ARIZONA DEPARTMENT OF TRANSPORTATION

BRIDGE GROUP

TUNNEL INSPECTION GUIDELINES

BRIDGE INSPECTION SECTION

Table of Contents

APPENDIX

TUNNEL INSPECTION GUIDELINES

CHAPTER 1. INTRODUCTION

1.1 History

Following the tragic ceiling collapse in the Interstate 90 Connector Tunnel in Boston, Massachusetts on July 10, 2006, the National Transportation Safety Board's Highway Accident Report, NTSB Number HAR-07/02, identified several safety issues including, "*Inadequate regulatory requirements for tunnel inspections*". On July 6, 2012, the President signed the Moving Ahead for Progress in the 21^{st} Century Act (MAP-21), which requires the Secretary to establish national standards for tunnel inspections.

Specifications for the National Tunnel Inventory (SNTI) document was published in July 2015 by FHWA in coordination with the National Tunnel Inspection Standards (NTIS) regulation 23 CFR 650 Subpart E and the Tunnel Operations, Maintenance, Inspection and Evaluation (TOMIE) Manual.

Tunnel is defined per SNTI as "an enclosed roadway for motor vehicular traffic with vehicle access limited to portals, regardless of type of structure or method of construction. Tunnels do not include bridges or culverts inspected under the National Bridge Inspection Standards (23 CFR 650 – Subpart C – National Bridge Inspection Standards). Tunnels are structures that require, based on owner's determination, special design considerations that may include lighting, ventilation, fire protection systems, and emergency egress capacity."

On November 6, 2020 FHWA issued a memorandum regarding inspection of non-structural tunnel elements located above roadways. In that memorandum, the National Transportation Safety Board (NTSB) made two recommendations:
1. It is important to inspect, document, and promptly repair significant corrosion in non-structural tunnel elements located above roadways.
2. Classify significant corrosion in non-structural tunnel elements located above roadways as a critical finding that requires immediate action.

See Appendix E for the memorandum and Appendix F for the flow chart and Significant Findings Form.

ADOT currently has 6 active tunnels meeting the above definition in its tunnel inventory database. It is expected that this number will increase with passage of time.

1.2 Purpose

The tunnel inspection program is designed to meet federal inspection requirements and the State's responsibilities. The program manager is responsible for:

1. Conducting inspections with qualified teams on a timely manner

2. Submittal of the inspection reports within reasonable time after the inspections

3. Providing guidance on the tunnels maintenance

4. Maintaining the tunnel inventory and reporting system

5. Submittal of the tunnel inspection data to FHWA on annual basis

6. Maintaining quality control and quality assurance (QC/QA) in the tunnel inspection program

CHAPTER 2. INSPECTION

2.1 - Introduction

Prior to 2015, ADOT inspected its tunnels as bridges with NBI item 43b (Main Structure Type, Design) coded as “18” (Tunnel). Since then, the tunnels have been inspected with appropriate tunnel elements under 2015 NTIS. ADOT currently collects and maintains tunnel inventory and inspection data, addresses critical findings, and maintains a registry of certified tunnel inspectors within its jurisdiction. Reports and electronic files are generated to document the actions taken in response to the inspection findings. Health and safety procedures are in-place to protect the inspection team, tunnel facility personnel, and the users of the tunnel facility.

Some of the responsibilities of ADOT tunnel inspection program include:

• Establishing written policies and procedures.

• Maintaining tunnel inventory and inspection data.

• Regularly reporting NTI data to the FHWA.

• Maintaining qualification records of personnel including national inspector certification.

• Establishing an effective quality control and quality assurance program.

2.2 Inspection

2.2.1 - Inspection Types

NTIS identifies several types of inspections that are regularly performed on highway tunnels similar to bridge inspection program. These inspections include initial, routine, damage, in-depth, and special inspections for tunnels. See Table 2.2.1 for tunnel inspection types.

2.2.1.1 - Initial Inspection

An initial inspection should be performed on existing highway tunnels within the interval specified in the NTIS. On new tunnels, the initial inspection should be conducted after the completion of construction activities and the testing of functional systems but prior to opening the tunnel to traffic. At a minimum, the initial inspection should consist of a sufficient number of observations and measurements to determine the physical and functional condition of the tunnel. These inspections are intended to be comprehensive covering the structural, civil, mechanical, electrical and lighting, fire and life safety, security, signs, and protective systems. The results are to be recorded in accordance with the instructions contained in the SNTI. The initial tunnel inspection establishes the baseline conditions of the tunnel; and it is used to field verify the initial tunnel inventory data. The baseline results can be used to evaluate changes over time to the tunnel systems and to help identify trends.

2.2.1.2 - Routine Inspection

Following the initial inspection, routine inspections are conducted within the intervals specified in the NTIS. Routine inspections are regularly scheduled inspections that help to ensure continued safe, reliable, and efficient service. These inspections are similar in scope to the initial bridge inspections. Routine tunnel inspections record the changes to the tunnel over time and can be used to help identify trends and predict future life expectancy of components. At a minimum, routine inspections consist of a sufficient number of observations and measurements that can be used to determine the physical and functional condition of the tunnel. These inspections are intended to be comprehensive covering the structural, civil, mechanical, electrical and lighting, fire and life safety, security, signs, and protective systems. The results are to be recorded in accordance with the instructions contained in the SNTI.

2.2.1.3 - Damage Inspection

Damage inspections are performed in response to natural disasters or human activities that damage the tunnel. Damage may occur by motor vehicle impact, fire, flood, earthquake, vandalism or explosions. When severe damage occurs, the tunnel should be closed and remain as such until a damage inspection has been completed and the damage is fixed. Structural analysis and follow-up emergency repairs may be needed. Structural materials may need further evaluation as identified in the Manual for Bridge Evaluation (MBE). Safety is of paramount importance after an incident. Devices such as breathing apparatus, protective clothing, and specialized equipment may be necessary. Inspection work should be coordinated with emergency responders. It is important that the tunnel inspection organization develop detailed plans and conduct training exercises with tunnel facility personnel in advance of these events.

2.2.1.4 - In-depth Inspection

In-depth inspections are close-up, hand-on inspections conducted on one, several, or all of the elements or functional systems. These inspections are used to identify deficiencies that are not readily detectable during initial, routine, or damage inspections. In-depth inspections may involve testing of tunnel system, components, and materials. More extensive disassembly and cleaning of equipment parts may occur. This type of inspection may be used to support a structural analysis or a functional system evaluation where more information is needed. In-depth inspections are scheduled based on the needs of the tunnel facility, inspection findings, and established written procedures.

2.2.1.5 - Special Inspection

A special inspection is typically performed after an initial, routine, damage or in-depth inspection when significant deficiencies have been discovered and need to be monitored. Special inspections are scheduled based on the needs of the tunnel facility, inspection findings, and established written procedures. These types of inspections continue, but perhaps at adjusted intervals or durations, until the deficiency is repaired, the component is removed from service, or further study determines that the conditions are no longer deteriorating at accelerated levels. For example, a light fixture built of dissimilar metals and installed over traffic might have problems with excessive corrosion. As such, this light fixture may be monitored on a regular basis to ensure that it remains securely anchored and safe until repairs can be made.

Table 2.2.1– Types of highway tunnel inspections

Inspection Type	Purpose
Initial	Establish the inspection file record and the baseline conditions for the tunnel.
Routine	Comprehensive observations and measurements performed at regular intervals.
Damage	Assess damage from events such as impact, fire, flood, seismic, and blasts.
In-Depth	Identify hard-to-detect deficiencies using close up inspection techniques.
Special	Monitor defects and deficiencies related to safety or critical findings.

Source: Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual

2.2.2 - Inspection Frequencies

The interval requirements for initial inspection and routine inspections are contained in the NTIS. Table 2.2.2 summarizes these requirements. ADOT is responsible for establishing the inspection intervals for in-depth inspections based on the particular needs of the tunnel facility. Special and damage inspections are performed on as needed basis.

Table 2.2.2 – Interval period contained in the National Tunnel Inspection Standards

Inspection Type	Application	Interval
Initial	New tunnel Prior to opening to traffic to the public.	Existing tunnel Within 24 months of NTIS effective date.
Routine	Default condition	Every 24 months over lifetime of the tunnel.
	Approved written justification	Possibly allow extension up to 48 months.
In-depth	Complex tunnels and for certain structural and functional systems.	Level and frequency to be established by the program manager.

Source: Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual

2.2.3 - Inspector Qualifications

The program manager and the team leader are specifically identified in the NTIS; other inspection personnel have been discussed in this chapter to include discipline specific specialists and field inspectors. ADOT may use specialized contract inspectors to assist with complicated or sophisticated tunnel systems. In accordance with the NTIS, an independent assessment is desired; therefore, the operating and maintenance personnel should not be used for inspection purposes.

2.2.3.1 - Program Manager

The program manager is the individual in charge of the tunnel inspection program for State of Arizona. ADOT currently has six active tunnels in its inventory database. The program manager must be capable of leading the tunnel inspection organization and ensuring that the requirements of the NTIS are fulfilled. The program manager may delegate duties and responsibilities to qualified delegates who take charge of a particular subset of tunnels; however, the program manager remains responsible for ensuring compliance. The program manager develops written procedures, schedules inspections, procures inspection and safety equipment, coordinates with tunnel facility staff, and advises the team leader as necessary. Ideally, the program manager should have a general understanding of all aspects of tunnel engineering including design, construction, operation, maintenance, inspection, evaluation, load rating, and rehabilitation. Good judgment is essential for this position in order to respond appropriately to safety and structural concerns within the tunnel. Refer to the NTIS for the complete requirements of this position. The program manager must be a registered professional engineer or have at least 10 years of tunnel or bridge inspection experience. This individual must also be a nationally certified tunnel inspector, which requires comprehensive training, end-of-course assessment, and periodic refresher training.

2.2.3.2 - Team Leader

The team leader is the person on-site who is in charge of the inspection team. This person is responsible for inspection planning, preparing, performing and reporting to include coordinating the field work. Refer to the NTIS for the complete requirements. The team leader is responsible for evaluating the deficiencies, quality checking of the inspection data, and making sure that the inspection reports are complete, accurate, and legible. The team leader should also conduct safety briefings as needed. The team leader should be able to provide recommendations for the repair of defective items and must initiate appropriate actions when critical findings are discovered. A team leader must be a nationally certified tunnel inspector. Additionally, the team leader is expected to meet at least one of the following:

- Registered professional engineer and at least 6 months of tunnel or bridge inspection experience.
- 5 years of tunnel or bridge inspection experience.
- Appropriate combination of education and experience as described in the NTIS.

In addition to the minimum requirements stated above, the team leader should be a professional engineer when the tunnel is complex or if it has distinctive features or functions. Team leaders must be on site at all times for initial inspections, routine inspections, and in-depth inspections.

2.2.3.3 - Inspection Assistance from Discipline Specific Specialist and Field Inspectors

Discipline Specific Specialist: When complex civil/structural, mechanical, or electrical systems need to be inspected, the team leader should assign discipline specific specialists with suitable training and experience to help conduct these inspections. Ideally, these specialist individuals should be registered professional engineers or at least engineers-in-training.

Field Inspectors: Field inspectors assist the team leader with the inspection work. Some duties of the field inspector include carrying inspection equipment, filling out inspection forms, taking photographs, and making sketches. Ideally, the field inspectors would have an engineering background with education, training, and experience within their respective fields of practice.

Discipline specific specialists and field inspectors should:

- Be knowledgeable of tunnel components and understand their function.
- Be able to climb and/or use equipment to access various areas of the tunnel.
- Be able to use equipment or apply appropriate test methods.
- Be able to print legibly and draw accurate sketches.
- Be able to read and interpret drawings.
- Be able to use appropriate technology as required for data collection.

2.2.4 - Inspection Procedures for Highway Tunnels

Qualified tunnel inspectors should conduct tunnel inspections and when needed, use assistance from qualified inspectors in other disciplines to complete the inspection tasks. The inspectors should be equipped with appropriate gear, e.g. hard hat, steel toe boots, and safety vests and other necessary equipment to access the tunnel elements. The inspectors should understand how defects impact the function and capacity of tunnel systems. They also should be able to recognize the common deficiencies that impact the structural, civil, and functional systems. The observations and measurements used to carry out the inspection should provide information on the overall safety and reliability of the NTI database regarding structural (elements, miscellaneous elements, and materials), civil, and functional systems.

Visual inspection is the first and the most important method. Once a defect or its indicator is observed, e.g. a crack or rust stain, other tests should be utilized to estimate size or confirm presence of the defect. General inspection techniques are discussed in the next chapters 3 and 4 for common structural materials and elements.

CHAPTER 3. STRUCTURAL MATERIALS

3.1- Introduction

Typical structural materials observed in tunnel elements are comprised of steel, concrete, timber, and masonry. In some cases, the natural rock formation provides the stability for the clearance through the tunnel.

3.2- Structural Materials

Structural elements such as steel, concrete, timber, and masonry and their defects are discussed below.

3.2.1 - Steel Structures

Steel structures are affected by corrosion, cracks, buckles and kinks. Other defects may also be present such as leaks and protective system failures. Inspectors should be concerned with any crack in the steel member as serious. It should be reported right away and evaluated by an engineer. Look for cracks radiating from holes, cuts, notches, and welds. The inspectors also should be concerned with corrosion and pitting in the steel member as the end result. The inspectors should look for any buckles and kinks which can be attributed to damage from collision, fire, or soil interaction. Steel is impermeable; however, leaks can occur where water is able to penetrate through joints, cracks, or holes in the steel. The joints, joint seals, gasket materials, and welds should be checked to determine if they are defective.

Steel used nowadays is often protected by paint, galvanizing, or weatherized. Paint systems fail by peeling, cracking, corrosion pimples, and excessive chalking. Galvanizing is done typically by applying molten zinc to form a tightly bonded alloy coating. Flaking and chipping are common defects.

3.2.2 - Concrete Structures

Some common concrete defects include scaling, cracking, delamination, spalling, pop-outs, mud balls, efflorescence, staining, honeycombing, and leakage.

- Scaling is gradual and continual loss of mortar and aggregate of a finished surface of hardened concrete. The scaling is considered light when the coarse aggregate below the surface is not exposed; however, the scaling is considered severe when the coarse aggregate is clearly exposed.

- A crack is a linear fracture in the concrete. Cracks can occur due to poor curing (non-structural shrinkage cracks), settling, or over loads (structural cracks). Cracks may extend partially or completely through the concrete member. The direction of the crack relative to axis of structure should be observed and measured. The location, width, length, depth, and the spacing between cracks should be measured and recorded. Based on various observations and measurements, the cracks can be classified. The common types of cracks found in tunnels include longitudinal, transverse, vertical, diagonal, pattern/map, D-cracks and random cracks. As the concrete hardens, water and air that is trapped below the surface can develop into subsurface voids or delamination. These types of voids eventually lead to concrete spalling.

- Delamination is one area of the concrete surface that produces a hollow sound when struck by a hammer. Determine the extent of these areas and document them.

- Spalling is the detachment of hardened concrete fragments that leave shallow, roughly circular or oval shaped depression in the concrete surface. Spall can also develop as an elongated depression along an expansion, contraction, or construction joint. Steel reinforcement may also be exposed where the spalling is severe. The inspector should record the location, width, length, and depth of the spalled area and note any exposed reinforcing.

- Pop-outs are conical fragments that break out at the surface of the concrete and leave a small hole. A shattered aggregate particle will often be found at the bottom of this hole adhering to the small end of the pop-out cone. Pop-outs should be noted for size, depth, location, etc.

- Mud balls are small holes that are created in the surface by the dissolution of clay balls or soft shale particles that were introduced into the concrete mix. Mud balls should be noted for size, depth, location, etc.

- Efflorescence is a deposit of water-soluble calcium hydroxide that forms on the concrete surface. It is usually white and emerges from the concrete as solution materials crystallize as salts. Efflorescence may also occur because of contaminates in the ground water or de-icing salts. Salt crystal stalactites can form on tunnel ceilings from severe efflorescence.

- Staining is a discoloration of the concrete surface due to emergence of water containing dissolved materials through cracks after water evaporates. Although staining can be of any color, brown staining usually signifies that corrosion is occurring in the underlying steel reinforcing.

- Honeycombing occurs in concrete when the mortar does not completely fill the voids between coarse aggregate particles.

- Leakage occurs in regions of the concrete surface where water has penetrated through cracks, joints, or other imperfections in the concrete. It is important to note the temperature when checking for leaks. The full effect of leakage might not be known when temperatures are below freezing since ice can mask the effects of leaks. The portions of the concrete structure that are below the water table should be carefully checked at joints for leaks.

3.2.3 - Timber Structures

Some common timber defects include decay by fungi /insects, checks /splits, and fires.

- ➢ Decay by fungi is the primary cause of timber deterioration. It is produced by living fungi that feed on the cell walls of timber. Molds, stains, soft rot (least severe), and brown or white rot (most severe) are common types of fungi that cause decay in timber materials. With heavy decay, timber may become discolored and soft, and section loss may occur. The amount of decay and section loss should always be noted in the inspection report.

- Decay by wood eating insects: Termites and carpenter ants are common types of insects that can cause timber deterioration. The presence of insect infestation should be noted in the inspection records and the type of insect should be recorded if known. An insect may be placed into a container or a picture taken for later identification. Saw dust or powdered dust on or around the timber members could indicate the presence of wood eating insects, and this dust should be noted. Photographs of the insect mounds may be used to document the extent of damage.

- Checks are cracks in timber, which extend partially through the timber member; the percentage of penetration through the members should be identified with checks. Checks result from shrinkage after drying or from seasoning of the timber and should be noted in the inspection report.

- Splits are cracks that extend completely through the member. Splits result from shrinkage after drying or from seasoning of the timber and should be noted in the inspection report.

- Fires can blacken and char timber and cause appreciable section loss. Fire damage is easily evaluated on most timber structures, but it can be a time consuming process. The best way to ascertain the extent of damage is to chip away at the charred remains in several locations and then measure the section remaining in the undamaged timber. The greatest section loss often occurs where two or more members have been fastened together.

A hollow area usually indicates either advanced decay in the interior of a timber or the presence of wood eating insects. Hollow areas should be noted in the inspection report to show the size, location, and extent of damage in the area hollowed. Leaks occur in timber where water is penetrating through a joint, check, split, or some other defect in the timber such as a knot.

3.2.4 - Masonry Structures

The individual stones, bricks, or blocks of masonry structures should be checked for displaced, cracked, broken, crushed, or missing units. Some types of masonry surfaces are susceptible to deterioration or weathering. The mortar should be checked to ensure that it is effectively bonded to the masonry unit at the joint. It is particularly important to note cracked, deteriorated, or missing mortar. Masonry arches are primarily used in compression applications; flattened curvature, bulges in walls, or other shape deformations may indicate unstable conditions with tension cracks. The vertical and horizontal alignment of the masonry should be checked visually. Plumb bobs and lasers may be useful tools for assessing these conditions. Leaks often occur in regions of the masonry where water penetrates through joints, cracks, or other imperfection. Efflorescence accumulations might help locate areas with active leaks.

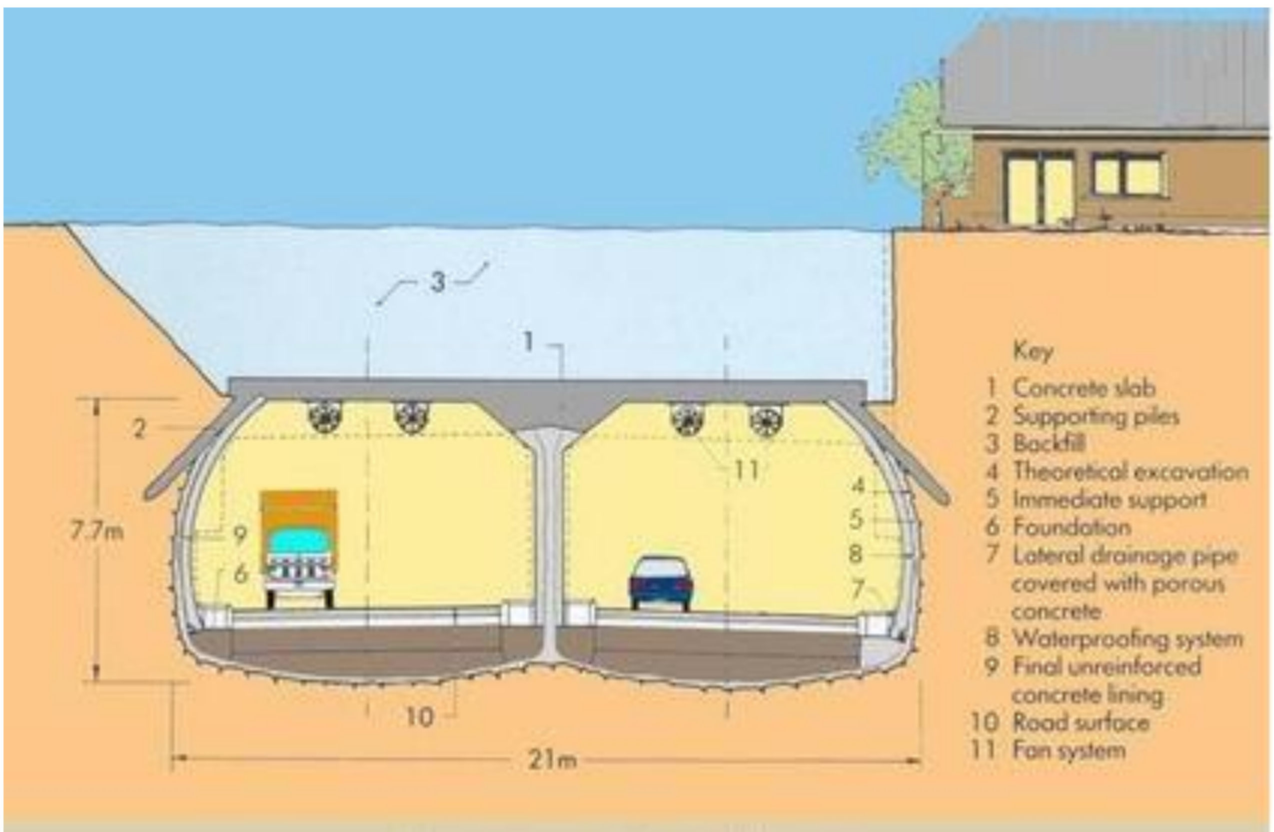
CHAPTER 4. STRUCTURAL ELEMENTS

4.1 – Introduction

Structural elements for tunnel s include liners, segmental rings, roof girders, columns and piles, cross passageways, interior walls, portals, ceiling slabs, ceiling girders, hangers and anchorages, ceiling panels, invert slabs, slabs on grade, invert girders, joints, and gaskets. Each element may provide support for one or more function.

4.2 - Structural Elements

Structural elements for tunnel s and their functions are discussed below.



4.2.1 - Liners

The tunnel liner supports the ground around the tunnel and restricts groundwater infiltration into the tunnel. Many tunnels have a two-pass liner system consisting of an initial liner (or temporary support) and a final liner (or permanent support). Initial support is typically provided by shotcrete and rock bolts, ribs and lagging, and slurry walls. The final liner is usually made of either cast-in-place concrete liners or bolted and assembled precast concrete segments.

4.2.1.1 - Steel Liners

Structural steel is not typically used as a final liner material due to its relatively high cost, fabrication requirements, and susceptibility to corrosion. Many rock tunnels in mountains have exposed steel liner plate above the spring-line to prevent rocks from falling onto the roadway. Older tunnels in soft ground, hard rock, or under water may have incorporated steel components as part of their initial support. Common temporary liner components include liner plates, steel ribs, columns, beam, and prefabricated shell elements. Many of these steel elements were not designed to be part of the permanent structural load-carrying component of the tunnel and were not sufficiently protected against corrosion. Typically, the temporary steel elements were covered or encased in concrete final liners. If structural steel components have been incorporated into the tunnel liner, then these steel elements should be inspected as structural steel materials.

4.2.1.2 - Concrete Liners

Concrete Liners and Shotcrete – Precast concrete liners and cast-in-place concrete liner make up the bulk of all permanent final lining systems installed in highway tunnels. Because of its availability, ease-of-use, durability, and relatively low cost, concrete liners have been installed in all types of tunnel projects. Shotcrete, also referred to as pneumatically sprayed concrete, is commonly used for temporary support and as final liners in lightly loaded structures such as a rock tunnel that supports only the loose rock that could fall onto the roadway. Concrete liners should be inspected using the methods previously described for structural concrete materials. Many concrete tunnel liners are covered by an architectural finish such as ceramic tiles or metal panels. When inspecting these surfaces, it is recommended that the inspector sound the finish surface. This should be done at multiple locations throughout the tunnel, and it should be done near known defects or when defects are suspected to determine the limits of the defective areas. Visually inspect cracks for moisture, leakage, corrosion, staining, and efflorescence. Record the amount of active leakage in number of drips per minute or estimate the continuous rate of flow.

4.2.1.3 - Timber Liners

Timber liners have been installed in some mountain tunnels to prevent loose rock from falling onto the roadway. The timber liner may be composed of roof or ceiling sections with or without wall elements. Timber liners should be inspected using the methods previously described under structural timber materials.

4.2.1.4 - Masonry Liners

Masonry tunnel liners have not seen much use for highway tunnels since this method was largely supplanted by concrete technology that came into existence before many highway tunnels were built. Nevertheless, masonry structures are quite common at tunnel portals and other ancillary buildings. Masonry materials should be inspected using the methods previously described under structural masonry materials.

4.2.1.5 - Unlined Tunnels in Hard Rock

Tunnels may be unlined in some hard rock applications; however, these tunnels typically need reinforcing to prevent loose rock from falling into the roadway. Rock bolts and dowels are often used for this purpose. Support from timbers, steel plates, or shotcrete may also be used in limited areas of unlined tunnels to prevent rocks from falling onto the roadway. Unlined tunnels are self-supported by the competent rock. A qualified geologist or geotechnical engineer should assist the inspection team when inspecting self-supported tunnels in rock. Identify the deficiencies in the rock mass that could potentially pose safety and stability problems or nuisance issues for maintenance of traffic. The cross-sectional shape of the tunnel should be monitored for potential changes by taking measurements at predetermined intervals (approximately 200 ft. intervals). The distances between the spring line and vertical sidewalls should also be measured at specific points; the locations should be permanently marked.

4.2.1.6 - Segmental Rings

When inspecting precast concrete tunnel segments, the concrete should be inspected using the techniques previously discussed. The joints of the precast concrete liners should be inspected for cracks and leaks. Joint hardware such as end plates, bolts, and gaskets should also be inspected for each segment for discoloration due to moisture and humidity conditions in the tunnel. This condition does not downgrade the structural capacity of the bolt. Particular attention should always be given to bolts in regions of water leaks to check for loss of section. If losses in the section are observed, then this should be noted in the inspection report. The cross-sectional shape should be compared against the shape shown in the drawings to evaluate possible changes in cross section.

4.2.2 - Roof Girders

A roof girder is the main horizontal support for a flat tunnel roof. The roof girders support the tunnel roof and the loads from the backfill, surcharge, and traffic above. Girders are used to support a deck system, and these girders can be steel or concrete. Inspect these elements using the methods previously described for structural concrete or steel materials.

4.2.3 - Columns and Piles

Columns and piles are vertical load bearing elements that are usually comprised of concrete or steel components. Piles are embedded into the ground. Columns are free standing members located above the ground level. Lateral bracing may be incorporated to stiffen the columns. A typical set of columns may have a bent cap. Inspect these elements using the methods previously described for structural steel and concrete materials.

4.2.4 - Emergency Corridors

Emergency corridors provide a means of escape from the tunnel. Parallel tunnels may be linked by cross passageways. In emergencies evacuees can move to safety through a cross passage and escape through an adjacent tunnel. Therefore, these evacuation passageways should not be cluttered with objects or debris, and doors should be operable. These areas should ideally be slightly pressurized to maintain positive air flow to prevent smoke from entering the escape route, which helps to maintain a tenable environment for evacuees and emergency responders. The inspector should check for cracks, delamination, and spalls in the concrete walls, ceilings, and floors. Check for leaks. Look for build-up of maintenance debris in the rooms. Examine the utilities, lights, and electrical conduit, and any safety systems for deterioration. If the passageway is pressurized, an operational check of this system is required. Miscellaneous structural checks should be performed on all of the structural connections, doors, windows, frames, roofs, floors, curbs and walkways, staircases, brackets and supports, and structural finishes.

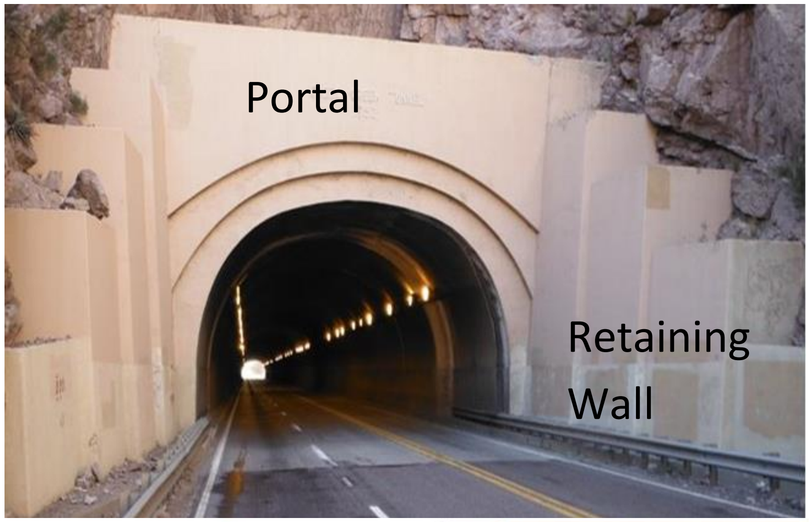
4.2.5 - Interior Walls

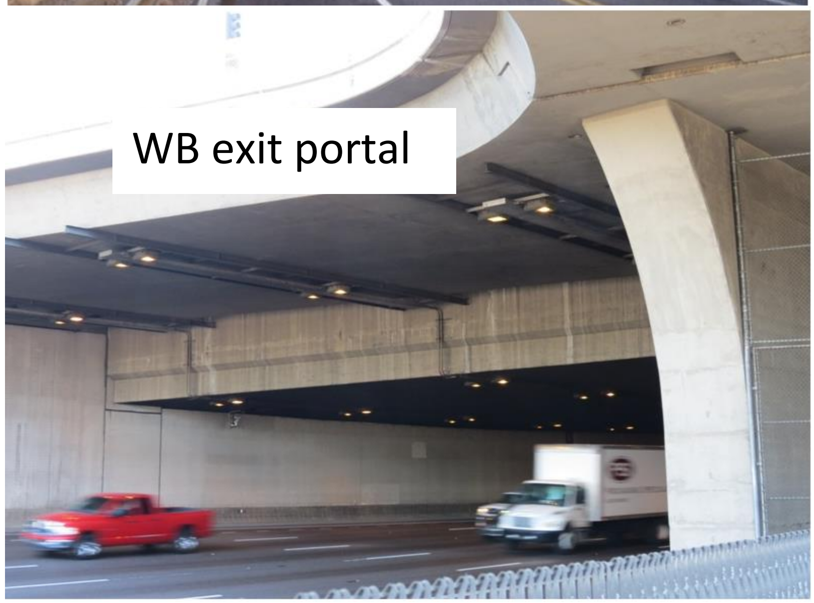
The tunnel liner is in contact with the ground; whereas, interior walls are not. Interior walls are usually constructed using concrete materials. These walls separate opposing traffic, the travel way from the ventilation plenum, or the travel way from the emergency egress corridor. Written procedures should address the unique identification of interior walls and the survey control processes for reporting inspection findings. Concrete walls should be inspected using the methods previously described under structural concrete materials. Concrete walls should be inspected using a hammer to sound the substrate concrete or a rubber mallet to tap on the tile finish at random locations and at areas adjacent to defects. When hollow sounding areas are detected, the limits of these areas should be defined. Mark out these areas using keel or paint. Note the size, maximum depth, and location of the spalls; and note any exposed reinforcing steel. Check and document the percentage of section loss, if present, at exposed reinforcing steel. Document the length, width, depth, and location of cracks. Visually inspect for moisture, leakage, corrosion, staining, and efflorescence. Note any cracks with moisture penetration or corrosion staining. Record the amount of active leakage in number of drips per minute or measure the flow rate.

Architectural Finishes – Many concrete tunnel walls are not visible because they are covered by architectural finishes such as ceramic tiles or metal panels. Tile walls should be checked for cracked, delaminated, or missing tiles that could indicate defects in the underlying substrate concrete. Missing tiles may be the result of moisture and water penetration through the concrete substrate. Check the exposed substrate concrete for cracks, delamination, and spalls. Look for spalled concrete behind missing tiles and at construction joints between wall segments where reinforcement steel may be exposed. The degree of surface deterioration and condition of anchor bolts should be checked on metal panels. Note all conditions described above in the inspection report.

4.2.6 - Portals

Tunnel portals are located at the entrances and exits of the tunnel. When inspecting the portal facades, it is important to consider the condition of the elements that are above the roadway since spalls or falling objects from above could impact the safety of tunnel users. It is also important to document the condition of material outside and above the portals, especially if there are concerns for landslides. A landslide could easily damage the portal façade or portal buildings. A qualified geotechnical engineer or geologist should assist the inspection team when evaluating the potential for landslides. Inspect the walls, ceilings and floors of the portal building for cracks, delamination, and spalls using the methods described for the appropriate structural material. Use a hammer to sound the walls at random locations and around defects. Look for build-up of debris in the rooms. Examine the utilities, lights, and electrical conduit within the rooms for deterioration. Miscellaneous structural checks should be performed on all of the structural connections, doors, windows, frames, roofs, floors, staircases, brackets and supports, and structural finishes within the portal buildings and auxiliary structures. Implement miscellaneous structural checks as appropriate.





4.2.7 - Tunnel Ceiling Structures

Tunnel ceiling structures consist of slabs or panels that are supported by girders or hangers and anchorages. Many tunnels were installed with ceilings above the roadway to create space for ventilation. This space, commonly referred to as the upper plenum, is used to either exhaust or supply air to the tunnel. Sometimes the upper plenum also contains utilities. The configuration of the upper plenum depends on the shape of the tunnel. For example, a circular tunnel will have roughly a half moon shape, while a box tunnel will have a box-shaped plenum. The inspector should ensure that all air distribution diffusers, registers, and passages are in good condition and free of debris accumulation. The structural elements of tunnel ceilings include either reinforced concrete ceiling slabs or precast concrete ceiling panels that are supported by either girders or hangers and anchorages. These structural support systems carry loads from their own weight, ventilation pressures, live loads from personnel, wind pressure from trucks, and earthquakes. Many ceiling structures are relatively heavy, providing stability when large trucks pass through the tunnel and create air pressure waves between the truck and the ceiling. Because the ceilings are located directly above the roadway, the potential exists for these objects to fall onto the roadway below. When inspecting ceiling structures, it is critical to carefully and thoroughly examine each component of the ceiling support system to ensure that the ceiling loads are being transferred into the support members as intended. It is advised that detailed written inspection and maintenance procedures be fully developed and completely implemented when tunnels have heavy ceilings elements installed over traffic. Prior to conducting an inspection of ceiling elements, the inspector should review all pertinent drawings and procedures.

Hangers and Anchorages – If the ceiling structure is supported with hangers and anchorage held by adhesive epoxy anchors, then these anchorages should be repaired in accordance with FHWA's Technical Advisory – Use and Inspection of Adhesive Anchors in Federal-Aid Projects. The inspector should refer to FHWA Technical Advisory T 5140.30, which superseded T 5140.26. A copy of this document is found at the link below:

http://www.fhwa.dot.gov/bridge/t514030.cfm

If anchors have pulled out or are loosening, the tunnel owner (mainly ADOT) should be immediately notified since this poses a significant safety concern. Remedial action may be necessary such as installing new supports that incorporate mechanical anchorages with the hanger rods, or a similar system that does not rely on epoxy in sustained tension. Exposed steel support system elements should be inspected for corrosion and section loss as well as for missing bolts at the connection points for the support beams or the hangers and anchorages. Document the locations of missing bolts, deteriorated beams, or hangers. Verify that the hanger connections are intact; and ensure that there is no vertical displacement in any of the embedded supports or exposed anchors. Visually inspect the hangers to determine if they are bowed. A bowed hanger possibly indicates that the ceiling slab was pushed up from either vehicle impact, air pressure, or other means. One method to verify hangers are in tension is by "ringing" each hanger. Ringing a hanger is done by lightly striking it with a mason's hammer. A hanger in tension will vibrate or ring like a bell after being struck; while a hanger that is not loaded in tension because of a loose connection or other defect, will not ring. Rather, a dull thud will be heard. If the hanger does not ring, inspect the hanger carefully and verify that the ceiling system is structurally sound.

Tunnel Roof – If the tunnel has a ceiling support structure with hangers attached to the roof, check the connection locations of these supports at both ends (tunnel roof and ceiling slab or panel) for cracks, delamination, and spalls. Check the roof area in the vicinity of the hangers for cracks in the concrete, delaminated concrete, and spalls to verify solid embedment. Use a hammer to sound random areas and areas suspected of concrete defects adjacent to the hangers.

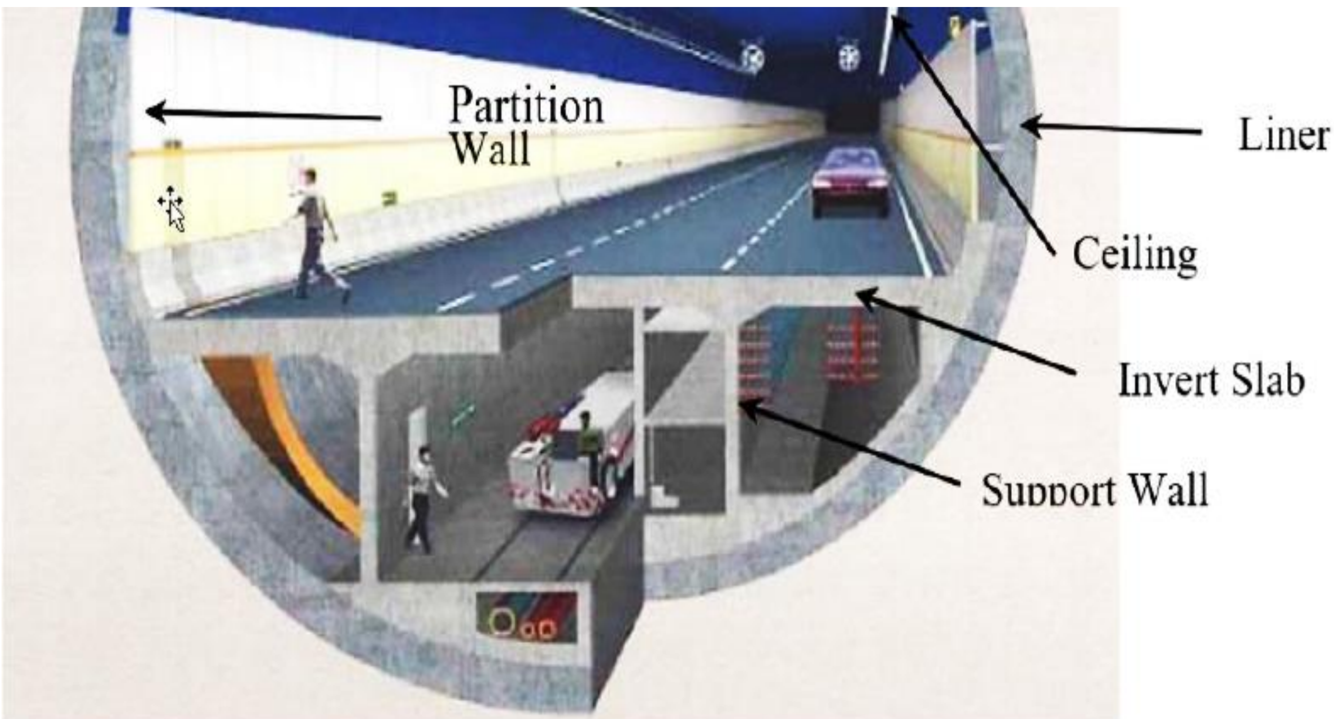
Ceiling Girder – A ceiling girder is the main horizontal support for the ceiling panels or slabs. These structural elements are used in place of hangers and anchorages. Ceiling girders use various structural shapes. They are usually steel or concrete and should be inspected using the methods previously described for structural concrete and steel materials.

Ceiling Slabs and Panels – Slabs are cast-in-place concrete elements, whereas, panels are precast concrete elements. Both serve the same function in the ceiling system. The topside and underside of the ceiling should be inspected. Note the location of any cracked or deteriorated ceiling panels. Document the length, width and locations of cracks in the ceiling slab. Visually inspect for spalling. Note the size, maximum depth, location and any exposed reinforcing steel details at the locations of the spalls. Note the locations of cracks; look for moisture penetration and corrosion staining. At random locations and adjacent to all defects, a hammer should be used to sound the substrate concrete or a rubber mallet to tap the tile finish. The top side of the ceiling panels and the ceiling support system are often examined from within the upper plenum. Check the top side of the ceiling panels for cracks, corrosion stains, efflorescence, spalls, disintegrated concrete and evidence of moisture. Observe for displaced seals between the panels. Examine the ceiling support system for corrosion and section loss as well as missing bolts. At the bottom face of the ceiling panels, inspect concrete surfaces using the methods previously described for structural concrete. Focus on the inspection techniques for scaling, cracks, delamination, and spalling. Check for exposed reinforcing steel at any spalls and document the section loss. Visually inspect for moisture and corrosion staining at cracks; and note efflorescence at crack locations.

An architectural finish may be placed on the underside of the ceiling slabs or panels in some cases. If ceramic tiles, concrete-filled metal pans, or steel composite metal pans make up the underside finish, their condition is evaluated more rigorously than on the walls, since delaminated tiles can fall onto the roadway. Check the ceramic tile finish for cracked, delaminated or missing tiles, which could indicate defects in the substrate concrete. Examine any exposed substrate concrete for cracks, delamination, and spalls.

4.2.8 - Tunnel Invert Structures

Slabs, Girders, and Slabs on Grade Tunnel invert structures consist of slabs that are supported by girders or on grade. When the roadway is a structurally supported slab, then the space below the supported roadway is used for ventilation and drainage. The supported invert slab acts like a bridge deck that carries traffic loads. When inspecting invert structures, the size and location of the defects should be documented. Check the concrete for cracks, delamination, and spalls; use a hammer to sound random areas of the invert for delaminated concrete and sound areas around cracks and spalls. Record the sizes and maximum depth of the spalls. Note any section loss for exposed reinforcing steel. If severe spalling is present, a sketch should be prepared to show the extent and location of the spalling. Note exposed reinforcing steel in the spalls and record any section loss. Cores may be needed to determine the chloride ion content prior to making recommendations for repair or replacement. Document the length, width, and location of all cracks and delamination. Check for signs of moisture penetration. Note all corrosion staining, dampness, map cracking, and efflorescence. Document the severity and locations of all other defects. Provide percentages of total invert area for map cracking, moisture penetration, efflorescence, and delamination. Check for excess debris accumulation resulting in standing water, and confirm that the lower plenum is draining into the sumps. Invert Slab – Inspect the topside and underside of the slab. The topside of the slab might be obscured by the wearing surface; nondestructive testing can supplement the inspection process. The tight space below the slab could also preclude direct inspection from below the slab in the lower plenum; and robotic video inspection techniques can be used for inspecting tight spaces like these. Examine the concrete slabs for cracks, delamination, and spalls. Use a hammer to sound random areas of concrete for delamination, and sound the concrete adjacent to cracks and spalls. Note exposed reinforcing steel in the spalls and record any section loss. Check for signs of moisture penetration through the concrete. Also note corrosion staining, dampness, and efflorescence. Document the amount of active leakage in number of drips per minute or measure flow rate. Check for areas of potential localized failure due to punching shear at large spall locations and where large potholes occur. Invert Girder – An invert girder refers to the main horizontal support for the slabs. These steel or concrete girders should be inspected using the methods previously described for structural concrete and steel materials.



Source: FHWA

4.2.9 - Joints and Gaskets

Joints are integral to many structural elements and are used to simplify construction or accommodate strains from thermal movements. Joints are typically sealed or have gaskets to keep out water. Joints – Examine joints for deterioration, efflorescence and moisture penetration. Check for joints at the transitions between segments, at the connections to ancillary buildings, and at auxiliary structures. Check the concrete around the joint for cracks, spalls and delamination. Use a hammer to sound the concrete adjacent to the joint. Check the position and condition of the joint material. Check the condition of sealants between precast panel members. Closely examine the alignment and check for any signs of differential settlement, which can lead to other serious defects. Document the locations and severity of moisture penetration or joint deterioration. Gaskets – There are many types of gaskets such as lead, mastic, or rubber. Gasket materials can become dislodged from the joint due to water infiltrating though the joint, loosening of fastening bolts, etc. Gaskets can also fail due to chemical or biological deterioration of the material. Structural movements of the liner can also tear or otherwise distort the gasket and cause it to leak. Differential settlement often leads to other defects. Extra time should be spent investigating transition areas such as where the tunnel support conditions change at connections to buildings. The location of these areas should be evident from existing as-built drawings. Note all gasket deficiencies including the length, width and locations of cracks, loose or broken fasteners, or leaks of any kind.

4.2.10 - Miscellaneous Structural Elements

Miscellaneous structural elements that are not inventoried but should be inspected periodically to maintain safety include structural connections, doors, windows, frames, staircases, roofs, floors, brackets and supports, machinery pedestals, and structural finishes. These items should be included in the written inspection procedures developed by the tunnel owner.

4.2.10.1- Structural Connections

The connection bolts, rivets, and welds should be carefully checked. Bolts on precast concrete, steel, and cast iron liners may be discolored due to moisture and humidity conditions in the tunnel; however, the discoloration usually does not reduce the structural capacity of the bolt. Particular attention should be given to bolts in regions where leakage occurs as section loss might result. A bolt can be rung with a hammer to determine if it’s tight, but it’s preferable to use a wrench. Section loss and missing or loose bolts should be noted in the inspection report. Observe the condition of welds for cracks and tears. Dye penetrant inspection may be helpful for detecting cracks. Coatings may protect welds from corrosion.

4.2.10.2 - Doors

During the inspection, all of the doors and windows encountered should be opened and closed to verify their operability. Some door components may be deteriorated, stuck, or inoperable. The door hardware should be checked to ensure that the latches sufficiently engage the door frame and that the door can be closed securely. The door and the frame might have corrosion, delamination, or section loss. Security sensors should also be checked to be sure they are operational.

4.2.10.3 - Windows and Frames

Steel window frames may be corroded, deteriorated, or experience section loss. Some of these may be stuck or inoperable. When concrete window frames are inspected, check for cracks, delamination, and spalls in the concrete material. The condition of protective coatings should also be documented. Stairs – Stairs are typically built with either reinforced concrete or steel. Reinforced concrete stairs sometimes have steel tread plates incorporated in the concrete. Inspect the rails, posts, and railing anchorages for missing or broken sections, damage and deterioration, cracks or corrosion, and section loss. Inspect for cracked welds at the connections and for loose or missing bolts. Document the severity and location of any defects.

4.2.10.4 - Staircases

Inspectors should check stairs and ladders for loss of the steps and supports. In addition, inspectors should make note of any separated or missing plates and connections.

4.2.10.4.1 - Concrete Staircases

Inspectors should check concrete stairs for cracks, delamination, and spalls. Note exposed reinforcing steel in the spalls and record any observed section loss in the reinforcing steel. Check for signs of moisture penetration, corrosion staining, dampness, and efflorescence. Use a hammer to sound random areas of the stairs and check for delaminated concrete. Also sound areas adjacent to defects such as cracks and spalls. Document the length, width and location of all cracks and delamination. Record the area, maximum depth and location of all spalls along with the condition of exposed reinforcing steel. Document the severity and locations of all other defects including moisture penetration, efflorescence, and corrosion staining. Examine the steel tread plates, if present, for adjacent spalls and looseness. Use a rubber mallet to tap the tread plates and make note of any separated or missing plates.

4.2.10.4.2 - Steel Staircases

Inspectors should check steel stairs and ladders for corrosion and section loss of the steps and supports. Examine for crevice corrosion between plates of the stairs. Document the severity and location of corrosion and section loss found. Note the length, location, and distance of spread of all crevice corrosion.

4.2.10.5 - Roof

Check the roof of any Ancillary Buildings or Auxiliary Structures for any deterioration which would allow water to penetrate through the roof into the building. Check that the water drainage system is functioning properly and not clogged with debris. Check the drains in the roof and the overflow scuppers in the barriers for debris accumulation. Inspect the barriers around the perimeter of the roof for deterioration. If present, examine expansion joints in the roof for debris accumulation and deterioration of the joint material. Look at the exterior surface of the exhaust stacks for any defects or deteriorated materials. Note the location and severity of any defects on the roof. Document any locations of water penetration. Record the condition of the roof coating material and the drainage system.

4.2.10.6 - Floors

Check concrete floors for cracks, delamination, and spalls. Note exposed reinforcing steel in the spalled areas and record any section loss. Check for signs of moisture penetration, corrosion staining, dampness, map cracking, and efflorescence. Use a hammer to sound random areas of the floor and check for delaminated concrete. Also sound areas adjacent to defects to define the extent of the area. Examine the floors for evidence of distortion and settlement. Document the length, width, depth, and location of all cracks and delamination. Record the area, maximum depth and location of all spalls along with the condition of exposed reinforcing steel. Document the severity and locations of all other defects including moisture penetration, efflorescence, corrosion staining, and settlement.

4.2.10.7 - Brackets and Supports

Brackets and supports are structural elements that are mounted against the ceiling or walls. They are used to support longitudinal ventilation fans, CCTV cameras, ITS signs, traffic signs, over-height detection signs, lighting supports, conduit supports, and fan or motor supports. Check for corrosion, dissimilar metals, cracks, buckles, and kinks. Dissimilar metals may promote corrosion at accelerated rates when not sufficiently insulated from stray electrical currents. Particular attention should be given to bolts in regions where leakage occurs to evaluate any section loss. A bolt can be rung with a hammer, but it's preferable to use a wrench for checking the tightness. Observe the condition of welds for cracks and tears. Dye penetrant inspection may be helpful for detecting cracks.

4.2.10.8 - Machinery Pedestals

Check concrete pedestals for cracks, delamination, and spalls. Use a hammer to sound random areas of the pedestals to check for delaminated concrete, also sound areas adjacent to defects. Examine the floors for signs of settlement. Note exposed reinforcing steel in the spalls and record any section loss. Check for signs of moisture penetration, corrosion staining, dampness, map cracking, and efflorescence. Document the length, width, and location of all cracks and delamination. Record the area, maximum depth, and location of all spalls along with the condition of exposed reinforcing steel. Document the severity and locations of all other defects including moisture penetration, efflorescence, and corrosion staining.

4.2.10.9 - Structural Finishes

Tiles should be checked to determine whether they pose a hazard to passing motorists since loose tiles can fall into the roadway. A good technique for inspecting tiles is to tap firmly on a select number of tiles in multiple locations using a rubber mallet. A scraper may facilitate removal or checking loose tiles.

4.3 - Civil Elements

The civil elements included in the NTI database are roadway wearing surfaces, traffic barriers, and pedestrian railings. The SNTI defines condition states for invert wearing surface, traffic barriers, and pedestrian railing systems. Although the drainage systems are discussed under mechanical systems and pumps, but the drainage itself, less pumps, will be discussed under Civil Elements. Miscellaneous civil elements are not contained in the NTI database but should be inspected periodically to maintain safety.

4.3.1 - Wearing surfaces

Tunnel roadways have either bituminous or concrete wearing surfaces on the structural invert. When inspecting the wearing surface, examine the skid resistance of the surface, look for grooving or rutting in the wearing surface. A glossy or shiny surface or exposed polished aggregate may be indicators of wear.

Check that water properly drains from these surfaces. When wearing surfaces are not properly drained, they can wear prematurely and develop holes and present safety hazards to motorists. The roadway surfaces on tunnel ramps can also be impacted by high groundwater levels. Concrete – Concrete wearing surfaces should be checked for potholes, cracking, scaling, and delamination. Look for exposed reinforcing steel. For spalls, document the size, maximum depth, and location. Also, document any exposed reinforcing steel, and identify section loss. Use a hammer to sound random locations of the concrete wearing surface and areas adjacent to cracks, delamination, and construction or expansion joints. Document the areas and locations of delaminated concrete. Areas of delaminated concrete may spall and present hazards to traffic. Provide an estimate of total crack length as well as the average length, width, location, and spacing.

Asphalt – Asphalt wearing surfaces should be checked for cracking, wheel path rutting, surface irregularities, and potholes. Use a hammer to sound random locations of the wearing surface. Note any dull thuds, which could be indicators of future potholes. Also, investigate whether the pavement is drying out, and verify a good seal between the wearing surface and the curbs.

4.3.2 - Traffic Barriers

At roadway level the tunnel walls are typically protected from errant vehicles by concrete curbs and barriers. These barriers are usually concrete; however, their vertical surface may be covered with ceramic tiles. A concrete safety walkway is usually provided in the tunnel bore. Document the length, width, and location of all cracks and delamination. Record the area, maximum depth, and location of all spalls along with the condition of the reinforcing steel if it is exposed. Document the severity and locations of all other defects including moisture penetration, efflorescence, and corrosion staining.

4.3.3 - Pedestrian Railings

Pedestrian railings are common where raised sidewalks are used. These are commonly constructed of tubular steel, stainless steel, or aluminum with posts spaced along the walkway to support the lateral railing, and it can be produced using pipe, W-beam, or other shapes. The railing members can be coated with a structural finish such as paint or galvanized metal. Railings are a safety measure to prevent personnel on top of the walkway from falling into vehicles in the adjacent traveled lane. All aspects of the railings should be inspected and deficiencies noted. During inspection, check the rails, posts and anchorages. Examine the railing for vertical and horizontal misalignment, missing or broken sections, impact damage and deterioration such as cracks or corrosion with section loss. Inspect for cracked welds at the connections and loose or missing bolts. Section loss can be found most commonly in the base of the posts and the anchor bolts, especially if debris accumulation is present. Evaluate the condition of the paint or galvanizing. Document the location and severity of any defects.

4.4 - Miscellaneous Civil items

Although these items are not specifically reported to the FHWA, it is good practice to perform miscellaneous civil checks on all curbs and sidewalks in the tunnel, ancillary buildings, or ancillary structures. These items should be included in the written inspection procedures. Curbs and Safety Walkways – Curbs and safety walkways protect the tunnel operation and maintenance staff and users who need to evacuate during emergency conditions.

Curbs – Curbs are typically constructed of concrete. Check the curbs for proper alignment. Improper alignment or a protruding curb section can become a safety hazard for vehicles. Visually examine these elements for any buildup of dirt or debris that may reduce their effectiveness to transport the surface runoff into the drainage system. Examine the curbs for cracks and spalls. Check spalled areas for exposed reinforcing steel and document any section loss in the steel. Walkways – The inspector should look for cracks, scaling, delamination, spalls, tripping hazards, debris accumulation, and ponding of water. Examine spalls for exposed reinforcing steel and report any section loss. Advanced cracks and spalls can undermine the structural integrity of the safety walkways. Document the size and locations of any defects found. Document the length, width and location of all cracks and delamination. Record the area, maximum depth and location of all spalls along with the condition of the reinforcing steel if it is exposed. Document the severity and locations of all other defects including moisture penetration, efflorescence, and corrosion staining.

Emergency Egress – The quality of the walking surface on every safety walkway or emergency egress should be examined. Under emergency conditions, these walkways may be used for self-rescue or by first responders. Check for locked or inoperable doors and access to refuge areas, considering that some users have reduced mobility. Note in the inspection documents any deficiencies found.

Maintenance walkways – Some of the more complex tunnels have concrete or steel maintenance walkways. Inspect these in accordance with procedures for other steel and concrete elements.

4.5 - Functional Systems: The functional systems include the mechanical, electrical and lighting, fire and life safety, security, systems, sign, and protective systems. Only tunnel drainage with exclusion of pumps will be discussed here. For more details regarding functional systems, refer to TOMIE manual.

4.6 - Tunnel Drainage

The tunnel drainage system is designed to remove water from the roadway and is made up of grates, scuppers, piping, drainage troughs, and pumps. For information regarding pumps refer to NIT under mechanical systems and pumps. Check if the drain lines are clear of debris and flush with water to ensure that water drains freely. Look for ponded water. Check the inlet grates for deterioration or broken ribs. Ensure the roadway drain piping is in good condition and free of debris or leaks. Document the location and extent of the defects.

CHAPTER 5. INSPECTION FINDINGS AND INSPECTION REPORTS

5.1 - Introduction

Tunnel Inspections are performed on a regular basis by qualified inspection teams in order to ensure public safety, comply with federal requirements, and keep the tunnels in good working condition. The results of the inspection are presented in several documents, collectively known as an inspection package. The inspection package includes TI & A (Tunnel Inventory and Appraisal), Inspection Report, Photo Report, Repair Report, Clearance Diagrams, and any additional documents associated with the inspection.

5.2 - Inspection Report

Inspection reports are formal summaries of inspection findings for each element and system that was inspected. If a structural review was needed and performed on a defect, include the element, condition, review procedure, date of the review, and name of the reviewing Team Leader within the report. The report should be submitted in accordance with written procedures established by ADOT. The completed report should be furnished to the tunnel owner along with any repair recommendations. It is the responsibility of the Team Leader to inform the ADOT Program Manager in a timely manner and discuss the extent of the conditions. A structural review or systems analysis may be required at this point to determine if the strength and/or serviceability of the tunnel has been impacted.

5.3 - Condition State 4 Review Procedures

Any element defect that requires a review under Condition State 4, and is in Condition State 4, shall be reviewed by either the Team Leader and/or a professional engineer (PE) licensed in the State of Arizona. The review is to be documented in the inspection report in the element commentary section. The review information should include: a photograph of the defect, the date of the structural review, the extent of the damage for the element being reviewed, and the name of the Team Leader or PE who performed the review. This process will ensure this information is provided for future inspections and ease tracking of the defect over time. If the defect is deemed to not affect the serviceability of the tunnel, the quantity shall be placed in Condition State 3 and proper documentation provided as described to mitigate unnecessary further analysis. Ensure defect description and documentation is sufficient to monitor increase in severity in subsequent inspections to trigger repeat analysis, if necessary.

A Structural Review is defined as the process that is followed when there is the need for assessment based on Condition State 4 definitions. Structural review shall be completed by either the Team Leader and/or a Professional Engineer in the state of Arizona. Engineering judgement is an acceptable form of review provided the Team Leader or PE has appropriate training and expertise for the defect, element, or system being considered. When a Condition State 4 is coded following a review, procedures for a CF/AF2 may be necessary. Follow the steps for repair in Section 5.4 and for Critical Findings in Appendix F of this manual.

If an element is in Condition State 4 because of an immediate safety concern, ensure the reasoning is clearly communicated. Often an immediate safety concern does not imply large scale damage of the element or system but is a matter of location of the defect, such as over the roadway. Examples of elements that may pose an immediate safety concern are:

• Delamination in the concrete or shotcrete liner of the tunnel directly over traffic that is in danger of breaking off and falling onto the roadway

• Rockfall danger in an unlined tunnel due to unstable blocks or slabs over the roadway

• Slope/ground instability at the portals

• Missing bolts or connectors on overhead equipment that creates unstable conditions

These elements may or may not warrant a structural review, however, because they pose an immediate safety concern to the traveling public the ADOT Staff Bridge Engineer, Program Manager, and appropriate maintenance personnel should be notified. This process ensures safety issues are recognized and rectified in a timely manner.

5.4 - Repair Priorities

The following are the repair priorities for defective elements or functional systems in an inspection report:

As defined within the Tunnel Inspection database (BrM), priority varies from 1 to 5 depending on severity:

Priority	Description	Expected Time from Notice to Repair Completion
1	Immediate action required (Critical Finding = Arizona Finding 1)	Within 30 days
2	Priority over routine (Arizona Finding 2)	Within 60 days
3	Can be scheduled (routine - Arizona Finding 3)	Sum of planning, bidding, and construction periods
4	No repair (monitor)	Typically at next inspection
5	No action required (flag)	Typically at next inspection

5.4.1 - Significant Findings

Significant findings are defined by ADOT Tunnel Repair Priorities 1 (AF1= CF) and 2 (AF2).

A Critical Finding (CF=AF1) is defined in 23 CFR 650.305 as “A structural or safety related deficiency that requires immediate follow-up inspection or action.” Per 23 CFR 650.513(j), a Critical Finding is to be reported to the FHWA within 24 hours.

Priority repair over routine repair (AF2) refers to conditions for which further investigations, design, and implementation of interim or long-term repairs should be undertaken on a priority basis, i.e., taking precedence over other scheduled work. These repairs will improve the durability and aesthetics of the structure or element and will reduce future maintenance costs. Elements that do not comply with the current code requirements are also priorities for repair.

All CFs and AF2s (see table above) shall be documented via the template provided in Appendix F. If necessary, email notification including all information within the template is acceptable for immediate notification provided follow up documentation is provided per the standard. All CFs and AF2s shall be additionally documented via the ADOT tracking system developed by the Program Manager including follow up action taken by the owner when appropriate.

In general, a tunnel element with a portion in Condition State 4 is considered for either CF or AF2. However, a rating of Condition State 4 does not always qualify as CF or AF2. If a CF or AF2 is filed, a Condition State 4 is warranted. Examples of Condition State 4 that do not require supplemental notification are:

• Dripping or flowing water infiltration via the liner

• Steel or concrete protective coating has failed and is no longer protecting the underlying material

Further evaluation of observed defects may lead to one of the following actions:

1. Close the tunnel until the severe defect is removed or repaired, if such defect may impact user or users safety

2. Restrict the area from public access until the defect is removed or repaired.

3. Repair the structure member or address the functional or safety issue.

As such, any defect of a member or system that renders a portion of or the complete closure of a tunnel shall qualify as a CF. Additionally if a finding poses an immediate and imminent safety hazard to the traveling public, it should be qualified as a CF.

Examples of Critical Findings may include but are not limited to:

a. Delamination or incipient spall, in a concrete portal posing a direct safety hazard for traffic below

b. Growing crack within tension zones of critical load bearing steel members

c. Failure of emergency systems, or extremely poor conditions that affect the serviceability or safety of the tunnel

d. Locked or nonfunctional egress doors

e. Significant corrosion in non-structural tunnel elements located above roadways

5.4.2 - Routine Repair (AF3)

Routine repair refers to conditions requiring further investigation or remedial work. This work can be undertaken as part of a scheduled maintenance program, scheduled project, or routine facility maintenance. Items identified in the preventive maintenance program can be put in this category.

5.4.3 - No Repair - Monitor (Priority 4)

No Repair - Monitor refers to situations which require checking current status of a previously-perceived unsatisfactory condition. This work can be undertaken as part of a scheduled inspection. This monitoring can be continued, stopped, or changed to one AF3 or Priority 5 (see section 5.4.4 below) depending on the inspector's recommendation.

5.4.4 - No Action - Flag (Priority 5)

No Action - Flag refers to situations which emphasize checking current status of a previously-perceived significant item. This work can be undertaken as part of a scheduled inspection. This flag can be continued, stopped, or changed to one AF3 or Priority 4 (see sections 5.4.2 and 5.4.3 above) depending on the inspector's recommendation.

5.5 - Inspection Package

5.5.1 - Draft Package

When an inspection is completed, the inspector should enter the data and notes into the ADOT tunnel inventory database. This may include notes, measurements, photos, diagrams, sketches and additional information. Once the data entry task is complete, the inspector should print a copy of various reports, collectively called an inspection package, associated with the inspection including but not limited to the following:

a. Tunnel Inventory and Appraisal

b. Tunnel Inspection Report

c. Tunnel Repair Report

d. Tunnel Clearance Diagram

e. Tunnel Inspection Photographs

The package is submitted through a submittal form, namely Summary of Bridges Inspected Form, which identifies the tunnels inspected by a combination of the tunnel ID number and the route/milepost (ADOT structures) or the owner (Local entity) for quality control/quality assurance purposes.

The inspection report could be extensive and as a result may include the following sections with their descriptions for an inspection report:

• Table of Contents - This provides information to the reader on where to find information of a particular interest.

• List of Tables - Used to identify the title and location of any tables that were used.

• List of Figures, Drawings, and Sketches - Used to identify the title and location of any figures or drawings.

• List of Photographs - Used to identify the title and location of any photographs. These may be included as an appendix to the report.

• Executive Summary - Provides a concise summary of the inspection, findings, and recommended repairs.

• General Description - Provides a general description of the tunnel or tunnels that were inspected. This information could include the location of the tunnel(s), age, general geometry, and any other pertinent descriptive information.

• General System Descriptions - Provide general descriptions of the structural, civil, and functional systems inspected and the scope of the elements covered by the inspection. This should precede the detailed descriptions for the inspection findings of each element.

• Inspection Procedures - The procedures used to inspect the tunnel elements should be explained and illustrated. If extensive written procedures were followed, these may be included as an appendix to the report. Documentation of any specialized testing processes and outside expertise should be included.

• Inspection Findings - The condition state of all tunnel elements should be documented per instructions and guidelines in the SNTI.

• Inspection Results - A detailed description of the results of the inspection should be included for the various tunnel elements below:

o Structural and Civil - For structural and civil elements, the report should contain descriptions of the various deficiencies found, their locations and their severity. Any special testing, such as concrete strength, freeze-thaw analysis, or petrographic analysis, should be included with the findings for the record.

o Mechanical - For the mechanical inspections, the general condition and operation of all equipment should be described and deficiencies noted. Specialized testing required to effectively determine the operational condition of the equipment, such as vibration testing and oil analyses, should be included for the record.

o Electrical - For the electrical inspections, the general condition and operation of all equipment should be described and the deficiencies noted. Any specialized testing needed to effectively determine the operational condition of the equipment, such as power distribution and emergency power, should be included for the record. In addition, comparisons of light level measured to recommended levels should be provided to the owner. Remediation work that may accompany testing and inspection should be included.

• Recommendations - This section includes recommendations for minor work (maintenance), posting of clearance signs (repair) as well as substantial repair/ rehabilitation of the tunnel components found to be deficient or not meeting current code requirements. Substantial rehabilitation may require a life-cycle cost comparison of repair options. Repair and rehabilitation recommendations should be broken down for each of the main tunnel systems into the categories: critical finding, priority repair 2 and priority repair 3. Significant corrosion in non-structural tunnel elements over the roadway is considered as a critical finding that requires immediate action.

• Appendices - The appendices can be used for detailed and extensive inspection summaries that are lengthy, highly technical and detailed (such as structural panel ratings and lighting luminance levels), and reports from special testing agencies. Detailed information such as special permits, processes or qualifications can go in an appendix. An example of this would be a confined space entry permit. A summary of the inspection operation should be provided with a list of inspection personnel, identification of the team leader, the inspection tools used, the access equipment required, and the schedule maintained. This information is useful for planning future inspections as well as for documenting the inspection.

5.5.2 - Draft Package Review

The draft package submitted will be reviewed by certified tunnel inspector for QA/QC purposes. The redlined items are presented to the inspector for correction.

5.5.3 - Final Package Review

Once corrections are made by the inspector, a copy of the sealed and signed inspection report and other supporting documents (final package) for the structure is resubmitted subject to a final review. If any parts of the final package include unjustified errors, the errors are reported back to the inspection team for corrections. The sealed and signed revised copies of inspection report along with other documents in the package are resubmitted in order to be included in the tunnel folder.

5.6 - Quality Control and Quality Assurance

5.6.1 - INTRODUCTION

Quality Control and Quality Assurance are integrated into all aspects of tunnel inspection work. They contain the essential requirements to demonstrate that care, skill, and diligence is used in the preparation of tunnel inspection report.

The quality of the tunnel inspection program will be controlled through regularly scheduled training workshops, office review of inspection documents, and independent/concurrent field review of inspections. In addition, the FHWA may conduct its own random review of the tunnel inspection program.

5.6.2 - Quality Control (QC): Quality Control is a set of planned procedures which ensures that the tunnel inspection quality is performed per NTIS. This includes monitoring and improvement of the inspection techniques via nationally sanctioned or state sponsored training. The focus here is on the inspection itself.

5.6.3 - Quality Assurance (QA): Quality assurance is associated with a systematic approach to improve the overall program effectiveness, verify the accuracy of the quality control procedures, and ensure that established standards are met. The focus here is on the process.

QC/QA procedures are performed by an office team of professional tunnel inspectors independent of the inspection and load rating teams performing the work.

Quality control and quality assurance programs are used to promote accuracy, ensure consistency, facilitate improvement, and help maintain a high level of reliability. Periodic field reviews of inspection team and their work, quality checks on data, and independent reviews of the inspection results is part of the program. The use of checklists is recommended.

The quality control engineer's responsibilities include but not limited to the review of the inspection reports, review of inspection methods in field, and performing quality assurance work. Quality control engineer should not be the same person as the team leader being reviewed. Quality control engineer should have extensive experience in the tunnel safety inspection area and should be familiar with inspection procedures and requirements.

The quality assurance engineer is responsible for ensuring that the defined quality control procedures are enforced.

5.6.4 - REVIEW SELECTION ON INSPECTION DOCUMENTS

Independent office review of tunnel inspection documents will be performed to enhance quality assurance. Quality control engineers must select 50% of tunnel inspection packets for the review regardless of tunnel ownership and whether ADOT personnel or consultants performed the inspections.

5.6.5 - REVIEW INSPECTION DOCUMENTS

Quality control engineers shall indicate on the draft inspection report any incorrect information found and its correction. In case of on-call consultants, quality control engineers shall summarize findings from the reviews into a document, and return the document to the inspectors for correction. Quality control engineers shall summarize findings from the review, and assist the tunnel inspection program manager in developing a training plan which will ensure these errors will not be repeated.

The quality control engineer's review includes but not limited to the following:

Review the inspection report to ensure that the correct structure is identified. This includes a check that correct tunnel has been identified through examination of information such as structure number, structure name, route, mile post, and location. Further detail review should assure all required information has been entered correctly in accordance with the Specifications for the National Tunnel Inventory (Report No. FHWA - HIF-15-006). This review includes but not limited to a check to see if proper coding conventions, formats, correct significant digits and units have been used.

1. Check the structural element ratings. The element inputs should be reviewed for accuracy, including elements numbers, units and quantities under different condition states.

2. Check all photographs and/or sketches for proper cross referencing to the inspection report.

3. Check consistency of information between the current inspection report and pervious inspection reports and load rating report.

4. Review all items in the TI & A to check they have been properly and correctly entered.

5. Check the inventory data on the TI & A against the record drawing to ensure that the data is consistent.

5.6.6 REVIEW COMMENT CORRECTION

Tunnel inspection personnel are reminded that assuring quality during their field inspection and throughout their documentation is their responsibility. The independent office review of tunnel inspections is provided to maintain consistency throughout the state and shall not replace the due diligence that an inspector must exercise while performing and documenting each tunnel inspection.

Review corrections should be implemented prior to sealing and signing reports. Inspection personnel should strive to maintain objectivity and factual reporting of field observations. While some relevant comments with professional judgment are desirable and made to pinpoint source of a potential problem area, subjective reporting and editorializing of review comments are not acceptable.

Special attention should be accorded to pattern errors. Since the review may not entail every inspection report in a submitted packet, some errors may be repeated in non- reviewed reports. Therefore, the inspector must correct non-reviewed reports for similar types of comments.

5.6.7 - FIELD INSPECTION REVIEW

At least once every year, the Tunnel Inspection Program Manager and the quality control engineer should randomly choose 50% of all active tunnels (total number of active tunnels in Arizona database is currently 6) to review in the field for each inspection team. This allows the review of all tunnels on a 24-month cycle.

The quality control engineer shall keep a logbook of the dates, review team, and Tunnel Inspection Quality Assurance Review Form (see Appendix G) and shall have the logbook available to present to FHWA on the occasion of FHWA review.

5.6.8 TRAINING WORKSHOP

To minimize common mistakes and omissions from structure inspections, at least once every year, Tunnel Inspection Program Manager should establish a training workshop to all tunnel inspection personnel by utilizing the training plan developed in consultation with quality control engineers.

The plan should address concerns and not be limited to the following:

- Changes to the present tunnel coding
- Changes to the element coding
- Changes to the tunnel management software
- Changes to structures inspection scheduling
- Common errors or problems occurring due to inspectors’ inputs or the software

The Training Workshop should include inspectors' views and observations in the field which may help to improve quality of the inspection reports.

5.7 - Critical Findings and Condition State Ratings

Critical findings and condition state ratings are used to represent the condition of tunnel components. A critical finding is a significant safety or structural concern that must be acted upon and reported in accordance with the NTIS. Critical findings require immediate attention in accordance with agency and NTIS requirements.

5.7.1 - Critical Findings

Critical findings are defined in the NTIS as "A structural or safety related deficiency that requires immediate follow-up inspection or action". ADOT has established written procedures dealing with critical findings during the inspection. See the flow chart and Significant Findings Form in Appendix F. The flow chart ensures that critical findings are addressed in a timely manner and actions are taken, are underway, or are planned to resolve the issue. The ADOT Program Manager will monitor the status of all CFs and provide quarterly updates to FHWA Arizona Division Office. An annual summary report detailing all Critical Findings identified within the prior year will also be compiled by ADOT and submitted to the FHWA Arizona Division Office.

It is imperative that the inspection team have communication protocols in place to ensure that immediate action can be taken to respond to a critical finding. After discovery of a CF, the inspection Team Leader (or other ADOT personnel) will notify the ADOT Program Manager as soon as possible. The ADOT Program Manager will notify the FHWA Arizona Division Office within 24 hours.

Critical findings normally require one or more of the following actions to be taken as soon as possible:

• Close the tunnel until the severe defect is removed or repaired, if such defect may impact users or user safety.

• Restrict the area from public access until the defect can be removed or repaired.

• Repair the structural member or address the functional or safety issue.

Detailed descriptions and photographs should be provided that describes the safety or structural concern. Identify appropriate actions or follow-up inspections and maintain a record of the actions taken to resolve or monitor the critical finding. For example, with a large concrete spall that is on the verge of falling into the roadway, the inspection team or tunnel operations personnel can block off the traffic; and the maintenance personnel or a specialty contractor can take down and remove the spalled concrete. See Section 5.4 for guidance on repair priorities.

5.7.2 - Condition State

Condition states are used to represent the condition of an element at the time it was inspected. Condition states as defined in the SNTI are:

1=good,

2=fair,

3=poor, and

4=severe

Structural and civil elements in severe condition (Condition State 4) usually warrant a structural review to determine if there are any impacts to strength or serviceability. For functional systems in severe condition, evaluate safety and serviceability of the element. Condition states are recorded in the inspection report and database and then submitted to the FHWA for annual review.

Appendices

Appendix A - Tunnel Inventory Items:

Table A.1 - Identification & Location	
Item ID	Item Description
I.1	Tunnel Number
I.2	Tunnel Name
I.3	State Code
I.4	County Code
I.5	Place Code
I.6	Highway Agency District
I.7	Route Number
I.8	Route Direction
I.9	Route Type
I.10	Facility Carried
I.11	LRS Route ID
I.12	LRS Mile Point
I.13	Tunnel Portal's Latitude
I.14	Tunnel Portal's Longitude
I.15	Border Tunnel State or Country Code
I.16	Border Tunnel Financial Responsibility
I.17	Border Tunnel Number
I.18	Border Tunnel Inspection Responsibility

Table A.2 - Age and Service	
Item ID	Item Description
A.1	Year Built
A.2	Year Rehabilitated
A.3	Total Number of Lanes
A.4	Annual Average Daily Traffic
A.5	Annual Average Daily Truck Traffic
A.6	Year of Annual Average Daily Traffic
A.7	Detour Length
A.8	Service in Tunnel

Table A.3- Owner, Operator, & Highway Classification Items	
Item ID	Item Description
C.1	Owner
C.2	Operator
C.3	Direction of Traffic
C.4	Toll
C.5	NHS Designation
C.6	STRAHNET Designation
C.7	Functional Classification
C.8	Urban Code

Table A.4 - Geometric Data Items	
Item ID	Item Description
G.1	Tunnel Length
G.2	Minimum Vertical Clearance over Tunnel Roadway
G.3	Roadway Width, Curb-to-Curb
G.4	Left Sidewalk Width
G.5	Right Sidewalk Width

Table A.5 - Inspection Items	
Item ID	Item Description
D.1	Routine Inspection Target Date
D.2	Actual Routine Inspection Date
D.3	Routine Inspection Interval
D.4	In-Depth Inspection
D.5	Damage Inspection
D.6	Special Inspection

Table A.6 - Load Rating and Posting Items	
Item ID	Item Description
L.1	Load Rating Method
L.2	Inventory Load Rating Factor
L.3	Operating Load Rating Factor
L.4	Tunnel Load Posting Status
L.5	Posting Load – Gross
L.6	Posting Load – Axle
L.7	Posting Load – Type 3
L.8	Posting Load – Type 3S2
L.9	Posting Load – Type 3-3
L.10	Height Restriction
L.11	Hazardous Material Restriction
L.12	Other Restrictions

Table A.7 - Navigation Items	
Item ID	Item Description
N.1	Under Navigable Waterway
N.2	Navigable Waterway Clearance
N.3	Tunnel or Portal Island Protection from Navigation

Table A.8 -Structure Type and Material Items	
Item ID	Item Description
S.1	Number of Bores
S.2	Tunnel Shape
S.3	Portal Shapes
S.4	Ground Conditions
S.5	Complex

Appendix B - Tunnel Elements:

Table B.1 - Structural

Table B.2 - Civil

Table B.3 - Mechanical Systems

Table B.4 - Electrical and Lighting Systems

Table B.5 - Fire/Life Safety/Security Systems

Table B.6 - Signs

Table B.7 - Protective Systems

Table B.1- Structural

Element Type	Element Name	Element #	Unit of Measure
Liners	Steel Tunnel Liner	10000	area, ft2
	Cast-in-Place Concrete Tunnel Liner	10001	area, ft2
	Precast Concrete Tunnel Liner	10002	area, ft2
	Shotcrete Tunnel Liner	10003	area, ft2
	Timber Tunnel Liner	10004	area, ft2
	Masonry Tunnel Liner	10005	area, ft2
	Unlined Rock Tunnel	10006	area, ft2
	Rock Bolt/Dowel	10007	Each
	Other Tunnel Liner	10009	area, ft2
Tunnel Roof Girders	Steel Tunnel Roof Girders	10010	length, ft
	Concrete Tunnel Roof Girders	10011	length, ft
	Prestressed Concrete Tunnel Roof Girders	10012	length, ft
	Other Tunnel Roof Girders	10019	length, ft
Columns/ Piles	Steel Columns/Piles	10020	Each
	Concrete Columns/Piles	10021	Each
	Other Columns/Piles	10029	Each
Cross Passageway	Steel Cross Passageway	10030	length, ft
	Concrete Cross Passageway	10031	length, ft
	Shotcrete Cross Passageway	10033	length, ft
	Timber Cross Passageway	10034	length, ft
	Masonry Cross Passageway	10035	length, ft
	Unlined Rock Cross Passageway	10036	length, ft
	Other Cross Passageway	10039	length, ft
Interior Walls	Concrete Interior Walls	10041	area,ft2
	Other Interior Walls	10049	area,ft2
Portal	Concrete Portal	10051	area,ft2
	Masonry Portal	10055	area,ft2
	Other Portal	10059	area,ft2
Ceiling Slab	Concrete Ceiling Slab	10061	area,ft2
	Other Ceiling Slab	10069	area,ft2
Ceiling Girder	Steel Ceiling Girder	10070	length, ft
	Concrete Ceiling Girder	10071	length, ft
	Prestressed Concrete Ceiling Girder	10072	length, ft
	Other Ceiling Girder	10079	length, ft
Hangers and Anchorages	Steel Hangers and Anchorages	10080	Each
	Other Hangers and Anchorages	10089	Each
Ceiling Panels	Steel Ceiling Panels	10090	area,ft2
	Concrete Ceiling Panels	10091	area,ft2
	Other Ceiling Panels	10099	area,ft2
Invert Slab	Concrete Invert Slab	10101	area,ft2
	Other Invert Slab	10109	area,ft2
Slab-on- Grade	Concrete Slab-on-Grade	10111	area,ft2
	Other Slab-on-Grade	10119	area,ft2
Invert Girder	Steel Invert Girder	10120	length, ft
	Concrete Invert Girder	10121	length, ft
	Prestressed Concrete Invert Girder	10122	length, ft
	Other Invert Girder	10129	length, ft
Joints	Strip Seal Expansion Joint	10130	length, ft
	Pourable Joint Seal	10131	length, ft
	Compression Joint Seal	10132	length, ft
	Assembly Joint With Seal	10133	length, ft
	Open Expansion Joint	10134	length, ft
	Assembly Joint Without Seal	10135	length, ft
	Other Joint	10139	length, ft
Gaskets	Gaskets	10140	length, ft

Table B.2 - Civil

Element Type	Element Name	Element #	Unit of Measure
Wearing Surface	Concrete Wearing Surface	10151	area,ft^2
	Asphalt Wearing Surface	10158	area,ft^2
	Other Wearing Surface	10159	area,ft^2
Traffic Barrier	Steel Traffic Barrier	10160	length, ft
	Concrete Traffic Barrier	10162	length, ft
	Other Traffic Barrier	10169	length, ft
Pedestrian Railing	Steel Pedestrian Railing	10170	length, ft
	Concrete Pedestrian Railing	10171	length, ft
	Other Pedestrian Railing	10179	length, ft

Table B.3 - Mechanical Systems

Element Type	Element Name	Element #	Unit of Measure
Ventilation System	Ventilation System	10200	Each
	Fans	10201	Each
Drainage and Pumping System	Drainage and Pumping System	10300	Each
	Pumps	10301	Each
Emergency Generator System	Emergency Generator System	10400	Each
Flood Gate	Flood Gate	10475	Each

Table B.4 - Electrical and Lighting Systems

Element Type	Element Name	Element #	Unit of Measure
Electrical Distribution	Electrical Distribution System	10500	Each
Emergency Distribution	Emergency Distribution System	10550	Each
Tunnel Lighting	Tunnel Lighting Systems	10600	Each
	Tunnel Lighting Fixtures	10601	Each
Emergency Lighting	Emergency Lighting Systems	10620	Each
	Emergency Lighting Fixtures	10621	Each

Table B.5 - Fire/Life Safety/Security Systems

Element Type	Element Name	Element #	Unit of Measure
Fire Detection	Fire Detection System	10650	Each
Fire Protection	Fire Protection System	10700	Each
Emergency Communications	Emergency Communications System	10750	Each
Operations and Security	Operations and Security System	10800	Each

Table B.6—Signs

Element Type	Element Name	Element #	Unit of Measure
Traffic Guidance	Traffic Sign	10850	Each
Egress Signs	Egress Sign	10870	Each
Variable Message Boards	Variable Message Board	10890	Each
Lane Signal	Lane Signal	10910	Each
	Lane Signal Fixture	10911	Each

Table B.7 - Protective Coating Elements

Element Type	Element Name	Element #	Unit of Measure
Protective Coating	Steel Corrosion Protective Coating	10950	Each
	Concrete Corrosion Protective Coating	10951	Each
	Fire Protective Coating	10952	Each

Appendix C - Tunnel Reports Examples

C.1 - TI & A Report

C.2 - Inspection Report

C.3 - Repair/Maintenance Report for Tunnel

C.4 - Vertical Clearance Diagram

C.5 - Photo Report

C.1. Tunnel Inventory & Appraisal

Date Printed : 11/06/2019

ARIZONA DEPARTMENT OF TRANSPORTATION

BRIDGE GROUP

Tunnel Inventory and Appraisal

Tunnel Number :	**00407**	Tunnel Name :	**Queen Creek Tunnel**	Feature Under :	**US 60**
Route : **60**	MP : **228.47**	Road Name :	**Queen Creek Tunnel** Agency: **ADOT**	Location :	**1.6 mi E Jct SR 177**

LOCATION INFORMATION

I3-State Code :	04
I6-State Hwy District :	Southeast
I4-County Code :	021
I5-Place Code :	00000
C8-Urban Code :	99999
I13-Latitude:	33 Deg 18 Min 15.67 Sec
I14-Longitude :	111 Deg 05 Min 0.66 Sec
I15/I16-Border St Code - % Resp:	
I17/I16-Border Bridge Number:	

INVENTORY ROUTE DATA

A7-Detour Length (miles):	37	
C4-Toll:	No tolls	
I9-Route Type:	2	
I7/I8-No/Direction Rte:	00060	0
A3-Total No. of Lanes:	3	
I11-LRS Rt ID:		
I12-LRS MP:		
C7-Functional Class:	3	
A4-Avg Daily Traffic:	8250	
A6-Year of ADT:	2018	
C6-STRAHNET:	1	
C3-Direction of Traffic:	2	
C5-NHS:	1	
A5-Truck Traffic:	750	

RESPONSIBILITY

C2-Operator:	01
C1-Owner:	01
A203-ADOT Org Number:	5356
A229-Agency:	ADOT

DIMENSIONS

G1-Tunnel Length (feet):	1217
G4-Lt Sidewalk Width (feet):	2.0
G5-Rt Sidewalk Width (feet):	2.0
G3-Roadway Width C-C (feet):	38.3

VERITCAL & HORIZONTAL CLEARANCE

L10-Height Restriction:	Yes
G2-Min Vert Clr (feet):	14.00

SERVICE, SHAPE, and BORE INFORMATION

A8-Service in Tunnel:	Highway
S2-Tunnel Shape:	Horseshoe
S3-Portal Shape:	Horseshoe
S4-Ground Conditions:	Rock
S5-Complex:	Not Complex
S1-Number of Bores:	1

LOAD, RATE, and POST

L4-Tunnel Load:	A
L1-Load Rating Method:	N
L3-Operating Load Rtg/Factor:	
L2-Inventory Load Rtg/Factor:	
L5-Posting Load - Gross (Tons):	
L6-Posting Load - Axle (Tons):	
L7-Posting Load - Type 3 (Tons):	
L8-Posting Load Type 3S2 (Tons):	
L9-Posting Load - Type 3-3 (Tons):	
A222-Date of Load Rtg:	
L11-Haz. Material Restriction:	0 - No
L12-Other Restrictions:	0 - No
A233-Posted Vert Clr NB/EB (ft-in):	13-6
A233-Posted Vert Clr SB/WB (ft-in):	13-6

CONSTRUCTION PROJECT DATA

A1-Year Built:	1952
A2-Year Rehabilitated:	0
A204-Orig Project Number:	F-16(14)
A205-Orig Project Station:	105+33.00
A223-TRACS Number:	
A225-Tunnel Area (sq. feet):	48342

INSPECTION

D2-Inspection Date:	08/19/2019
D3-Insp Freq (months):	24
A207-Inspection Quarter:	7
Inspection Types:	Routine
D1-Next Insp Date:	August 2021

CRITICAL FEATURES

D4-In-Depth Inspection:	No
D5-Damage Inspection:	No
D6-Special Inspection:	No

NAVIGATION

N1-Under Nav Waterway:	0
N3-Nav Island Prot:	0
N2-Nav Waterway Clr (feet):	0.0

A300T - GENERAL TUNNEL COMMENTS

This tunnel is in Active Status.

Initial inspection was on 8/7/2017.

C.2 - Tunnel Inspection Report - Page 1

Date Printed : 11/06/2019

ARIZONA DEPARTMENT OF TRANSPORTATION

BRIDGE GROUP

Tunnel Inspection Report

Tunnel No.:	00407	Tunnel Name:	Queen Creek Tunnel	Inspected by :	[illegible]
Route :	60	Road Name:	Queen Creek Tunnel	Inspection Type:	Rou[illegible]
MP :	228.47	Agency:	ADOT	Inspection Date :	Monday, August 19, 2019
ADOT District:	Southeast			Next Insp. Due By :	August 2021

Inspection Notes

Roadway/Safety: 1. Vertical clearance posting signs of 13'-6" are present at both approaches as a prewarning and are not posted on the tunnel itself. 2. The minimum vertical clearances are: 14.06' (EB) and 14.00' (WB). 3. Galvanized W-beam approach rail with timber blockouts and posts. East approach rail exhibits intermittent areas of rockfall damage (See Maintenance Report and Photo O). Embankment: 1. Northwest embankment exhibits rock fall wire mesh. Miscellaneous: 1. This was a routine inspection conducted by Stantec under Contract 2019-010.05 TO #1. 2. The tunnel was inventoried from west to east with stationing beginning at Station 0+00 and ending at 12+17. 3. Lower portions of the tunnel were accessed from the ground with traffic control. 4. One previous repair item was not completed and is repeated. One new maintenance item has been recommended. Repair: 1. Repair spall and deteriorating concrete in east portal tunnel liner over the eastbound lanes. Maintenance: 1. Repair southeast approach rails where damaged by rockfall. Photos taken: A. West portal ID looking west B. East portal ID looking east C. Typical slab-on-grade condition D. Typical liner joint condition E. Typical liner condition F. Tunnel overview looking east G. Typical condition of lighting system along crown of tunnel H. Typical condition of security camera near mid length of tunnel I. Transverse crack open to 1/8" wide in concrete slab on grade J. Slab-on-grade joints have cracked and missing seals K. 8' x 4' patched spall in the west portal fascia over the westbound lane L. 4' x 2' spall with exposed and corroded rebar in east portal fascia over westbound lane M. Spall, delaminations, and deteriorating concrete with exposed rebar in east portal liner over eastbound lanes N. Vertical crack open to 1/16" in northwest wingwall O. Southeast approach rail exhibits impact damage and damaged or failed timber blockouts for majority of length P. East approach roadway exhibits moderate to wide transverse cracks Q. Vertical clearance sign at west approach R. Vertical clearance sign at east approach

Element No.	Element Description	Quantity	Units	Condition State 1	Condition State 2	Condition State 3	Condition State 4
10001	Cast-In-Place Concrete Tunnel Liner	79105	sqft	72017	6138	950	0
CIP Reinforced Concrete Tunnel Liner							
82100	*Delamination / Spall / Patch*	4	sqft	0	4	0	0
1. The crown exhibits a 4 SF delamination near Station 1+50. 2. Construction joints have minor edge spalling (Photo D), with the heaviest concentration located at the first construction joint from the west portal. 3. North wall, at springline, exhibits intermittent areas of minor impact scrapes.							
82102	*Efflorescence / Staining*	2382	sqft	0	1582	800	0
1. Construction joints exhibit light to heavy efflorescence throughout, some isolated areas of stalactite buildup (Photo D). 2. Minor rust staining was evident in a few isolated locations. 3. Liner exhibits hairline diagonal cracks, some with efflorescence (Photo E).							
82103	*Cracking (Concrete Liner)*	4105	sqft	0	3955	150	0
1. Cracks open to 1/8" in the south wall, near the east end of the tunnel. 2. Hairline to moderate diagonal cracks throughout the tunnel liner. Heaviest concentration for the eastern-most 200 feet of the tunnel.							
10051	Concrete Portal	1500	sqft	1316	137	47	0
Reinforced Concrete Portal.							
82100	*Delamination / Spall / Patch*	129	sqft	0	92	37	0
1. West portal liner exhibits a 6" diameter spall with exposed rebar and a 32 SF area of delamination over westbound lanes. 2. West portal fascia has a 8' x 4' patched spall at top over westbound lane. 3. East portal liner exhibits a 20 SF of large spalls over westbound lanes. 4. East portal liner exhibits a 60 SF area of delamination. 5. There is a 15 SF spall with exposed rebar, near drain over the eastbound lanes, in the east portal liner (See Repair Report and Photo M). Spall is greater than 1" deep. Adjacent concrete is delaminating and deteriorating. Reinforcing steel exhibits surface corrosion with no measurable section loss. 6. East portal fascia exhibits a 4' x 2' spall with exposed rebar at top over westbound lane.							
82103	*Cracking (Concrete Liner)*	195	sqft	140	45	10	0
1. East portal liner exhibits a few hairline to moderate transverse cracks in the crown at centerline.							
10111	Concrete Slab-on-Grade	46550	sqft	36354	10096	100	0
Concrete Slab-on-Grade. 1. Wheel lines exhibits minor wear/abrasion throughout.							
82100	*Delamination / Spall / Patch*	466	sqft	0	466	0	0
1. Slab-on-grade exhibits isolated shallow spalls and aggregate popouts.							
82109	*Cracking (RC)*	2428	sqft	0	2328	100	0
1. Slab-on-grade has transverse cracks open between hairline and 1/8" wide (Photo I).							
10131	Pourable Joint Seal	3926	ft	3676	0	0	250
Pourable Joint Seal present in slab-on-grade longitudinal and transverse joints. Quantity reflects (2) full length longitudinal joints and transverse joints spaced approximately 30' to 40'.							
86000	*Seal Damage*	250	ft	0	0	0	250
1. Joints exhibit intermittent areas of missing sealant (Photo J).							

Inspection Report - Page 2

ARIZONA DEPARTMENT OF TRANSPORTATION

BRIDGE GROUP

Tunnel Inspection Report

Tunnel No. :	00407	Tunnel Name :	Queen Creek Tunnel	Inspected by :	BBBBBBBBBB
Route :	60	Road Name :	Queen Creek Tunnel	Inspection Type:	Routine
MP :	228.47	Agency :	ADOT	Inspection Date :	Monday, August 19, 2019
ADOT District:	Southeast			Next Insp. Due By :	August 2021

Element No.	Element Description	Quantity	Units	Condition State 1	Condition State 2	Condition State 3	Condition State 4
10500	Electrical Distribution System	1	each	1	0	0	0
Electrical conduit connecting lights and cameras. 1. No significant defects.							
10600	Tunnel Lighting System	285	each	0	285	0	0
Lights run full length of tunnel at centerline. Every 8th light is dimmer than rest. 1 . No significant defects.							
10601	Tunnel Lighting Fixture	285	each	285	0	0	0
Lighting fixtures run the full length of the tunnel at centerline. 1. No significant defects.							
10800	Tunnel Operations and Security System	1	each	1	0	0	0
(1) Surveillance Camera mounted to electrical distribution system along centerline at mid length through tunnel (Station 5+00). 1. No significant defects.							

C.3 - Maintenance Report (Repair Report is similar)

Date Printed : 11/06/2019

ARIZONA DEPARTMENT OF TRANSPORTATION

BRIDGE GROUP

Tunnel Maintenance Report

Tunnel Number :	**00407**	Tunnel Name :	**Queen Creek Tunnel**	Inspected by :	
Route :	**60**	Road Name :	**Queen Creek Tunnel**	Inspection Type:	**Routine**
MP :	**228.47**	Agency :	ADOT	Inspection Date :	**Monday, August 19, 2019**
ADOT District:	**Southeast**	District Org:	**5356**	Next Insp. Due By :	**August 2021**

Work Candidate ID:	8682C12-C056-091219-9FEEB05AEB		
Action:	1000 Approach Railing-Repair	**A216 - Actual Completion Cost**	$
Estimated Quantity:			
Estimated Cost:	$0.00	**A215 - Completion Date:**	
A212 - Repair Priority:	3-Can be scheduled		

Repair southeast approach rails where damaged by rockfall

C.4 - Clearance Diagram

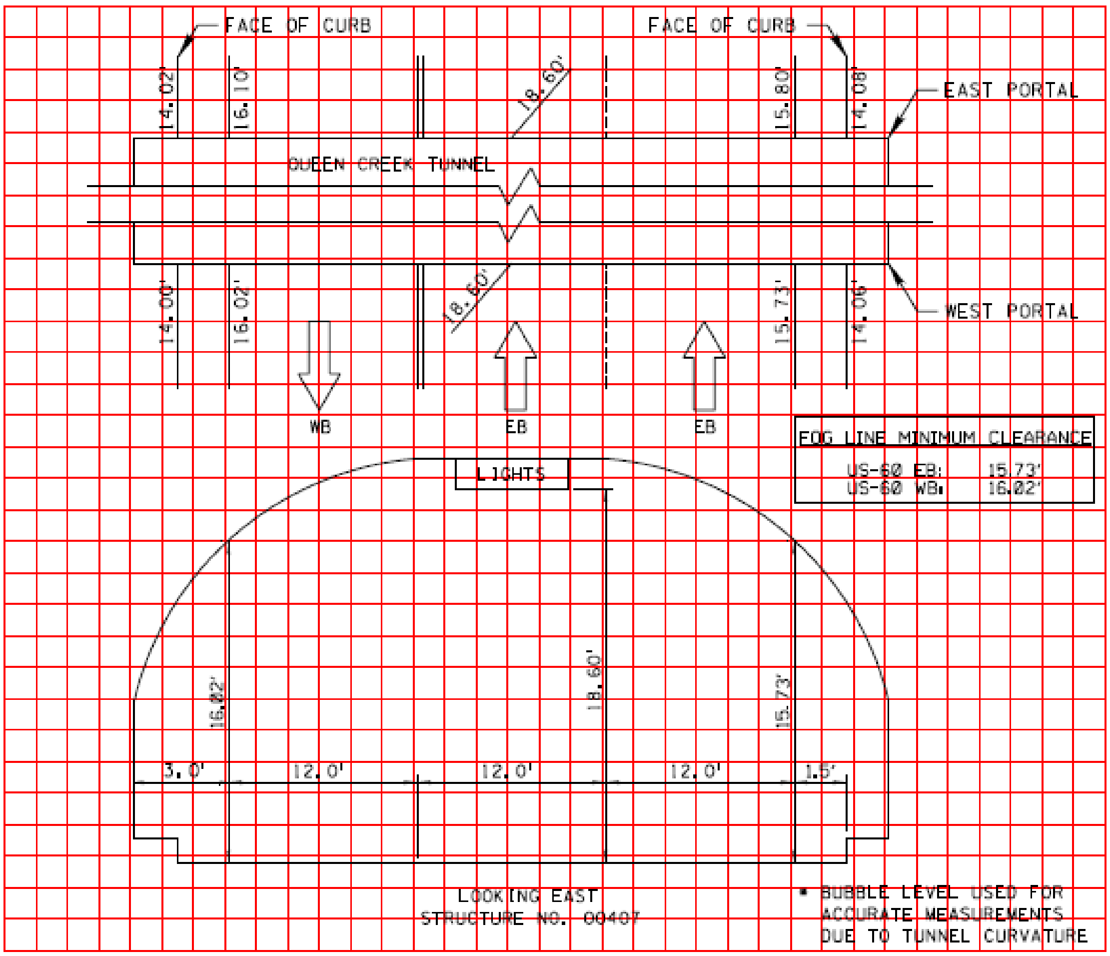
STRUCTURE NAME: QUEEN CREEK TUNNEL

STRUCTURE NO.: 407

LOCATION: 60 (ROUTE) 228.47 (MILEPOST)

INSPECTION					
DATE	8/7/17				
INITIAL	[redacted]				
NEW/REVISED DIAGRAM	REV.				

MIN. VERTICAL CLEARANCE	
14.06'	NB / (EB)
14.00'	SB / (WB)



C.5 - Photo Report (only 2 photos included)

a. West portal ID looking west

Date Printed : 11/06/2019 **ARIZONA DEPARTMENT OF TRANSPORTATION** Page 1 of 18

BRIDGE GROUP

Bridge Inspection Photographs

Structure Number :	**00407**	Structure Name :	**Queen Creek Tunnel**	Inspected by :	[redacted]
Route :	**60**	Road Name :	**Queen Creek Tunnel**	Inspection Type:	**Routine**
MP :	**228.47**	Agency :	**ADOT**	Inspection Date :	**Monday, August 19, 2019**
ADOT District	**Southeast**			Next Insp. Due By :	**08/19/2021**

File Name : 00407-2019-08-19-Photo-a.JPG

Description : West portal ID looking west

b. Photo m. Defects (delamination, spall, exposed rebar) in east portal liner over EB lanes

Bridge Inspection Photographs

Structure Number :	00407	Structure Name :	Queen Creek Tunnel	Inspected by :	[redacted]
Route :	60	Road Name :	Queen Creek Tunnel	Inspection Type:	Routine
MP :	228.47	Agency :	ADOT	Inspection Date :	Monday, August 19, 2019
ADOT District	Southeast			Next Insp. Due By :	08/19/2021

File Name : 00407-2019-08-19-Photo-m.JPG

Description : Spall, delaminations, and deteriorating concrete with exposed rebar in east portal liner over eastbound lanes

Appendix D - Digital Documents Naming Convention

D. Digital Documents Naming Convention

D.1 - INSPECTION Documents

D.1.1 - Photographs

D.1.2 – Other Documents

D.2 - BRIDGE Documents

D. Digital Documents Naming Convention

When adding a digital document to a given tunnel in BrM (tunnel database), there are two categories of documents to consider:

1. INSPECTION- documents in this category are added to the existing digital documents after a new inspection has been added to the BrM. Typical inspection documents added include photos, clearance diagrams, sketches, report supplements, etc.
2. BRIDGE- documents in this category, despite the name BRIDGE, belong to the life of a particular structure (tunnel) and are not necessarily associated with any specific inspection date. They are utilized for evaluation of structural integrity, structural capacity, and quantification of various elements. Any major change to the structure necessitates addition of new documents. Examples of such documents include original construction plans, reconstruction plans, load rating, etc.

Once the category of the document has been determined, it can be added to the BrM using an appropriate category (INSPECTION or BRIDGE) from the Context dropdown menu in the Multimedia section.

D.1 INSPECTION Documents

Select "INSPECTION" category from Multimedia Context dropdown menu in BrM in order to link properly-named documents of a given structure number to its new inspection report. In general, a document type "abcdefgh" with a sequence number "sn" (valid only for photos) and a file extension ".ijk" belonging to a structure number "sssss" during an inspection dated "yyyy-mm-dd" will be represented by the following chain of digits/characters:

(1) sssss-yyyy-mm-dd-abcdefgh-sn.jpg (photos only)

(2) sssss-yyyy-mm-dd-abcdefgh.pdf (other types of documents)

- sssss indicates structure number. Use leading zeros when the structure number is less than 10000. See table below.

Examples of Structure Number Format

Structure #	sssss
25	00025
146	00146
2179	02179
10105	10105

- Digits 6, 11, 14, 17, etc. are dashes "-", not underline character "_"
- yyyy indicates year of addition (4 digits)
- mm indicates month of addition (2 digits: 01, 02, 03, ….., 09, 10, 11, 12)
- dd indicates the day of month document added (2 digits: 01, 02… 09, 10… 20, 21….

31).
- Abcdefgh, including blank spaces, represents the document type. See table below.

Table 1. Various Inspection Document Types, Names and No. of characters

Document Type	Document Name Applied	Number of Characters
Photographs	Photo	5
Clearance Diagram	Clearance Diagram	17
Additional Information	Report Supplement	17
Other Drawings	Sketch	6

- sn represents the sequence number of the document (only used with photos, see Photographs below)
- .ijk identifies file extension. See table below.

Table 2. File Extension for Various Document Types

Document Type	File Extension
Photograph	.jpg
Others	.pdf

D.1.1 Photographs

Photographs are the most common type of documents in the tunnel inspection files. The general naming convention will be represented by the following naming scheme:

sssss-yyyy-mm-dd-Photo-sn.jpg

All photographs should be adjusted to a resolution of 800 x 600 pixels. Select "INSPECTION" from Multimedia Context tab in BrM for linking properly-named photographs of a given structure to a given inspection report. Since there are multiple photos (up to 99) associated with each inspection, it is necessary to use "sn" to uniquely identify each photograph.

The photograph names must contain 29 digits/characters:
- The first 17 digits (sssss-yyyy-mm-dd-) are the same as those described above.
- Digits 18-22, Photo, - 5 characters - indicates the document type
- Digit 23: Character in position 23 is a dash "-", not an underline character "_"
- Digits 24-25: sn (two digits) identifies each photograph's sequential number with leading zeros for photos 1 to 9 ("01", "02", "03"… "10", "11"… "99").
- Digits 26-29: .jpg (4 characters) represents typical photo file extension

Examples:
- During November 15th, 2016 inspection of tunnel #407 (3 digits), 10 photographs were taken which should be named:

00407-2016-11-15-Photo-01.jpg
……………………………….
00407-2016-11-15-Photo-10.jpg

- During December 18th, 2017 inspection of tunnel #2001 (4 digits), 12 photographs were taken which should be named:

02001-2017-12-18-Photo-01.jpg
……………………………….
02001-2017-12-18-Photo-12.jpg

- During June 10th, 2019 inspection of tunnel #20177 (5 digits), 14 photographs were taken which should be named:

20177-2019-06-10-Photo-01.jpg
……………………………….
20177-2019-06-10-Photo-14.jpg

D.1.2 Other Documents

It is assumed that all other documents, excluding photos, will be saved as ‘pdf documents. The total number of digits/characters representing various documents depends on the type of document. The general naming convention will be represented by the following naming scheme:

sssss-yyyy-mm-dd-abcdefgh.pdf

- The first seventeen (17) digits/characters in this group (sssss-yyyy-mm-dd-) will be represented by the same digits/characters shown in Section D.1, format (2) above. Do not use underline character ‘_’ for dash (-).
- Digits 18-25 (varies with type of document), abcdefgh, indicates the document type. See Table 1 above for type of documents.
- The last four characters (.pdf) are for the file extension.

Typical documents include Sketch, Clearance Diagram, and Report Supplement. The clearance diagrams must be in upright position (portray format) on the screen for better readability.
A “Miscellaneous” document type is included to represent the applicable naming convention when a new document type is encountered. The following is a list of typical documents associated with the inspection report of a given structure #407 on a given inspection date of January 14th, 2015:

00407-2015-01-14-Sketch.pdf
00407-2015-01-14-Clearance Diagram.pdf
00407-2015-01-14-Report Supplement.pdf
00407-2015-01-14-Miscellaneous.pdf

D.2 BRIDGE Documents

The BRIDGE documents are only added when a substantive change to the structure is made in such a manner that it impacts all the inspections thereafter such as dimensional changes, tunnel rail

retrofit/replacement, installation of lighting fixtures, etc. These documents are intended to be used at any time during the life of a structure including the inspection times. Typical documents include original construction/reconstruction plans, special inspections, Tunnel load rating summary, tunnel inspection procedure, etc.
Selecting “BRIDGE” from Multimedia Context dropdown menu in BrM for linking properly-named documents to a given structure number. The term “BRIDGE” is generic and applies to culverts and tunnels as well.

The general naming convention for these documents will be the same as the other documents described in section D.1 above except for the inspection date to be replaced by the date document is added. The following examples show the naming convention of various documents linked to the structure #407 digital file in BRIDGE Context dropdown on May 10th, 2018:

- Original Construction plans:

00407-2018-05-10-Plans-Record Drawing-Original Construction.pdf

- Reconstruction plans:

00407-2018-05-10-Plans-Record Drawing-Tunnel Reconstruction.pdf

- Special Inspection

00407-2018-05-10-Special Inspection.pdf

- Tunnel Load Rating Summary:

00407-2018-05-10-Load Rating.pdf

- Miscellaneous (any document other than the above):

00407-2018-05-10-Miscellaneous.pdf

Appendix E - FHWA Memorandum, Inspection of Non-Structural Tunnel Elements

FHWA 2020 Memorandum regarding Non-Structural Tunnel Elements Located above Roadways

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION:** Inspection of Non-Structural Tunnel Elements Located above Roadways

Date: November 6, 2020

In Reply Refer to: HIBS-30

From: Joseph L. Hartmann, Ph.D., P.E.
Director, Office of Bridges and Structures

To: Division Administrators
Federal Lands Highway Division Directors

The purpose of this memo is to notify tunnel owners of the circumstances of the February 21, 2018 fatal crash in the Lehigh Tunnel and to emphasize the importance of inspecting, documenting, and promptly repairing significant corrosion in nonstructural tunnel elements located above roadways.

On February 21, 2018, a truck-tractor in combination with a semi-trailer, was traveling south on Interstate 476 (Pennsylvania Turnpike) in the right lane inside Tunnel No. 2 of the Lehigh Tunnel in East Penn Township, Pennsylvania. After traveling about 1,000 feet through the 4,379-foot-long tunnel, the truck-tractor struck a 10-foot-long section of electrical conduit whose support system had failed. The conduit impacted the vehicle's windshield and struck the truck driver. The truck driver died in the crash. No other injuries or damaged vehicles were reported.

Investigators from the National Transportation Safety Board (NTSB), along with experts from the Federal Highway Administration (FHWA) assisting the NTSB investigators, examined various portions of the electrical conduit and suspension system throughout tunnel No. 2 after the crash. Investigators found corroded, fractured, and missing transverse conduit supports at multiple locations.

The NTSB determined that the probable cause was the failure of the electrical conduit support system in Lehigh Tunnel No. 2 due to long-term corrosion, which resulted in displacement of the electrical conduit into the travel path of the truck-tractor. The NTSB made two recommendations:

1. Notify tunnel owners of the circumstances of this crash, emphasizing the importance of inspecting, documenting, and promptly repairing significant corrosion in nonstructural tunnel elements located above roadways.
2. Revise the Tunnel Operations, Maintenance, Inspection, and Evaluation Manual (TOMIE); Specifications for the National Tunnel Inventory (SNTI); and inspection training courses to classify significant corrosion in nonstructural tunnel elements as a critical finding that requires immediate action.

The NTSB issued a Highway Accident Brief on August 20, 2020. This can be accessed at https://www.ntsb.gov/investigations/AccidentReports/Pages/HAB2004.aspx

The Office of Bridges and Structures (HIBS) has worked with the National Highway Institute (NHI) since the incident to revise the NHI tunnel inspection courses so they emphasize the importance of corrosion in non-structural items and critical findings. In addition, the HIBS reviewed the TOMIE to verify it discusses the inspection of overhead non-structural elements and found that it does. Additionally, in the TOMIE's next revision cycle, the HIBS will add additional clarifying language that further reinforces the significance of corrosion to overhead non-structural tunnel elements.

The SNTI does not have an item to specifically track critical findings but has multiple items for tracking the condition of certain overhead non-structural items. These data items alone are not meant to be used as the only source of identifying critical findings. The National Tunnel Inspection Standards require States, Federal agencies, and tribal governments to have procedures to ensure critical findings are identified and addressed in a timely manner (23 Code of Federal Regulations 650.513(j)).

Lastly, the Office of Bridges and Structures launched a Critical Findings Database (CFD) early this year to serve as a repository of information on critical findings and to provide information that can be used to identify and target vulnerabilities and trends in bridge and tunnel performance. The guidance for the CFD will be updated in FY2021 to include the corrosion of attachments of overhead non-structural items as one of the defects which may be recorded into the database.

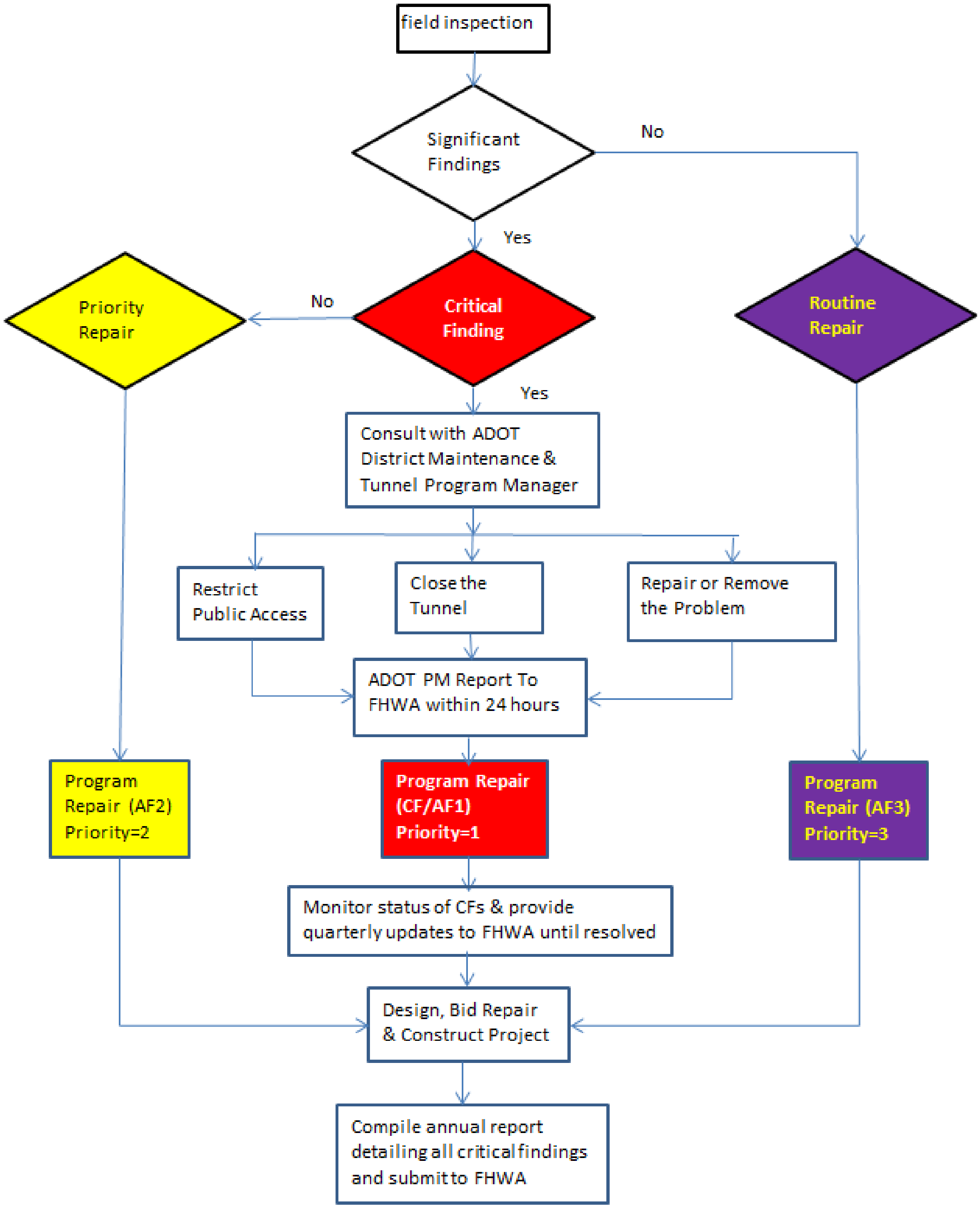
Please share this information with your State, Federal, and tribal partners and work with them to ensure tunnel inspection procedures include appropriate requirements for inspecting overhead elements.

Please direct questions to John Thiel at (202) 366-8795 or e-mail at John.Thiel@dot.gov or to Shay Burrows at (202) 366-4675 or e-mail at Shay.Burrows@dot.gov.

cc: Directors of Field Services
Director of Technical Services
HIBS-30

Appendix F - Significant Findings Flow Chart and Reporting Form

1. Flow Chart for response to field inspection Significant Findings



2. Sample Form to report Significant Findings

ARIZONA DEPARTMENT OF TRANSPORTATION

Bridge Group

Bridge Inspection Section

To: Don Q ADOT Tunnel Program Manager	From: John Do Inspection Team Leader
Arizona Department of Transportation Engineering Building, 2nd Floor 205 South 17th Ave Phoenix, AZ 85007	Inspector Address (if not ADOT location)
Project: NTIS Tunnel Inspections	Date:
	Critical Finding ☐ Repair Priority 2 ☐
Tunnel #: Tunnel Name:	Element # : Location:
Route Name:	Description of defect
Inspection Date:	Recommendation:
CF/AF1: Immediate Attention - Red	Action required:
AF2: Above Routine - Yellow	☐ Close the tunnel until the severe defect is removed or repaired, if the defect may impact users or user safety
	☐ Restrict the area from public access until the defect can be removed or repaired.
	☐ Repair the structural member or address the functional or safety issue (as specified in the recommendation)

Appendix G - Quality Control & Quality Assurance Form

ADOT

Tunnel Inspection Quality Assurance Review

Agency		Str No.		Str Name		Route		Letter		Milepost	
Inspection Team		Inspection Date		QA Review Team		QA Date					

Tunnel Inventory Item			Inspection Team	QA Review Team
#	Description	Units		
A7	Detour Length	mi		
A3	No. of Lanes	#		
C3	Direction of Traffic	#		
A4	Avg Daily Traffic	#		
A6	Year of ADT	#		
L11	Haz. Material Restrictionn	#		
L12	Other Restrictions	#		
L10	Height Restriction	Y/N		
G2	Min Vert Clearance	ft		
S1	Number of Bores	#		
S2	Tunnel Shape			
S3	Portal Shape			
S4	Ground Condition			
G1	Tunnel Length	ft		
G3	Roadway Width	ft		
G4	Lt Sidewalk Width	ft		
G5	Rt Sidewalk Width	ft		
S5	Complex			
C5	NHS	#		
A5	Truck Traffic	#		
A233	Posted Vert Clr Pos	ft-in		
A233	Posted Vert Clr Neg	ft-in		
A225	Tunnel Area			
D3	Insp Freq	mo		
	Inspection Type			

Element				Condition State (Inspect)				Condition State (QA Review)			
#	Description	Qty	Units	1	2	3	4	1	2	3	4

Quality Assurance Review Comments

QA Review Evaluation

[ ] Complies with established QC Procedures. No noted findings.

[ ] Complies with established QC Procedures. Minor findings noted.

[ ] Does not comply with established QC procedures. Major findings noted.

[ ] Does not comply with established QC procedures. Critical findings noted.

Quality Assurance Reviewers

Signature____________________ Date__________

Signature____________________ Date__________