine inspections.

4.9 Inspection staff qualifications
4.9.1 Review engineer

The review engineer as defined in Section 5.2.3 shall possess the following minimum qualifications:

a) Be a registered professional engineer; or be qualified for registration as a professional engineer under the laws of the state the property/structure is located in; and

b) Have experience in the design and/or inspection of system structures.

4.9.2 Structural inspection team leader

The individual in charge of the structural inspection team shall possess the following minimum qualifications:

a) Have the qualifications specified in section 4.9.1; or possession of a 4 year related technical degree; or

b) Possession of a two year technical degree and have a minimum of five years experience or 10 years experience in structural inspection assignments in a responsible capacity and,

c) Current certification as a Level II, III or IV Bridge Safety Inspector under the National Society of Professional Engineer’s program from NICET or equivalent NICET certification.

4.9.3 Inspectors

The individual inspectors must have the following minimum qualifications:

a) High school diploma and extensive background in ironwork, welding or concrete construction; and

b) Must have successfully completed a comprehensive training course based on the Bridge Inspectors Training Manual 90.

5. Inspection controls

5.1 Frequency

Inspections shall be performed at intervals as indicated for the following structures. Additionally, special inspections shall be performed as directed by the rail transit system’s engineer following extraordinary events such as major flooding, collisions, fire and seismic occurrences.

5.1.1 Bridges (elevated structures)

Each bridge shall be inspected at regular intervals at least once every 2 years.

Certain types or groups of bridges will require inspection at an interval more frequent than once every 2 years. The intensity and frequency to which a bridge shall be inspected will be determined by factors such as age, state of maintenance, and known deficiencies. The evaluation
of these factors will be the responsibility of the review engineer.

**5.1.2 Ventilation shafts**

Ventilation shafts shall be inspected at intervals at least once every 2 years. However certain safety elements such as stairs gratings at street level, spalled concrete areas, etc. shall be inspected more frequently- as determined by the review engineer.

**5.1.3 Tunnels**

Each tunnel, including penetrations such as doors and pipes, shall be inspected at regular intervals at least once every 5 years. However, certain types of structures such as old tunnels or underwater tunnels shall be inspected every 2 years or at more frequent intervals. Such intervals shall be determined by the review engineer.

**5.1.4 Barrier walls**

Barrier walls shall be inspected at regular intervals at least once every 5 years.

**5.1.5 Culverts**

Culverts shall be inspected at regular intervals at least once every 5 years. Scour susceptibility may require a more frequent interval.

**5.1.6 Pier protection**

Pier protection shall be inspected at regular intervals at least once every 5 years.

**5.1.7 Retaining walls**

Retaining walls shall be inspected at regular intervals at least once every 5 years.

**5.1.8 Special structures**

Special structures such as catenary structures and communication towers, etc. shall be inspected at intervals determined by the review engineer.

**5.2 Documentation**

**5.2.1 Structure and defect database**

A computerized database consisting of the structural inventory and the inspection frequency, dates and condition rating of all structural elements that make up the various structures included in Sections 4.2 and 5.1 shall be maintained.

**5.2.2 Report format**

A structural inspection report, which identifies the asset, documents the inspection, date, name of inspector and conditions of structural elements shall be maintained.
5.2.3 Engineering review

Inspection reports shall be reviewed by the review engineer for final determination of condition and recommendation for mitigation as necessary. The review engineer will be responsible to assure inspection reports are complete and consistent with good inspection practices.

5.2.4 Document control

Permanent files shall be established for all structures. Each file shall contain all pertinent drawings, inspection records, records of maintenance and repair work.

5.2.5 QA/QC program

A quality assurance/quality control program shall be provided to assure that all structures are being adequately inspected at the required frequency and that complete documentation is being provided according to proper procedures.

6. Maintenance

6.1 Qualifications

6.1.1 Welding

Welders, welding operators, and tack welders shall be qualified based upon the certification requirements of ANSI/AWS D1.1 and D1.5 as required by application. Each RTS or contractor shall be responsible for the qualification of welders.

6.1.2 Safety

Individuals involved in the maintenance of structures shall be trained and qualified per the system safety plan of the RTS.

6.1.3 General qualifications

The RTS shall hire, or contract for service, individuals who are trained and competent to maintain structural systems at a level consistent with the RTS guidelines and performance criteria.

6.2 Maintenance items

6.2.1 Coatings

The person in charge of structure maintenance shall establish a maintenance schedule for each type of coating system (paint, elastomeric membrane, etc.) based upon the life expectancy of the coating.

6.2.2 Drainage

Drainage system maintenance shall be performed on a scheduled to assure compliance with original design considerations and in response to deficiencies noted in inspection reports.
6.2.3 Joint sealing

Joint seals shall be maintained periodically to perform as designed and in response to deficiencies noted in inspection reports.

6.2.4 Bearings

Bearings shall be maintained per manufacturers’ recommendations and in response to deficiencies noted in inspection reports.

6.2.5 Sealing concrete

Sealing of concrete shall be scheduled to prevent corrosion or deterioration associated with water penetration and in response to deficiencies noted in inspection reports.

6.2.6 Cleaning

Structures shall be cleaned to prevent corrosion and drainage problems. This shall be done in accordance with a schedule established by the individual in charge of structure maintenance. Cleaning of structures for aesthetic purposes shall be determined by the RTS.

6.2.7 Vegetation

Vegetation shall be removed from structures in order to provide a clear view for the inspection of structural elements.

6.2.8 Stray current control

See APTA RT-S-FS-005-03, Standard for Traction Electrification Stray Current/Corrosion Control Equipment Inspection and Maintenance.

6.3 Frequency

A plan shall be established by the RTS for frequency of maintenance.

6.4 Documentation

When deteriorated structural elements are repaired or replaced, an entry indicating the new element condition shall be made in the inspection records called for in Section 5.2.1.

6.5 Inspection/maintenance record review

Inspection records shall be reviewed periodically by the person in charge of structure maintenance to assure compliance with the program and, in particular, that all high priority defects have been addressed.
Annex A

(informative)

Bibliography

