NCHRP

RESEARCH REPORT 833

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Assessing, Coding, and Marking of Highway Structures in Emergency Situations

Volume 3: Coding and Marking Guidelines

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Assessing, Coding, and Marking of Highway Structures in Emergency Situations

Volume 3: Coding and Marking Guidelines

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research is the most effective way to solve many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation results in increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

Recognizing this need, the leadership of the American Association of State Highway and Transportation Officials (AASHTO) in 1962 initiated an objective national highway research program using modern scientific techniques—the National Cooperative Highway Research Program (NCHRP). NCHRP is supported on a continuing basis by funds from participating member states of AASHTO and receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine was requested by AASHTO to administer the research program because of TRB's recognized objectivity and understanding of modern research practices. TRB is uniquely suited for this purpose for many reasons: TRB maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; TRB possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; TRB's relationship to the Academies is an insurance of objectivity; and TRB maintains a full-time staff of specialists in highway transportation matters to bring the findings of research directly to those in a position to use them.

The program is developed on the basis of research needs identified by chief administrators and other staff of the highway and transportation departments and by committees of AASHTO. Topics of the highest merit are selected by the AASHTO Standing Committee on Research (SCOR), and each year SCOR's recommendations are proposed to the AASHTO Board of Directors and the Academies. Research projects to address these topics are defined by NCHRP, and qualified research agencies are selected from submitted proposals. Administration and surveillance of research contracts are the responsibilities of the Academies and TRB.

The needs for highway research are many, and NCHRP can make significant contributions to solving highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement, rather than to substitute for or duplicate, other highway research programs.

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FOREWORD

By Amir N. Hanna
Staff Officer
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This report presents a process for assessing highway structures in emergency situations and guidelines for related coding and marking that can be recognized by highway agencies and other organizations that respond to emergencies resulting from natural or man-made disasters. This information will help highway and other emergency response agencies deal more effectively with these emergencies and provide a safer condition for the public. The material contained in the report should be of immediate interest to the personnel at state agencies and other organizations that generally respond to emergency situations affecting highway structures.

The assessing, coding, and marking of highway structures are necessary for ensuring safety in the event of emergencies resulting from natural or man-made disasters, and several state DOTs have adopted processes for performing these activities. However, there are currently no processes that provide a uniform means for conducting these assessments or a common form of coding and marking; neither do current processes explicitly consider the practices of other organizations that often respond to such emergencies with assistance. Also, these processes do not generally address the full range of emergency events, the different highway structure types, or the ranges of traffic levels. These issues tend to impede the effectiveness of involved organizations in dealing with these situations and may lead to undesirable consequences. Research was needed to develop a process for assessing highway structures and guidelines for related coding and marking that can be recognized and adopted by highway agencies and other organizations. These uniform processes and guidelines would help coordinate the emergency response effort in a safe and efficient manner.

Under NCHRP Project 14-29, "Assessing, Coding, and Marking of Highway Structures in Emergency Situations," Oregon State University worked with the objective of developing (a) a process for assessing highway structures in emergency situations, (b) guidelines for coding and marking, and (c) material to facilitate the acceptance and adoption of the developed process and guidelines by state agencies and other organizations.

The research was conducted in two phases. The first phase collected background information through a literature review and a survey of state departments of transportation. The review dealt with common hazards, critical highway structures, inspection technologies, emergency management and response, assessment procedures, and coding and marking practices. Specific hazards considered included earthquakes, tsunamis, tornados, hurricanes, storm surge, high winds, flooding, scour, and fire. Highway structures considered included bridges, tunnels, culverts, walls, embankments, and overhead signs. This work identified assessment, coding, and marking technologies that can be practically implemented by transportation and other emergency response agencies. An evaluation of these technologies led to the identification of methods that could be used in each stage in the process for rapid assessment of highway structures in emergency situations.

The second phase of research focused on developing the (a) *Assessment Process Manual* and (b) *Coding and Marking Guidelines.* The *Assessment Process Manual*—intended for managers who will oversee the emergency response—identifies technologies that are appropriate for each structure type and addresses prioritization, coordination, communication, and redundancy. The *Coding and Marking Guidelines* are intended as a field manual for Preliminary Damage Assessment responders who will evaluate the highway structures. In addition, the project produced Preliminary Damage Assessment Forms for each structure type, development guidelines to help create a mobile device smart application for the assessment process, and four types of training material to further help highway agencies and other emergency response organizations with the implementation of the developed manual and guidelines. This training material includes: (a) general training for the general audience who will interface with those involved in the assessment process, (b) basic training for damage assessment responders, (c) specialized training for managing engineers who will oversee the assessment process, and (d) a quick refresher for damage assessment responders on the most relevant procedures for Preliminary Damage Assessment.

The *Research Overview,* which provides background information and an overview of the process, supporting manuals, and training materials, and *Assessment Process Manual* are published as Volumes 1 and 2, respectively, of this report. *Guidelines for Development of Smart Apps for Assessing, Coding, and Marking Highway Structures in Emergency Situations* is available on the TRB website (www.trb.org) as *NCHRP Web-Only Document 223.* To facilitate use, the assessment forms and training material are posted on the *NCHRP Research Report 833* summary page, available by searching the TRB website for NCHRP Research Report 833.

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PREFACE

The assessing, coding, and marking (or sometimes referred to as "posting") of highway structures is necessary to ensure the integrity and usability of highway structures before, during, and after emergency events such as earthquakes, tsunamis, tornados, hurricanes, storm surge, high winds, flooding, scour, and fire. Orderly evacuation, when necessary, and subsequent emergency response require that bridges, tunnels, walls, culverts, embankments, and overhead signs be capable of safely supporting necessary loads and functioning satisfactorily. In addition, geotechnical and hydrological issues affecting these structures such as slope stability, liquefaction, settlements, and scour must also be considered.

Not only is the highway network relied upon to transport people, but it is also the economic lifeline of the affected region, facilitating the movement of emergency supplies and services. Restoring power, supplying fuel, transporting injured residents, and providing food stocks can be just a few of the critical needs of a region affected by a catastrophic event.

As seen over the past few years with disastrous events such as the 2012 Hurricane Sandy and the 2011 Tohoku earthquake and tsunami in Japan, the need for emergency preparedness planning is essential to a coordinated, timely, and effective response, particularly in terms of communication between the various agencies that need to be involved. The extent of advance notice will depend on the type of event, but, in all cases, the greater the level of planning and interagency discussions that can be performed to analyze a range of what-if scenarios, the better.

One of the critical components of any emergency response plan is the process for inspectors to assess the integrity of highway structures impacted by an event. To date, a uniform methodology for rapidly assessing, coding, and marking highway structures after an emergency event does not exist. Current processes do not generally address the different highway structure types, the full range of emergency events, the range of traffic levels (i.e., the amount of traffic that a highway structure normally carries), or methods employed by other responding agencies. To this end, the primary purpose of this report is to establish a uniform methodology along with a consistent framework for coordinating the emergency response effort in a safe and efficient manner. This scalable approach provides guidance on response levels based on the severity of the event.

In fact, this recommended approach to the issue of structural assessment is based on a "First You Plan" strategy. During this vital planning phase, regional factors, interagency needs, and communication issues can be identified and addressed in a non-emergency environment. Access by inspectors to all available information (which can vary significantly) can be planned and tested under simulated event conditions (e.g., ShakeOut earthquake drills).

The assessment process presented in this report consists of four stages: Fast Reconnaissance (FR), Preliminary Damage Assessment (PDA), Detailed Damage Assessment (DDA), and Extended Investigation (EI).

This hierarchal approach accounts for the need for rapid yet reliable information at the early periods of the emergency situation followed by progressively more detail as the process continues to ensure appropriate allocation of resources during the repair and recovery phase. The approach also accounts for the diverse skill sets and capabilities of persons needed for the assessment process. Finally, it provides guidance for determining appropriate response levels and mobilization based on incoming warnings or information for each emergency event.

Given the immense scope and ranges of damages from the plethora of emergency events possible across the country, the assessment procedure was developed with a simplified taxonomy in order to group common forms of damages so that a systematic process could be implemented that is nearly independent of the hazard type.

A coding and marking procedure was developed for use after the assessment is completed where each structure is physically marked with a placard and digitally marked in a database to improve communication between responders for various organizations. The coding and marking following a PDA stage establishes whether a structure has been INSPECTED or is UNSAFE. Quick-response (QR) codes are also used on these placards to link and communicate important structural or other information to field responders.

Technology is a critical component for recording and communicating these assessment results. It can help improve the process if staff are appropriately trained and prepared to utilize the technology. For example, a geographic information system database for the structures that was prepared (and continually updated) prior to the event can be used to help prioritize assessment routes, track progress, and analyze the condition of the highway network in order to provide decision makers with up-to-date information.

Incoming data from video networks, crowdsourcing, and other sources can be quickly collected to help determine the optimal locations to send personnel for rapid inspections. While a human-centered, visual assessment process is recommended for the PDA stage, this process can be guided and enhanced through the use of applications on smart devices that enable information to be systematically recorded and routed back to the central office. In the later stages, performing more detailed assessments can also benefit from more advanced tools and resources.

Providing PDA responders (from all responding agencies) with a uniform process will help to support the overall emergency response framework, regardless of the scale of the event. Nonetheless, it is recognized that each agency will have different capabilities, resources, organizational structures, challenges, and priorities. Hence, the assessment process was developed to identify and recommend methodologies that can be practically implemented by today's state highway agencies, along with the training materials to support these activities.

PART I

Background

This part of the field manual provides background information helpful for performing evaluations of highway structures during emergency situations. The chapters comprising the background are the introduction, the overview of highway structure safety evaluation, the Preliminary Damage Assessment guidelines, and an overview of emergency events. These chapters should be reviewed prior to conducting evaluations of highway structures.

1 Introduction

1.1 Purpose and Scope

This report volume is a field reference manual to be used for assessing, coding, and marking of highway structures during emergency situations. Highway structures include bridges, tunnels, culverts, walls, embankments, and overhead signs. These assessments are made to determine whether damaged, or potentially damaged, highway structures are safe for continued use, or if their use should be restricted or prohibited. Coding and marking follows the assessment process to clearly communicate within and between agencies.

This manual is intended to be used primarily by Preliminary Damage Assessment responders. This can include inspectors, bridge engineers, structural engineers, maintenance personnel, and others involved in highway structure inspections during emergency situations. Many of those needed for emergency assessments will likely not be regularly involved in routine inspections, especially for larger events. The intent is to have a uniform process, regardless of the experience level of the Preliminary Damage Assessment responder.

These guidelines are focused on providing information needed for rapid yet reliable field assessments of highway structures in emergency situations. Advice is provided to assess damage states of specific elements for each type of highway structure being considered. The basic approach is to provide guidance on where to look for damage, give advice on how to rate the safety of the structures, and document the different degrees of damage found.

Guidelines are also provided on how to code and mark the structures after assessment. These include inspection forms and placard templates for physical marking on the structure as well as digital coding and marking procedures. For each type of structure, the basic elements that need to be examined in order to determine the overall structural rating are listed.

More detailed information on the overall process for assessing, coding, and marking of highway structures in emergency situations can be found in the companion reference manual to this document. The reference manual is intended for a management audience; however, it may also be helpful to the Preliminary Damage Assessment responders to understand their role in the overall process.

1.2 Organization of the Manual

This manual contains three main parts as well as several appendices. Part I (Chapters 1 through 4) presents background information, including an overview of the assessment procedure, Preliminary Damage Assessment procedures and technologies, and an overview of emergency events. Part II (Chapters 5 through 9) provides Preliminary Damage Assessment procedures for the different highway structures. For each structure, damage states are discussed and assessment forms are presented. In Part III (Chapters 10 to 15), example damage photos along with classification in terms of level of damage are provided as visual aids for responders and inspectors. Finally, five appendices are presented. These contain suggested Preliminary Damage Assessment equipment lists; field safety considerations; contact list templates; an emergency route template useful in emergency events situations, including pre-event planning; and an example completed assessment form.

1.3 Definitions of Key Terms

1.3.1 Assessment Stages

The main types of inspections that will be conducted range from fast overview assessments to slower, more detailed assessments. Refer to Section 2.1 for more detailed definitions.

- Fast Reconnaissance (FR)—Provides an overview to establish the extent of the damage region immediately following an emergency event.
- Preliminary Damage Assessment (PDA)—An assessment performed for each structure immediately after an event, preferably within hours, to provide information on the status of the structure and to determine whether subsequent assessment stages will be needed. This stage is typically conducted by PDA responders (PDARs).
- Detailed Damage Assessment (DDA)—Provides an evaluation of structural damage and decisions on use restriction after the PDA. This stage is typically conducted by specialists (e.g., structural, geotechnical, hydrological, mechanical, and material engineers).
- Extended Investigation (EI)—An in-depth inspection that requires specialized technologies. This stage is typically performed after an UNSAFE rating from the DDA stage to determine how to repair or replace the structure.

1.3.2 Element Damage Rating

One of the following ratings is given to each element by a PDAR based on the amount of damage visually observed:

- None—The element shows no signs of damage.
- Minor—The element shows cosmetic or non-structural damage.
- Moderate—The element has experienced some structural or geotechnical damage.
- Severe—The element is significantly damaged and cannot function properly.

Refer to Section 3.3 for more detailed definitions.

1.3.3 Marking Classifications

A final marking classification shall be assigned to each structure indicating appropriate usage during and following an emergency event. Refer to Section 2.3 for more detailed definitions.

- INSPECTED—This classification is denoted by a green color which indicates that no apparent damage was found and the structure can function without further evaluation.
- LIMITED USE—This classification is denoted by a yellow color and indicates that minor to moderate damage conditions were observed or are believed to be present. The structure requires further evaluation but can still be used for restricted traffic.
- UNSAFE—This classification is denoted by a red color and indicates the structure has experienced severe damage or collapse and cannot function properly under traffic loads.

1.3.4 Emergency Management Roles

The following roles are defined:

- Managing Engineer (ME)—The ME is the key lead for making all structural assessment decisions regarding highway structures.
- Chief (Structural, Geotechnical, Hydrological, Mechanical, Materials) Engineer—This role is reserved for the engineer who will coordinate specialty inspectors including structural, geotechnical, hydrological, mechanical, and materials.
- PDA Responder—A PDAR is an individual who will perform PDA evaluations following an emergency event. For a Level I response, PDARs will typically be routine inspectors. For higher response levels, PDARs can be trained emergency responders (e.g., maintenance and operations crews, and design engineers).

2 Overview of Highway Structure Safety Evaluation

2.1 Assessment Stages

The four distinct procedures that can be performed in the assessment of highway structures during emergency situations are briefly described in the following list; an estimated inspection time per highway structure is also provided.

- **Fast Reconnaissance** (within 4 to 6 hours)—The objective of the FR assessment stage is to provide an overview and to establish/update the extents of the damage region as necessary. This work can be completed both in the office and in the field. While FR should be completed at all response levels, the type and detail of FR will depend heavily on the size of the event.
- **Preliminary Damage Assessment** (typically 10 to 30 minutes per highway structure)—This assessment stage is performed immediately following an incident, likely within hours, to provide information on the need for action such as closures or restricted use and to define immediate remedial action if needed. This stage is the focus of this manual and can provide valuable information for the DDA stage. The onsite PDA will be conducted by PDARs.
- **Detailed Damage Assessment** (typically 1 to 2 hours per highway structure)—The DDA stage is performed as soon as possible following an UNSAFE rating from a PDA, likely within 8 hours of the incident, if needed, and will continue as necessary to provide an evaluation of structural damage level and decisions on use restriction, or the need for an EI. This is a "Damage Inspection" as defined by the *Manual for Bridge Evaluation* (MBE) and is not considered a rapid assessment for an emergency situation. It is therefore beyond the scope of these guidelines.
- **Extended Investigation** (following the DDA)—The EI stage is performed as soon as possible following an UNSAFE or LIMITED USE rating from a DDA. This is an "In-Depth Inspection" as defined by the MBE and may also include a "Special Inspection" or an "Underwater Inspection." The EI is not considered a rapid assessment for an emergency situation and is therefore beyond the scope of these guidelines.

Each procedure is used for a specific purpose and should be performed by the appropriate personnel (see Table 2-1).

Figure 2-1 diagrams the assessment stages.

Table 2-1. Highway structure assessment methods.

Method	Suggested Personnel	Objective
Fast Reconnaissance	Chief engineers or managing engineer in aircraft or vehicle; specialized technicians as needed; the public	Determine the geographic extent of damage, identify impassable routes and collapsed structures, and suggest priority for site assessments.
Preliminary Damage Assessment	PDARs—Trained emergency responders (maintenance & operations crews, design engineers)	Determine the extent and type of damage to each structure, close unsafe structures, code and mark, and recommend DDA if needed.
Detailed Damage Assessment	Trained inspectors	Provide recommendations for restriction, repairs, or further investigation; code and mark as necessary; close unsafe structures; reopen structures deemed safe that were closed; and provide a damage level estimate.
Extended Investigation	Specialists (e.g., structural, geotechnical, hydrological, mechanical, materials)	Provide specific recommendations on necessary restrictions and/or repair, detailed damage analysis, and approximate cost estimate for remedial work.

2.2 Response Levels

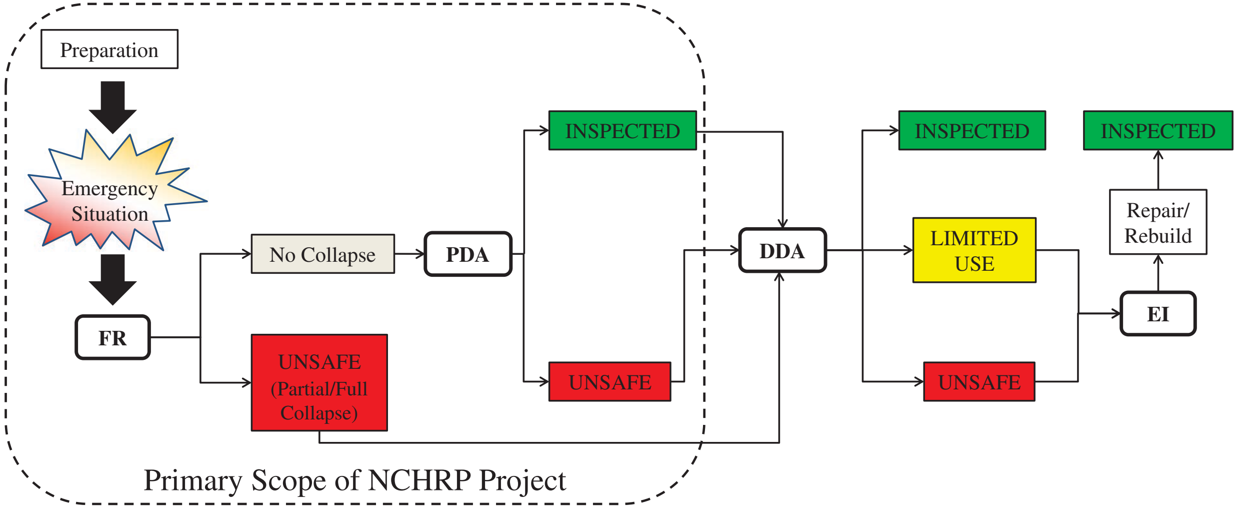
Response levels relate to the immediacy of the needed response, and the level of resources/ effort that will be needed during an emergency event. Actions associated with response levels are initiated when the ME has determined that it is safe to begin. The four response levels are as follows:

Level I — Routine inspectors in the affected region(s) are placed on call to perform PDA. Teams are mobilized when the ME determines that some damage has occurred based on FR observations.

Level II — State highway agencies (SHAs) complete PDAs with their maintenance crews and DDAs using inspection crews. Additional personnel such as design engineers are placed on call and mobilized to assist with PDAs when the ME deems appropriate.

Level III — Inspectors focus directly on DDAs, while maintenance crews, design engineers, and others (as needed) in the region are immediately mobilized to perform PDAs. Inspectors from other regions could be placed on call to assist. External consultants from local firms who are appropriately trained could be utilized, as necessary. Federal assistance and coordination may also be required.

Level IV — In addition to the mobilization strategy in III, the SHA requests immediate assistance from inspectors, maintenance crews, design engineers, and external consultants from other regions to assist with the PDAs. Significant federal assistance and coordination will be necessary.



UNSAFE = The structure requires further evaluation in the next assessment stage prior to being open to traffic.
LIMITED USE = Potentially dangerous conditions are believed to be present and usage is restricted to ensure public safety.
INSPECTED = The structure appears to be in the same condition as it was prior to the event.

Figure 2-1. Assessment stages and subsequent primary level of coding.

2.3 Coding and Marking System

A coding and marking system was developed to support uniform communication between inspectors, maintenance crews, engineers, and others as necessary. All inspected structures within the affected region should be marked both physically (in the PDA phase) and digitally (in the FR and PDA phases) after conducting an assessment and establishing the coding for the structures.

Structures shall be marked physically in an obvious location on both ends of major elements of the structure using placards affixed with a color decal with the coding option (see Figure 2-2 for the placard and Figure 2-3 for the coding options). For example, the placard with decal would be on the right-hand side of the approach to the bridge (i.e., on railings or fixed structural elements at both bridge abutments). These marking placards and decals should be available at all offices and in the inspection vehicles.

Structures shall be marked digitally in a central database and/or geographical information system (GIS) map that is accessible to authorized staff with a secure connection. The use of quick-response (QR) codes on the placard in concert with smart devices (i.e., smartphones or tablets) or standalone readers can significantly reduce coding time and improve information flow and reliability between personnel and across agencies. PDARs should have a decal/sticker with a QR code or have access to a mobile QR code printing machine.

The marking (and hence contents of the QR codes) must clearly indicate the agency that made the marking, the assessment stage (i.e., PDA or DDA), the date and time of the assessment, the resultant coding (i.e., INSPECTED, LIMITED USE, UNSAFE), actions taken (i.e., close structure, close lane), and name/initials of the inspectors.

After undergoing PDA, highway structures should be marked with one of two placards: INSPECTED or UNSAFE (refer to Figure 2-1). If a structure is marked UNSAFE during a

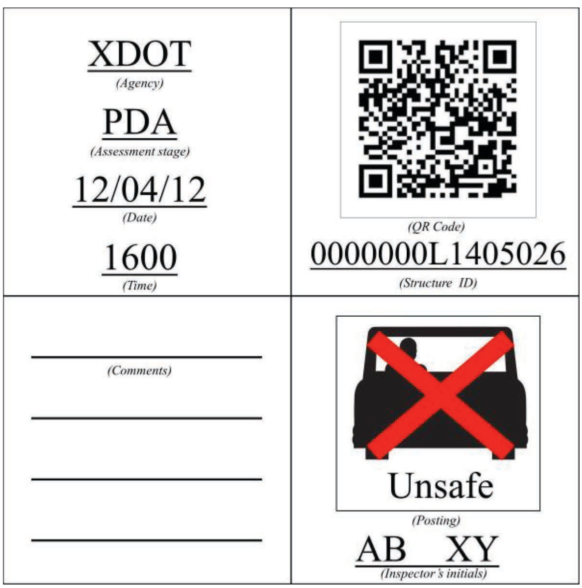


Figure 2-2. Example marking placard.

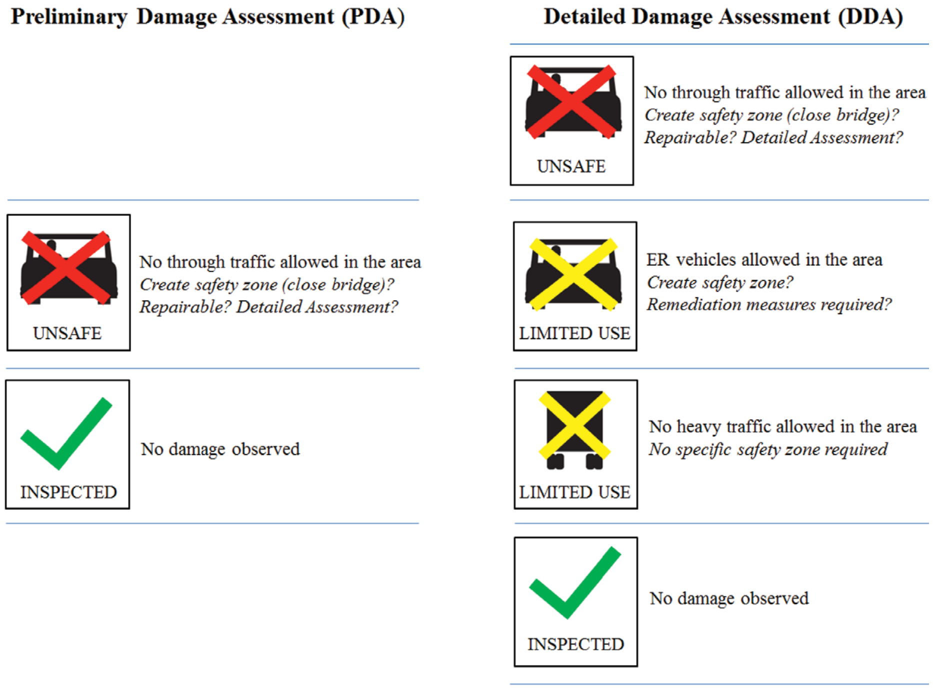


***Figure 2-3. Marking codes for PDA* (left) *and DDA* (right).**

PDA, it will be further evaluated using DDA. During DDA, highway structures are marked with one of three decals on a new/updated placard: INSPECTED, LIMITED USE, or UNSAFE (refer to Figure 2-1). This marking lets the SHAs, responders, inspectors, and the public know the condition of the structure as well as the date and time the assessment was performed. The system used for marking a highway structure and the definition of each marking category are summarized in Table 2-2.

In addition to marking a highway structure, it may be necessary to designate restricted use of certain parts of the structure that may be hazardous areas. For example, if a bridge deck is badly cracked or raised on one side, traffic could be redirected onto the non-damaged portion of the bridge.

2.3.1 Marking and Barricading Procedures

After the assessment of a highway structure has been completed, the structure should be marked using the following procedures and criteria:

1. Place the appropriate placard in a clearly visible location near the entrance on the right side of the structure (e.g., right side of a bridge approach or railing, right side of a tunnel entrance).

Table 2-2. Highway structure coding and marking classifications.

Marking Classification	Description
INSPECTED (Green)	This classification utilizes a green color code and indicates that subject to the inspection at the current stage, no apparent damage was found and the original load carrying capabilities of the structure appear to be fully intact. **No restrictions on use.**
LIMITED USE (Yellow)	This classification utilizes a yellow color code and indicates that dangerous conditions are believed to be present. **Usage is restricted to ensure public safety**. The restrictions to use must be clearly defined by symbols and can include lane closures, vehicle load limits, or use by emergency vehicles only.
UNSAFE (Red)	This classification utilizes a red color code and indicates that extreme hazards are present, the structure is in imminent danger of collapse, or the structure has collapsed. **The structure is closed to all traffic.**

2. Affix the placard using metal clips or wire. If not available, use durable tape, plastic ties, or any other reliable method.
3. If the structure was marked as UNSAFE, determine the appropriate barricading techniques from the following list:
   a. Physically park vehicles across both road approaches and arrange for someone to standby at both ends of the structure.
   b. Call the district to arrange for barricades and cordoning off structures. If necessary, cordoning should include personnel for monitoring the barricades at all times.
   c. If it is a critical structure, notify the policing agencies and general public via public safety announcements on commercial radio and television stations.
   d. Other techniques as recommended by the district.

2.3.2 Changing a Coding/Marking

There may be a need to change the coding and marking of a highway structure. This can result from several possible situations:

- A DDA following an initial PDA
- An EI
- Reinspection to verify or correct an existing marking
- Reinspection after another emergency event
- Reinspection after temporary repairs have been made
- Reinspection after removal of finishes to expose concealed conditions

Any change in coding and marking category must be done by an authorized representative of the agency in charge of that particular highway structure.

2.4 Use of Judgment Required

The use of ***judgment*** is essential in the assessment of damaged highway structures, both for personal safety as well as safety of the general public. This section will address both of these.

All personnel should have adequate training and should have been briefed on the contents of these guidelines through an annual highway structures inspection safety seminar before performing damage assessments. PDARs are then responsible for their safety under possibly extreme conditions as a consequence of the emergency event. PDARs should only proceed if they are confident their actions do not pose a risk to themselves or others. PDARs should use best judgment to ensure they are safe and aware of their surroundings at all times. Not every dangerous situation that may be encountered is covered by the guidelines and procedures provided herein.

The use of ***judgment*** is essential in the assessment of damaged highway structures. In most cases, the type and nature of the damage will not easily fit into a checked box or match the sample images. The materials in this manual are meant to help in making a determination, but ultimately judgment should prevail. ***For those situations where no guidance beyond this manual has been provided, or if the guidance furnished is not appropriate for the emergency situation, the PDAR team must rely on their collective experience and judgment.*** When necessary, obtain additional help from a superior and/or request a DDA.

3 Preliminary Damage Assessment

Each PDA team will be assigned to a route with a list of structures to assess. Due to the unpredictable nature of emergency events, it is important to be flexible as changes to planned routes may occur as more information becomes available. This flexibility will ensure that the highest priority structures are addressed first.

3.1 PDA Strategy

The objective of PDA is to quickly inspect and assess highway structures in the damaged area that were determined to be at risk from the FR stage. It is performed by evaluating damage on a highway structure according to the PDA procedure listed below. Each highway structure should be evaluated in its entirety as well as by looking at system elements. PDA should only result in a structure being coded/marked as INSPECTED or UNSAFE.

PDA evaluations should be performed by teams of two PDARs. Members of PDA teams should independently make a coding/marking decision regarding the highway structure and then jointly review their decisions. In doubtful situations, the use of judgment is required. In particular, highway structure elements with moderate damage can be difficult to assess, especially during a PDA. When there is uncertainty about coding/marking a structure UNSAFE, consider coding/marking it UNSAFE and request a DDA. To be conservative, in the event one PDAR decides to code/mark as INSPECTED and the other UNSAFE, the structure should be coded/marked as UNSAFE and a DDA requested.

If a highway structure is found to have minor or no damage (i.e., non-structural damage), and if there are no other hazards or unsafe conditions present, it should be deemed as being safe and it can be coded/marked as INSPECTED. If a highway structure or element is found to be moderately to critically damaged, or if more severe damage (i.e., partial collapse) is imminent, it should be coded/marked as UNSAFE.

3.2 Conservative vs. Unconservative Assessments

Conservative coding and markings are those in which there is some doubt on the structural integrity of the highway structure. If it is not clear that the structure is safe for traffic in any way, it should be marked conservatively as UNSAFE. Highly conservative markings should be considered for highway structures that are critical links in the transportation network and those that have a high consequence of failure (e.g., incurring life losses). Factors that influence these structures include operational classifications, level of traffic, detour availability, and lifeline route designation. Although these structures should be opened as soon as possible to the public, in the event of any questionable damage, they should be marked as UNSAFE.

It should also be noted that PDARs should be more conservative with regards to high-risk highway structures such as bridges and tunnels. Other structures such as walls and overhead signs may not pose as much risk as a bridge or tunnel collapse; therefore, reduced conservativism in the assessment/coding/marking procedures can be applied. However, some conservatism is always important because of information incompleteness, visibility limitation from debris, potential human errors, and uncertainties in the available information.

Less conservative markings are reserved for highway structures that do not pose an immediate threat to the transportation network. If a highway structure is moderately damaged but does not pose a threat to the traveling public, it may be marked as INSPECTED with low-priority DDA checked on the assessment form.

3.3 Element Damage Levels

Prior to coding and marking the overall structure, the PDARs should quickly assess the state of individual elements. This is useful information for load rating analyses at the DDA stage as well as for tracking the amount of damage for loss estimates.

This section provides definitions for the individual element ratings for each highway structure. It should be noted that these damage levels are separate from the final decision for overall coding and marking of the structure as either INSPECTED or UNSAFE. These damage levels are specific to basic structure elements and are used to provide information for repair, prioritization, and subsequent assessment procedures. These damage levels are marked in the inspection forms.

For each highway structure, a list of common elements is provided in this manual. These elements should be reviewed independently and coded using Table 3-1. Each highway structure has different elements corresponding with a damage level to be used for reference. When the condition of an element is not clear, it should be coded conservatively.

It should be noted that some damage (e.g., corrosion) may be a result of structure degradation. These damages are likely not a result of an emergency event. However, they are still

Table 3-1. Element damage level descriptions.

Damage Level	Description
None (Green)	The element and/or structure show little to no signs of damage.
Minor (Yellow)	The element shows signs of cosmetic or non-structural damage that has little to no effect on the system integrity. Structure appears capable to carry traffic.
Moderate (Orange)	The element has experienced structural or geotechnical damage that may affect the system integrity.
Severe (Red)	The element is damaged where it cannot function properly. Element may be in danger of collapse. If any element is marked as severe, the structure should be marked as UNSAFE.

worth noting during PDA as they may result in the structure being weakened. Such damage should also be considered when making a final call for the structure posting (INSPECTED or UNSAFE).

Upon coding the individual elements, an overall marking will be decided for the structure. When elements are coded as minor or moderate, the overall marking is less clear. A conservative judgment should be used when making the final marking decision. If a structural element (e.g., bridge columns, bearings, or wingwall; tunnel deck; overhead sign column support) receives a moderate damage level rating, the structure should be marked as UNSAFE. If a nonstructural element (e.g., bridge parapet, tunnel railing, and overhead sign catwalk) receives a moderate damage level ranking, the structure may be marked as INSPECTED, if there is no other structural damage, although precautions and cordoning off the affected areas should be done to ensure safety and to make sure users are aware that there is a safety hazard.

3.4 PDA Procedure

The following list outlines the steps for the PDA procedure:

1. Upon receiving notification of an emergency event, PDARs review Chapter 4 for a list of likely damages for highway structures.
2. PDARs assist in rescue efforts, if necessary.
3. If any hazardous condition is encountered during the inspection, such as downed power lines, faulty traffic control devices, or roadway obstructions, the appropriate authorities should be contacted in order to secure the area.
4. Prior to starting PDA, PDARs confirm with each team member the division of tasks. Generally, only one team member should fill out a single form for each structure. Both should make observations and be alert to the conditions of the scene.
5. PDARs approach the structure with caution and never walk or drive immediately under, over, or adjacent to the structure until the safety of the environment has been assessed.
6. Each PDAR (each team should have at least two people) should remain reasonably separated from each other but remain within visible range at the same time and never go underneath a structure at the same time.
7. When first arriving to a structure site, take a photograph of the identification tag, a photograph of the overall structure, and obtain geographic positioning system (GPS) coordinates. If available on the structure, the QR code should be scanned. With a smart device and app, these activities can be completed from the same device.
8. A site visit is estimated to take 15 to 30 minutes to complete. However, if the structure is clearly collapsed and unsafe, PDARs can simply complete the basic elements of the form and move onto the next site after notifying the ME that the structure should be closed. PDARs should be conscious of the time and make sure that they do not spend too long at a particular site so they can efficiently move through their route.
9. A more detailed process for each structure is written in Part II to help quickly walk PDARs through the process. When necessary, PDARs should consult the damage state lists and photographic examples provided in Part III to aid in damage state ratings.

10. PDARs look for evidence of disturbance or irregularities—such as shifts in guardrails or striping—and note these on the form.
11. PDARs provide an element damage level rating (none, minor, moderate, severe) for all applicable elements of the structure (Section 3.3).
12. Once PDA inspection is complete, the PDAR team meets and comes to a conclusion on the overall marking of the structure (INSPECTED or UNSAFE).
13. PDARs fix the placard to the structure in the appropriate location (refer to Section 2.3.1 for suggested procedures).

The outcomes of this procedure are both an overall coding for the structure as well as coding of individual elements.

Completing the forms can be efficiently carried out using a smart app running on a smart device. The smart app should include assessment forms, making filling out the form while assessing a structure easier. The smart app can contain existing database information for the structure directly on the device or can access it in the cloud. When communication links are available, the data in the completed form can be transmitted in real time back to the central command. When these communication links are not available on site, the PDAR can send the data when returning to a suitable area.

At a minimum, the smart app should include the following:

- This manual with keyword search capabilities.
- Digital forms of the element damage levels, including links to sample photo pictures of each level of damage for different structural elements.
- Digital forms of the damage matrix (Section 4.2), wherein each decision tab is digitally linked to the element damage level description and the sample photographs.
- Access to the geospatial location of the structure and geospatial route for all structures to be inspected.
- Access to the SHA's structure inventory database.
- Ability to read QR codes on existing placards and digital links to the database.
- Photo capture and geo-tagging that automatically forms imagery metadata for evidence archival for the structure (or an element of the structure).
- Ability to annotate photographs.

Full details and templates for key components of a smart app can be found in *NCHRP Web-Only Document 223: Guidelines for Development of Smart Apps for Assessing, Coding, and Marking Highway Structures in Emergency Situations*.

3.5 Filling out Placards and Assessment Forms

Placards and PDA forms should be filled out with the following considerations:

1. Provide information in all applicable fields on the inspection form. If an item is not known during the PDA, leave the field blank. When using a smart app, many fields can be filled automatically through a geo-referenced direct link to the database.

2. When element damages are not clear, provide comments that supply sufficient information to understand the observed damage state.
3. When making a recommendation for DDA priority following an UNSAFE rating, provide reasoning for low-priority or high-priority DDA evaluations.
4. If there is any damage that is particularly unique and not covered in the element damage levels, provide comments and/or sketches.
5. For the sake of time, do not draw sketches for every type of damage on a structure. Instead, focus on the moderate to severe damages that will provide better information for the DDA stage. Take photographs instead, when appropriate.
6. When physically marking a structure, write clear and legibly on the placard as this must be readable by inspectors performing subsequent inspections.
7. Assessment forms should be turned in as frequently as reasonable. At a minimum, reports should be turned in at the end of each day upon return from the field. For smart app users, forms can be completed and turned in continuously, provided Wi-Fi or network connectivity is available. If Wi-Fi is limited, reports can be uploaded during breaks and lunches at locations with Wi-Fi access.
8. In the event of an UNSAFE structure, contact the ME via call, text, or other communication methods. UNSAFE structures should be reported immediately in order to avoid delays. It is vital that contact be made as soon as possible to ensure appropriate barricading and subsequent measures are taken.

3.5.1 Damage Summary

The assessment form provides a space to indicate estimated percentage damage for the highway structure. This damage summary may help subsequent inspections with determining the monetary and economic loss of a structure. The following guidelines provide examples that may be used to estimate the damage summary of a structure. These examples do not cover all damage scenarios and ultimately the damage summary percentage should be decided based upon the PDARs' collective experience and judgment.

1. None (0%)—No apparent structural or cosmetic damage is found.
2. Slight (0–1%)—Structure has slight cosmetic damage (e.g., broken concrete on a bridge railing, slight chipping of a tunnel wall, minor concrete spalling in an isolated area).
3. Light (1–10%)—Structure needs minor repairs (e.g., minor deck cracking on a bridge, tunnel roof with minor spalling, overhead sign with minor cracking).
4. Moderate (10–30%)—Structure is likely repairable with some structural damage (e.g., a few inches of expansion joint movement on a deck, spalling and section loss of tunnel walls, culvert with cracking around bolts).
5. Heavy (30–60%)—Structure is partially intact with multiple elements having structural damage. Structure may be salvageable (e.g., visible column shear cracks, extensive cracking of culvert, cracking of overhead sign post).
6. Major (60–100%)—Structure is in danger of collapse with several elements having severe damage. Repairs are unlikely (e.g., excessive sag of bridge deck, displacement of girder off

bearing support, extensive cracking and spalling of culvert wingwall, very large column shear cracks propagating into concrete core).

7. Destroyed (100%)—Structure has failed completely and is unusable for traffic (e.g., deck unseating on a bridge, roof collapse of a tunnel, overhead sign tipped over).

3.6 PDA Technologies

3.6.1 Recommended PDA Technologies

The onsite PDA will likely be conducted by PDARs who will use the recommended technologies herein to generate structurally organized reports based on visual observations or equipment-based measurements (as time permits). Table 3-2 summarizes these technologies as well as their general availability annotations and resources.

PDARs are strongly encouraged to use smart tablets for completing the assessment forms. In the worst case, PDARs should have paper-based copies of the forms that can be sent back to an office and logged digitally. Due to the potential for backlog and errors in transcription, paper-based forms should be used as a last resort.

Table 3-2. Recommended technologies for PDA.

Recommended Technology	General Availability Classification	Available Resources
Digital camera	Commonly used	No training needed
Mobile imaging / video logging	Commonly used	No professional training needed
Personal laptops / mobile computers	Commonly used	No professional training needed
Personal communication devices	Commonly used	No professional training needed
Smart devices that embed digital cameras, GPS, and communication	Commonly used	No professional training needed
Personal GPS / Global Navigation Satellite System devices	Commonly used	No professional training needed
Digital or paper maps	Commonly used	No professional training needed
Cloth / tape measures / carpenter level / calipers / compass / level / laser distance measures and others	Commonly used	No professional training needed
Signs / marking supplies and materials	Commonly used	No professional training needed
Human visual inspection	Commonly used	*NCHRP Research Report 833, Volume 3: Coding and Marking Guidelines*

3.6.2 Recommended Field Inspection Supplies for PDA

Structures within a transportation network pose uncertain dangers to inspection personnel, especially after a major event. PDA tools and equipment for inspection, protection, emergency protocols, and safety gear should be in place.

Table 3-3 is a compressed list of recommended tools, gear, and materials (or "supplies" in general) for use in field inspection. When possible, these tools should be available in prepackaged kits. Appendix A provides a checklist of all the items listed in Table 3-3 to be used during PDA evaluations.

Table 3-3. Recommended PDA tools and equipment.

Inspection Equipment		
Clipboard	Inspection forms	100' measuring tape
Flashlight	Notepad	25' pocket tape
Red paint marker and ribbon	Yellow paint marker and ribbon	Green paint marker and ribbon
Pens and pencils	Hammer	Keel/crayon
Binoculars	Cellular phone	Flagging tape
Duct tape	Portable ladder	Digital camera
Pliers	Micrometer	Wire brush
Chipping hammer	Pocket knife	Scraper
Traffic control equipment	Rope	Shovel
Boat*	Waders*	Underwater probe*
Electronic and Communication Equipment		
State or local maps	Laptop computer with charger	Copies of latest structure inspection files
Flash drives	Identification badges	Walkie-talkies or state-wide radio
Traffic cones	Satellite phone	
Safety Equipment		
Hard hat	Work boots	Safety vest
Ear plugs	Safety glasses	Rubber boots
Rain gear	Work gloves	Rubber gloves
Dust mask		
Personal Supplies		
First aid kit	Drinking water	Toilet paper
Food		

*Specialized PDAR teams for evaluating scour-critical structures

4 Overview of Emergency Events

4.1 Overview

This chapter provides an overview of common damages and possible modes of failure for each emergency event. These tables do not cover all types of damages expected. The emergency events covered are earthquake, tsunami, tornado, high winds, hurricane and storm surge, flooding, and fire.

Damage types are classified as *geotechnical*, *structural, hydraulic*, or *special case*, independent of the highway structure type (see Table 4-1). Geotechnical damage involves the soil and foundations of the highway structures; structural damage includes the concrete, steel, timber, connections (or joints), and elements; hydraulic damage includes any water-related failures or consequences; and special cases include all damages that are not classified as one of the other three damage types.

Table 4-1. Common damages/modes of failure.

Damage Types	Common Damages / Modes of Failure
Geotechnical	• Ground failure such as liquefaction, lateral spreading, landslides, and slope instability • Erosion • Bearing capacity failure • Active or passive failure • Foundation settlement
Structural	• Cracking and spalling of reinforced concrete members • Flexural and shear failures of reinforced concrete or steel members • Buckling, fracture, and tension of steel members • Fatigue damage, including low-cycle fatigue • Inelastic deformation and buckling
Hydraulic	• Scour • Debris impact • Inundation leading to hydrostatic and hydraulic pressures • Washout
Special Cases	• Thermal expansion • Reduction of strength and material properties due to fire-induced thermal effects • Efflorescence causing deterioration • Decay of timber members • Corrosion

Table 4-2. Damage matrix in terms of emergency event types and highway structures.

Structures	Emergency Event						
	Earthquakes	Tsunami	Tornado and High Winds	Hurricane and Storm Surge	Flooding	Scour	Fire
Bridges	Significant	Significant	Minor	Significant	Moderate	Significant	Moderate
Tunnels	Moderate	Minor	Unlikely	Moderate	Moderate	Minor	Significant
Walls	Moderate	Moderate	Unlikely	Moderate	Moderate	Moderate	Minor
Culverts	Moderate	Minor	Moderate	Moderate	Significant	Significant	Moderate
Embankments	Significant	Moderate	Moderate	Moderate	Significant	Significant	Unlikely
Overhead Signs	Moderate	Moderate	Significant	Moderate	Minor	Minor	Moderate

Damage Scale

Significant	Significant damage – Several collapses and irreparable damage to multiple structures across a large area.
Moderate	Moderate damage – Repairable damage to several structures.
Minor	Minor damage – Localized damage to a few structures, most do not need significant repair.
Unlikely	Damage unlikely.

4.2 Damage Matrix

A two-dimensional matrix showing the expected level of damage to highway structures corresponding with emergency events is shown in Table 4-2. The main objective of this matrix is to provide a basis for prioritizing emergency response assessments of vulnerable highway structures. The four levels of damage are significant, moderate, minor, and unlikely. This table was developed based on the assumption that an emergency event has occurred that is significant enough to produce noticeable to significant damage to at least one structure of interest. However, it is possible that a structure could experience a higher level of damage at extreme intensities of an emergency event or when subjected to prolonged exposure.

4.3 Earthquake

Earthquakes primarily cause damage through intense ground shaking. The intensity of an earthquake is measured by both the moment magnitude scale and the modified Mercalli scale; however, for damage assessment purposes, ground motion intensity measures are used to characterize the potential for damage. Common ground motion intensity measures include

Table 4-3. Most likely earthquake damages.

Damage Types	Common Damages / Modes of Failure
Geotechnical	• Ground failure such as liquefaction, lateral spreading, landslides, and slope instability • Bearing capacity failure • Active or passive failure • Foundation settlement
Structural	• Cracking and spalling of reinforced concrete members • Flexural and shear failures of reinforced concrete or steel members • Buckling, fracture, and tension failure of steel members • Inelastic deformation and buckling
Hydraulic	• Pipes bursting
Special Cases	• Fire from utilities

peak ground acceleration, peak ground velocity, and spectral acceleration. A list of common damages resulting from earthquakes is highlighted in Table 4-3. The majority of earthquake damage can be categorized as structural or geotechnical failures.

4.4 Tsunami

The destructive force of a tsunami is measured by both the initial impact of a large wall of water hitting a coastline at great velocities and the overwhelming amount of water flowing off the land. Forces acting on structures created by tsunami waves are in the form of hydrostatic pressure, hydrodynamic pressure, impulsive forces, buoyancy, uplift, and debris-induced impact. Effects such as tsunami-induced liquefaction and foundation scour are also important to consider. A list of common damages resulting from tsunamis is highlighted in Table 4-4.

Table 4-4. Most likely tsunami damages.

Damage Types	Common Damages / Modes of Failure
Geotechnical	• Ground failure such as liquefaction, lateral spreading, landslides, and slope stability • Erosion
Structural	• Cracking and spalling of reinforced concrete members • Buckling, fracture, and tension failure of steel members • Fatigue damage, including low-cycle fatigue • Inelastic deformation and buckling
Hydraulic	• Scour • Debris impact • Blockage due to debris • Inundation leading to hydrostatic and hydrodynamic pressures • Washout
Special Cases	• Corrosion

Table 4-5. Most likely tornado and high wind damages.

Damage Types	Common Damages / Modes of Failure
Structural	• Fatigue damage, including low-cycle fatigue • Inelastic deformation and buckling
Special Cases	• Flying debris

4.5 Tornado and High Winds

One of the most damaging aspects of tornados in regard to highway structures is impact from debris. High speed winds can affect low weight structures such as overhead signs. High winds also have the potential to resonate the structure creating fatigue damage and loading. A list of common damages from tornado and high wind events is highlighted in Table 4-5.

4.6 Hurricane and Storm Surge

Hurricanes cause damage primarily to aboveground structures. The primary factors that cause damage to highway structures are hydrostatic uplift, restraint failure, hydrodynamic uplift and lateral loading, debris effects, and scour. Hurricanes often result in extreme wind, heavy rainfall, and storm surge, which can amplify the amount of damage. Storm surge causes widespread damage to highway structures due to repetitive wave loading. Structures near the coastline may become submerged by the storm surge creating hydrostatic uplift and the potential for liquefaction and scour. A list of common damages resulting from hurricanes and storm surge is highlighted in Table 4-6.

Table 4-6. Most likely hurricane and storm surge damages.

Damage Types	Common Damages / Modes of Failure
Geotechnical	• Ground failure such as liquefaction, lateral spreading, landslides, and slope instability • Erosion
Structural	• Cracking and spalling of reinforced concrete members • Buckling, fracture, and tension failure of steel members • Fatigue damage, including low-cycle fatigue • Inelastic deformation and buckling
Hydraulic	• Scour • Debris impact • Blockage due to debris leading to flooding • Inundation leading to hydrostatic and hydrodynamic pressures • Washout
Special Cases	• Corrosion • Flying debris

Table 4-7. Most likely flooding damages.

Damage Types	Common Damages / Modes of Failure
Geotechnical	• Ground failure such as liquefaction, lateral spreading, landslides, and slope instability • Erosion • Bearing capacity failure • Active or passive failure
Structural	• Inelastic deformation and buckling
Hydraulic	• Scour • Debris impact • Blockage due to debris • Inundation leading to hydrostatic and hydrodynamic pressures • Washout
Special Cases	• Corrosion

4.7 Flooding

Flooding is generally divided into three load cases: hydrostatic loads, hydrodynamic loads, and impact loads. The hydrostatic loads are both vertical (buoyant) and lateral (pressures) and can cause unusual loading due to uplift and lateral forces. Hydrodynamic loads are caused by water flowing around the structure causing frontal impact loads, drag loads on the sides, and suction loads on the back. Impact loads can occur as a result of debris being carried by the flood and can be especially destructive. Table 4-7 lists common damages resulting from flooding.

4.8 Fire

In concrete, the high temperature of fire causes chemical reactions as well as self-destruction stresses, which create cracks, spalling and deterioration of strength, and a loss in stiffness and ductility of the concrete as a material. Temperatures in excess of 400 degrees Celsius (752 degrees Fahrenheit) begin to reduce both the compressive strength of concrete and the yield strength of steel. Table 4-8 lists common damages from fire.

Table 4-8. Most likely fire damages.

Damage Types	Common Damages / Modes of Failure
Structural	• Cracking and spalling of reinforced concrete members
Hydraulic	• Pipes bursting
Special Cases	• Thermal expansion • Reduction of strength and material properties due to fire-induced thermal effects

4.9 Scour

Flooding events can compromise the safety of bridges susceptible to scour. In the event of hydro-hazard events all scour-susceptible bridges should be monitored. The National Bridge Inventory (NBI) (FHWA 2015) denotes field 113 to identify the current status of a bridge regarding its vulnerability to scour. Table 4-9 defines the codes used in field 113. When possible, PDARs should examine the latest inspection report that details the scour rating for the bridge.

These codes can help with determining if a bridge is likely to have scour related damages or impacts.

Table 4-9. Codes in NBI field 113.

Codes	Description
N	Bridge is not over waterway.
U	Unknown foundation that has not been evaluated for scour. Due to risk being undetermined, flag for monitoring during flooding events.
T	Bridge over "tidal" waters that has not been evaluated for scour but is considered low risk.
9	Bridge foundations on dry land well above flood water elevations.
8	Bridge foundations determined to be stable for the assessed or calculated scour condition. Scour is determined to be above top of footing by assessment, calculation, or installation of properly designed countermeasures.
7	Countermeasures have been installed to mitigate an existing problem with scour and to reduce the risk of bridge failure during flood event.
6	Scour calculations/evaluation has not been made. (Use only to describe case where bridge has not yet been evaluated for scour potential.)
5	Bridge foundations determined to be stable for assessed or calculated scour condition. Scour is determined to be within the limits of footings or piles by assessment, calculations, or installation of properly designed countermeasures.
4	Bridge foundations determined to be stable for assessed or calculated scour conditions; field review indicates action is required to protect exposed foundations.
3	Bridge is scour critical; bridge foundations determined to be unstable for assessed or calculated scour conditions: scour within limits of footings or piles, or scour below spread-footing base or pile tips.
2	Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations, which are determined to be unstable by: a comparison of calculated scour and observed scour during the bridge inspection or an engineering evaluation of the observed scour reported by the bridge inspector.
1	Bridge is scour critical; field review indicates that failure of piers/abutments is imminent. Bridge is closed to traffic. Failure is imminent based on a comparison of calculated and observed scour during the bridge inspection or an engineering evaluation of the observed scour condition reported by the bridge inspector.
0	Bridge is scour critical. Bridge has failed and is closed to traffic.

Source: Modified after Richardson and Davis (2001).

The following structures should be monitored for any of the following conditions:

- Bridge
  - Pressure flow (bridge deck is fully or partially submerged)
  - Water overtopping the bridge
  - Misalignment, settlement, or tilt damage
  - Vertical or lateral displacement of the superstructure
  - Excessive vertical or horizontal separation at bridge deck joints
  - Clear sign of structural distress
- Approach Roadway
  - Settlement damage
  - Water overtopping the approach roadway
  - Embankment erosion damage
- Waterway Channel
  - Significant debris buildup or formation of damming
  - Streambed has lowered to the scour-critical elevation at pier or abutment
  - Water surface elevation has risen to the bridge closure water surface elevation level when such markings have been determined for a bridge. If such markings have not been determined, then a judgment needs to be made on unsafe levels based on prior observation of water flow beneath the bridge.

If a highway structure is experiencing any of these signs, the structure should be marked as UNSAFE and the ME informed to proceed with DDA.

When grass and weeds are growing in a scoured area, it may be a long-existing issue not related to an emergency event and may not provide an immediate hazard. During periods of decreasing flow, sediments can backfill an area of scoured bed material. Scour hole sizes can also be difficult to assess due to backfill and sediment. In these instances, a risky scour situation can exist but be difficult to assess. When these issues occur, specialized PDAR teams are recommended to perform PDA evaluations. These specialized PDAR teams will focus specifically on scour-prone structures and can gain access to specialized equipment such as a boat, waders, or an underwater probe.

PART II

Preliminary Damage Assessment of Highway Structures

This part of the field manual will discuss the specific PDA procedures and considerations for bridges, tunnels, walls, culverts, and overhead signs. Each chapter provides a general overview of the highway structure, a schematic, the PDA procedure, a list of elements, and the damage states to define minor, moderate, and severe damage levels for each element.

5 Bridges

Bridges are the most common and complex type of highway structures in the United States. They are built with the purpose of providing passage over or under a physical object such as a watercourse, railway, road, or valley. Hence, collapse or closure of a bridge often has serious implications for the traveling public. Bridges play a critical role in the transport of emergency vehicles, personnel, and equipment in the aftermath of natural disasters. As a result their level of structural safety must be quickly evaluated.

The NBI classifies 10 bridge materials and 23 bridge design types, as shown in Table 5-1. This information in the NBI should be accessible to the PDAR.

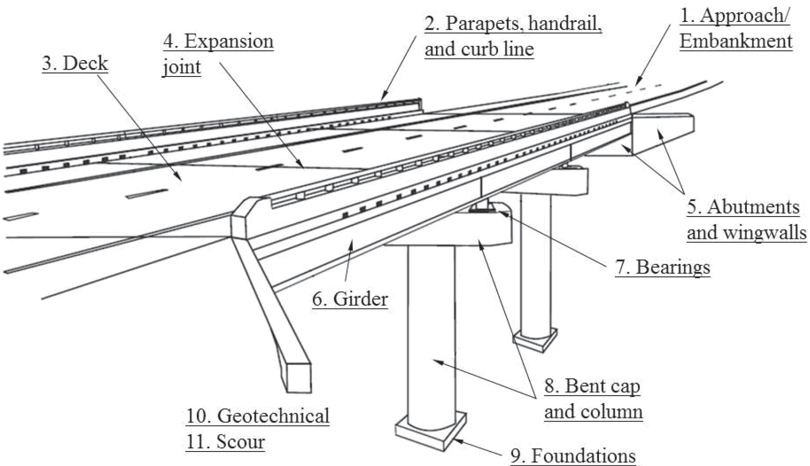
Each bridge is composed of several key elements that function to provide resistance to loads. Figure 5-1 shows a schematic of the key bridge elements. Each of these elements needs to be assessed in the PDA stage.

Table 5-1. National Bridge Inspection Standards coding for bridge material (43A) and design (43B).

NBIS Code 43A – Material	
Code	**Description**
1	Concrete
2	Concrete continuous
3	Steel
4	Steel continuous
5	Prestressed concrete*
6	Prestressed concrete continuous*
7	Wood or timber
8	Masonry
9	Aluminum, wrought iron, or cast iron
0	Other

NBIS Code 43B – Design	
Code	**Description**
1	Slab
2	Stringer/multi-beam or girder
3	Girder and floorbeam system
4	Tee beam
5	Box beam or girders – multiple
6	Box beam or girders – single or spread
7	Frame (except frame culverts)
8	Orthotropic
9	Truss – deck
10	Truss – thru
11	Arch – deck
12	Arch – thru
14	Stayed girder
15	Movable – lift
16	Movable – bascule
17	Movable – swing
18	Tunnel
19	Culvert (includes frame culverts)
20	Mixed types
21	Segmental box girder
22	Channel beam
00	Other

*Post-tensioned concrete should be coded as prestressed concrete.
Source: FHWA (1995).



Source: Modified from Missouri DOT (2014).

Figure 5-1. Bridge schematic illustrating basic elements.

5.1 PDA Procedure for Bridges

1. Review the general PDA procedures detailed in Section 3.4.
2. Document PDARs' names, IDs, bridge identification number, and arrival time. Mark the primary structure material. Take a photo of the ID placard and when possible take a second overall photo of the bridge. Photos taken at the site should preferably be geo-tagged.
3. Examine traffic flow on the bridge and mark on the assessment form. Although traffic may be using the bridge, that does not indicate the bridge is safe. Be sure to note how the bridge responds to traffic, particularly larger vehicles. Inspect all bridges assuming they may be damaged.
4. Make a quick visual inspection of the entire bridge.
    a. If the bridge has spans of different materials such as concrete, steel, or timber, evaluate each span separately. The coding/marking for the bridge will be based on the span type that produces the worst ratings.
    b. If the bridge structure is collapsed or non-functional (including totally or partially inundated), mark the structure as UNSAFE.
    c. In the case of hydro-hazards (flooding or storm surge), if the bridge deck is partially or totally inundated, mark the structure as UNSAFE.
    d. High water levels or high water velocities should be reported. (Note that some bridges may have high water level markings; others may require judgment).
    e. If deemed as UNSAFE, go to Step 10.
5. Begin by inspecting approaches and inspect the elements listed in Table 5-2. Scour may be visible or invisible. Note any signs of scour potential such as erosion around the foundation and abutment elements (refer to Section 4.9 for signs of scour). If scour is apparent, follow the procedure in the scour section of this manual (Section 4.9).

Table 5-2. Bridge inspection checklist.

Element	Check for:
1. Approach/ Embankment	Raised or lowered, cracks, or buckling. Settlement of embankment.
2. Parapets, Handrails, and Curb Line	Misalignment, bowing, dips, shifting, or separations.
3. Deck	Cracks, spalling, missing concrete, alignment, deflection, cracks, or exposed rebars.
4. Expansion Joint	Misalignment, cracks, spalling, exposed rebar, unusual openings, displacements, or torn expansion materials.
5. Abutments and Wingwalls	Cracks, spalling, movement, or scour at the ground level.
6. Girder	Misalignment, bending or buckling, spalling, or missing bolts or rivets.
7. Bearings	Unseating, misalignment, unusual deformation, or sheared or bent bolts.
8. Bent Cap and Column	Exposed rebar, bearing movement, missing keeper, chipped concrete, cracking, or movement at the ground level.
9. Foundation	Liquefaction, sand boils, settlement, misalignment, or scour.
10. Geotechnical	Landslides, liquefaction, lateral spreading, slope failures, soil fissures, or differential settlement.
11. Scour	Water elevation, bridge closure water level, overtopping, debris buildup, or displacement.

Source: Modified from Missouri DOT (2014) and O'Connor (2010).

6. Document all appropriate damages (none, minor, moderate, severe) in the assessment form for each bridge element after inspection. (See Section 5.2 for specific guidance on elements and Chapter 10 for photographic examples). Provide comments and observations in the assessment form.
7. Take photos of observed damage. When necessary for scale indications, use a tape measure, person, clipboard, or other distinguishing object to relate size variations.
8. Determine an overall damage rating (0–100%) using Section 3.5.1.
9. Discuss the observations with the team members and come to a consensus for the bridge (INSPECTED or UNSAFE). In the case that team members are equally split on the decision, classify as UNSAFE.
10. If any element damage is severe, mark the bridge as UNSAFE.
11. If UNSAFE, notify the ME immediately.
12. Place and secure the placard and appropriate decal in the predetermined location, in accordance with Section 2.3.1 of this manual.
13. Proceed to the next site.

5.2 Bridge Damage States

Tables 5-3 through 5-13 provide more detailed information on damage states for bridge elements 1 through 10 in Table 5-2 [Damage states are modified from Missouri DOT (2014), O'Connor (2010), Ramirez et al. (2000a, 2000b), and Sardo et al. (2006)]. Refer to Section 4.9 for possible screening signs of scour.

Table 5-3. Damage states for bridge approach/embankment.

Minor	Moderate	Severe
Approach slab settlement 0–1 inch	Approach slab settlement between 1–6 inches	Approach slab settlement over 6 inches
Embankment settlement 0–6 inches	Embankment settlement 6–12 inches	Embankment settlement over 12 inches

Table 5-4. Damage states for parapet, handrail, and curb line.

Minor	Moderate	Severe
Damage does not impede traffic	Damage impedes traffic	Damage severely disrupts traffic

Table 5-5. Damage states for deck.

Minor	Moderate	Severe
Normal driving conditions	Reduced driving speed or damage quickly repairable	Impassable
Localized crushing of concrete at joints	Limited crushing of concrete over the full length of joint	Crushing of concrete over the full length of joint or within the span
Very slight misalignment of joints	Moderate misalignment of joints	Severe misalignment of joints
	Shifting of bearings	Bearing/superstructure failure
		Differential settlement of deck panels
		Punching failure

Table 5-6. Damage states for expansion joint.

Minor	Moderate	Severe
0–1 in. offset in vertical or horizontal alignment	1–6 inches offset in vertical or horizontal alignment	Over 6 inches offset in vertical or horizontal alignment

Table 5-7. Damage states for abutments and wingwalls.

Minor	Moderate	Severe
Spalling at expansion joint	Damage of pedestals and exposed anchor bolts	Tilting or sliding of the wall
Fine inclined cracks in wingwall	Any other damage (e.g., cracks, spalling, rotation)	Major horizontal cracks near mid-height of wall
Minor localized spalling of concrete cover	Moderate localized spalling of concrete cover	Crushing of concrete at the bottom section of wall
		Major inclined flexural and shear cracking
		Major damage of back and side walls
		Scour compromising the structural integrity

Table 5-8. Damage states for concrete girder.

Minor	Moderate	Severe
Fine closed flexural cracks	Closed flexural cracks	Open flexural cracks
Slight shifting over bearings	Shifting over bearings	Unseated bearings
Localized spalling of concrete cover near ends	Localized spalling of concrete cover	Spalling of concrete cover and exposed strands at girder ends
	Fine closed shear cracks	Shear cracks
		Crushing of concrete

Table 5-9. Damage states for steel girder.

Minor	Moderate	Severe
Minor flange buckling	Buckling of flanges and web	Major buckling of flanges and web
Slight shifting over bearings	Shifting over bearings	Unseated off its bearings
Slightly buckled lateral bracing	Fracture of a bracing member	Fracture of a critical bracing member
	Small fracture of flange extended over no more than 1 inch	Serious fracture of flange extended over 1/4 of the flange width
	Localized yielding of bolts-holes, at bolted connection	Sheared bolts at bolted connections

Table 5-10. Damage states for bearings.

Minor	Moderate	Severe
Minor localized spalling	Shifting over bearings	Unseating off bearings

Table 5-11. Damage states for bent cap and column.

Minor	Moderate	Severe
Fine shear cracks	Very visible shear cracks	Steep shear cracks
Vertical cracks in beams or horizontal cracks in columns and piers	Diagonal cracks in beams and/or loss of concrete cover	Bar buckling in beams, columns, and piers
Small transverse cracks at the column ends (without longitudinal cracks)	Localized crushing of concrete	Crushing of concrete cover
	Slight spalling of concrete cover	Major spalling of concrete cover
	Slightly exposed transverse and main bars	Exposed transverse and main bars
		Fractured transverse ties

Table 5-12. Damage states for foundation.

Minor	Moderate	Severe
Foundation settlement 0–2 inches	Foundation settlement 2–6 inches	Foundation settlement over 6 inches
Minor foundation scour	Moderate foundation scour	Severe foundation scour
Low-velocity flow	Moderate-velocity flow	High-velocity flow
Evidence of foundation movements, but net displacements are small	Distinct and measurable net displacements, but repairable	Distinct and measurable net displacements that are difficult to repair or unrepairable

Table 5-13. Damage states for geotechnical elements.

Minor	Moderate	Severe
Landslides/rockfalls 0–4 inches	Landslides/rockfalls 4–12 inches	Landslides/rockfalls over 12 inches
Settlements 0–2 inches	Settlements 2–6 inches	Settlements over 6 inches
Liquefaction 0–1 inch	Liquefaction 1–4 inches	Liquefaction over 4 inches
Lateral spreading 0–1 inch	Lateral spreading 1–4 inches	Lateral spreading over 4 inches
Slope failure 0–1 inch	Slope failure 1–4 inches	Slope failure over 4 inches
Soil fissures 0–1 inch	Soil fissures 1–4 inches	Soil fissures over 4 inches
Minor differential settlement (0–1 inch)	Moderate differential settlement (1–4 inches)	Severe differential settlement (over 4 inches)

5.3 Bridge Assessment Form

Figure 5-2 shows the PDA form for bridges.

Preliminary Damage Assessment (PDA) Form – Bridges

Inspector 1 Name/ID: ______		Structure ID: ______		**PDA Outcome:**
Inspector 2 Name/ID: ______		Highway: ______		☐ INSPECTED (Green)
Agency: ______		Milepost: ______		☐ UNSAFE (Red)
Date and time: ______		Route Carried on: ______		
Latitude/Longitude: ______		Route Carried under: ______		
Structure material:	☐ Steel	☐ Concrete	☐ Other ______	

Damage Summary:	**Traffic Level:**	**Overall Comments:**
☐ 1 – None (0%)	☐ No traffic at all	______
☐ 2 – Slight (0-1%)	☐ Traffic on all lanes	______
☐ 3 – Light (1-10%)	☐ Traffic on some lanes	______
☐ 4 – Moderate (10-30%)	**Scour:**	______
☐ 5 – Heavy (30-60%)	☐ Unknown	______
☐ 6 – Major (60-100%)	☐ Unlikely	______
☐ 7 – Destroyed (100%)	☐ Likely, but cannot see	______
	☐ Definitely	

Feature Description:					**Notes: (additional notes on back)**
1. Approach/ Embankments	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
2. Parapets, Handrail, and Curb Line	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
3. Deck	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
4. Expansion Joint	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
5. Abutments and Wingwalls	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
6. Girder	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
7. Bearings	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
8. Bent Cap and Column	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
9. Foundation	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
10. Geotechnical	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Other______	☐ None	☐ Minor	☐ Moderate	☐ Severe	______

Recommendations: Choose a recommendation based on the evaluation and team judgment. DDA evaluations should only be recommended with an UNSAFE posting. Provide comments on the recommendations below.

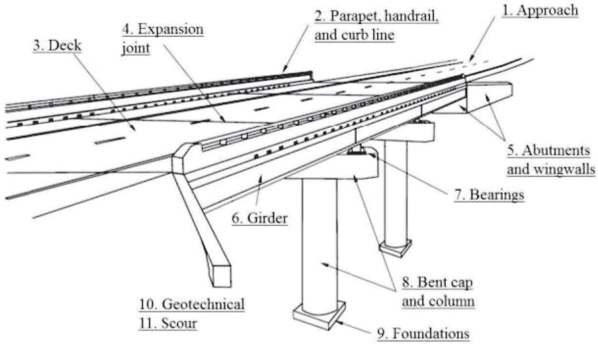
☐ **None** ☐ **DDA (Low Priority)** ☐ **DDA (High Priority)**

Record any recommendations:______

(QR Code)

Figure 5-2. Bridge assessment form (page 1/2).

Mark any areas of damage on the bridge:



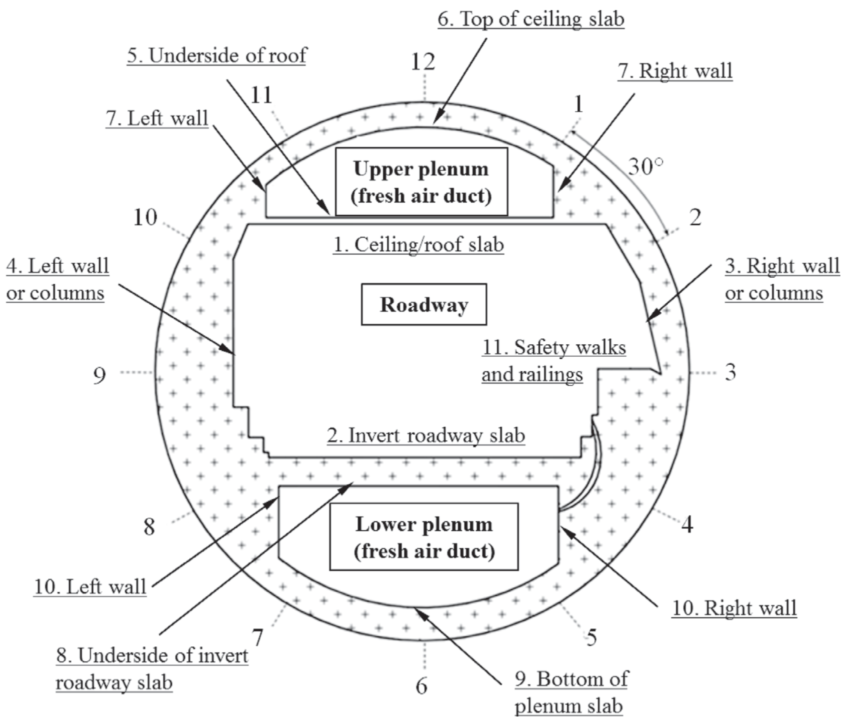
Notes/Drawings/Comments continued:

Figure 5-2. (page 2/2).

6 Tunnels

Tunnels are often critical links in the transportation network as many are built when no other transportation options are feasible. The structural integrity of tunnels is critical to the operation of the transportation network.

There are four common shapes of highway tunnels: circular, rectangular, horseshoe, and oval/egg (FHWA 2005). Figure 6-1 presents a typical schematic used for inspection of circular tunnels. Although this schematic is for circular tunnels, the elements and layout are similar with rectangular, horseshoe, and oval tunnels. When applicable, the upper and lower plenums should be inspected for damage. Circular tunnels use a clock designation system to determine the location of damage with respect to the tunnel. This clock designation system assumes the section cut is looking up-station and is applicable to other types of tunnels as well.



Source: Modified from FHWA (2005).

Figure 6-1. Circular tunnel schematic and clock system designations.

6.1 PDA Procedure for Tunnels

The PDA can be conducted on short tunnels. However, for long tunnels (e.g., > 1,000 feet), it is recommended to split the tunnel into sections and evaluate each section as a new structure. If there are only a few tunnels in the area, it may be preferable to skip the PDA and immediately proceed with a DDA of tunnels so that trained/certified inspectors can perform the assessment.

1. Review the general PDA procedures detailed in Section 3.4.
2. If necessary, assist in rescuing and/or helping motorists to exit the tunnel as quickly as possible.
3. If significant flooding, fire, or other internal damage is viewed from outside the tunnel making it unsafe, the PDAR should notify the ME to proceed with DDA. In this event, PDARs should look to assess any obvious signs of damage and report these as a PDA evaluation.
4. Work with maintenance crews to adjust ventilation equipment as necessary if a fire event has resulted.
5. Make a visual inspection of the tunnel entrance prior to entering.
   a. If the tunnel is partially or fully collapsed or non-functional, mark the tunnel as UNSAFE.
   b. If the tunnel is partially or totally inundated, mark the tunnel as UNSAFE.
   c. If deemed as UNSAFE, go to Step 9.
   d. If at any time during the PDA the tunnel appears unsafe, exit the tunnel immediately.
6. Begin inspecting the tunnel by examining the elements in Table 6-1. For long tunnels (> 1,000 feet), examine each 1,000-foot segment as a new tunnel.
7. Document all appropriate damages (none, minor, moderate, severe) in the assessment form for each tunnel element after inspection. See Section 6.3 for specific guidance on elements and Chapter 11 for photographic examples. Provide comments and observations in the assessment form.
8. Make an overall damage rating (0–100%) using Section 3.5.1.
9. If any element damage is severe, mark the tunnel as UNSAFE. Discuss the observations with the team members and come to a consensus for the tunnel (INSPECTED or UNSAFE). For long tunnels, when discussing the overall marking, use the worst case tunnel segment to mark the whole tunnel.
10. If UNSAFE, notify the ME immediately.

Table 6-1. Tunnel inspection checklist.

Element	Material	Check for:
Liner	Steel	Corrosion, cracking, connections, distortion, leakage
	Cast-in-place concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking, distortion, leakage
	Precast concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking, distortion, leakage
	Shotcrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking, distortion, leakage
	Timber	Connection, decay/section loss, check/shake, crack, split/delamination, distortion, leakage
	Masonry	Efflorescence/rust staining, mortar breakdown, split/spall, patched area, masonry displacement, distortion, leakage
	Unlined	Loose or cracked rock, roof bolt distress, patched areas, leakage
Roof Girder	Steel	Corrosion, cracking, connections, distortion
	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking
	Prestressed concrete	Delamination/spall/patched area, exposed rebar, exposed prestressing, cracking, efflorescence
Interior Walls	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking
Portal	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking, settlement
	Masonry	Efflorescence/rust staining, mortar breakdown, split/spall, patched area, masonry displacement, settlement
Ceiling Slab	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence, cracking
Ceiling Girder	Steel	Corrosion, cracking, connections, distortion
	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking
	Prestressed concrete	Delamination/spall/patched area, exposed rebar, exposed prestressing, cracking, efflorescence/rust staining
Ceiling Panels	Steel	Corrosion, cracking, connections, distortion
	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking
Invert Slab	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence/rust staining, cracking
Slab-on-Grade	Concrete	Delamination/spall/patched area, exposed rebar, cracking, settlement
Invert Girder	Steel	Corrosion, cracking, connections, distortion
	Concrete	Delamination/spall/patched area, exposed rebar, efflorescence, cracking
	Prestressed concrete	Delamination/spall/patched area, exposed rebar, exposed prestressing, cracking, efflorescence/rust staining

Source: Modified from FHWA (2010).

6.2 Tunnel Cracking Types

A crack is caused by tensile forces exceeding the tensile strength of the concrete. Cracks are categorized as follows (FHWA 2005):

- Transverse cracks—Fairly straight cracks that are roughly perpendicular to the span direction of the concrete member.
- Longitudinal cracks—Fairly straight cracks that run parallel to the span of the concrete slab or beam.
- Horizontal cracks—Generally occur in walls but may exist on the sides of beams. Similar in nature to transverse cracks.
- Vertical cracks—Occur in walls and are similar to longitudinal cracks.
- Diagonal cracks—Roughly parallel to each other in slabs. Usually shallow and are of varying length, width, and spacing.
- Pattern or map cracks—Interconnected cracks that vary in size and width. Found in both walls and slabs.
- D-cracks—Series of fine cracks at close intervals with random patterns.
- Random cracks—Irregular cracks on the surface of the concrete.

6.3 Tunnel Damage States

Tables 6-2 through 6-7 provide damage states for tunnels [modified from FHWA (2005)] and incorporate observations from Lanzano et al. (2008).

Table 6-2. Damage states for scaling.

Minor	Moderate	Severe
Loss of surface mortar 0–0.25 inch deep	Loss of surface mortar from 0.25–1 inch	Loss of coarse aggregate particles as well as surface mortar depth of loss over 1 inch

Table 6-3. Damage states for cracking.

Minor	Moderate	Severe
0–0.03 inch	0.03–0.125 inch	Over 0.125 inch

Table 6-4. Damage states for spalling.

Minor	Moderate	Severe
0–0.5 inch deep or 3–6 inches in diameter	0.5–1 inch deep and 3–6 inches in diameter	More than 1 inch deep and greater than 6 inches in diameter

Table 6-5. Damage states for pop-outs.

Minor	Moderate	Severe
Leaving holes 0–0.4 inch in diameter	Leaving holes 0.4–2 inches in diameter	Leaving holes between 2–3 inches in diameter; pop-outs larger than 3 inches in diameter are spalls

Table 6-6. Damage states for leakage.

Minor	Moderate	Severe
Concrete surface is wet with no drips	Flows at a volume less than 30 drips/minute	Flows at a volume greater than 30 drips/minute

Table 6-7. Damage states for corrosion.

Minor	Moderate	Severe
Light corrosion formation pitting the paint surface	Corrosion formation with scales or flakes	Stratified corrosion or corrosion scale with pitting of the metal surface

6.4 Tunnel Assessment Form

Figure 6-2 shows the PDA form for tunnels.

Preliminary Damage Assessment (PDA) Form – Tunnels

Inspector 1 Name/ID:	______	Structure ID:	______		**PDA Outcome:**
Inspector 2 Name/ID:	______	Highway:	______		☐ INSPECTED (Green)
Agency:	______	Begin/End station:	______		☐ UNSAFE (Red)
Date and time:	______	Latitude/Longitude:	______		
Tunnel shape:	☐ Circular	☐ Rectangular	☐ Horseshoe	☐ Oval	☐ Other ______
Liner type:	☐ Unlined rock	☐ Steel/Iron liner plate	☐ Masonry	☐ Precast concrete	
	☐ Shotcrete/Gunite	☐ Cast-In-Place concrete	☐ Timber	☐ Other ______	

Damage Summary:
☐ 1 – None (0%)
☐ 2 – Slight (0-1%)
☐ 3 – Light (1-10%)
☐ 4 – Moderate (10-30%)
☐ 5 – Heavy (30-60%)
☐ 6 – Major (60-100%)
☐ 7 – Destroyed (100%)

Traffic Level:
☐ No traffic at all
☐ Traffic on all lanes
☐ Traffic on some lanes

Specific damage:
☐ Fire
☐ Flooding
☐ Other______

Overall Comments:

Feature Description:						**Notes: (additional notes on back)**
Roadway	1. Ceiling/Roof Slab	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Roadway	2. Invert Roadway Slab	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Roadway	3. Right Wall	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Roadway	4. Left Wall	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Upper Plenum (if present)	5. Underside of Roof	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Upper Plenum (if present)	6. Top of Ceiling Slab	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Upper Plenum (if present)	7. Right and Left Walls (if applicable)	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Lower Plenum (if present)	8. Underside of Invert Roadway Slab	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Lower Plenum (if present)	9. Bottom of Plenum Slab	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Lower Plenum (if present)	10. Right and Left Walls (if applicable)	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Misc.	11. Safety Walks and Railings	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Misc.	Other______	☐ None	☐ Minor	☐ Moderate	☐ Severe	______

Recommendations: Choose a recommendation based on the evaluation and team judgment. DDA evaluations should only be recommended with an UNSAFE posting. Provide comments on the recommendations below.

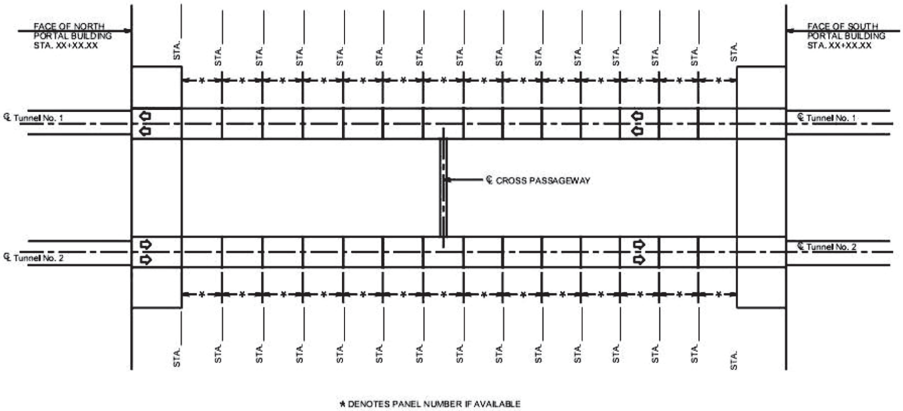
☐ **None** ☐ **DDA (Low Priority)** ☐ **DDA (High Priority)**

Record any recommendations:______

(QR Code)

Figure 6-2. Tunnel assessment form (page 1/2).

Tunnel inspection layout plan:



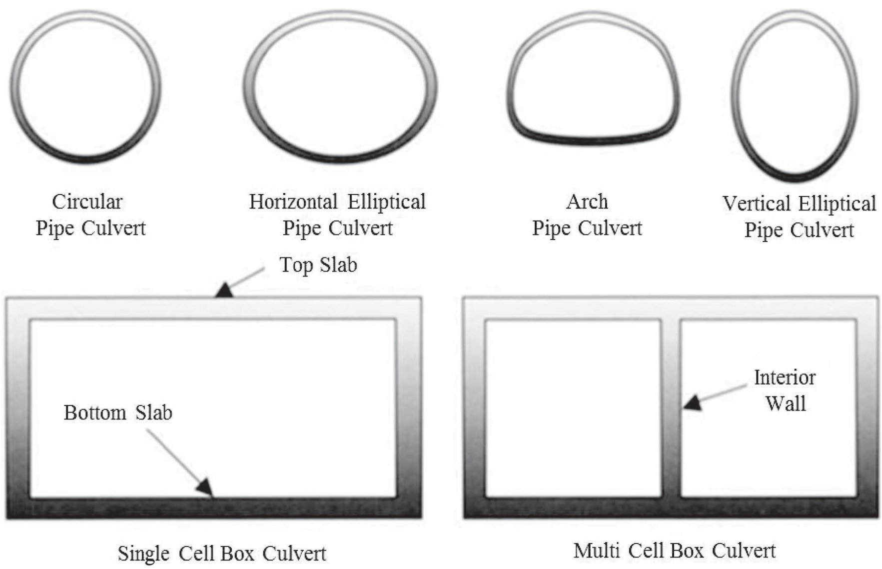
Notes/Drawings/Comments continued:

Figure 6-2. (page 2/2).

7 Culverts

Culverts enable water to pass below a road. They are designed for both hydraulic and structural loadings. The impacts of emergency events can increase the hydraulic loading and lead to serious failures or collapse of the culvert. Culverts are typically considered minor structures, but they are of great importance for adequate drainage and the integrity of the transportation network (Marek 2011).

Typical culvert shapes are circular/elliptical, arch, or rectangular (box) in cross section (see Figure 7-1). A typical culvert is characterized by basic elements that include the material and cross-sectional shape, invert, roadway, embankment, and headwall and wingwall (see Figure 7-2). Culvert materials include concrete, corrugated aluminum or steel, and plastic.



Source: Modified from Highways Agency (2007).

***Figure 7-1. Common types and cross sections of pipe culverts* (top four) *and box culverts* (bottom two).**

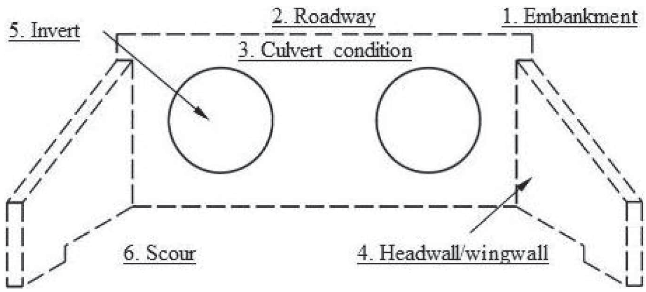


Figure 7-2. Culvert schematic.

7.1 PDA Procedure for Culverts

1. Review the general PDA procedures detailed in Section 3.4.
2. Document PDARs' names, IDs, structure identification number, and arrival time. Mark the shape and material of the culvert. Take a photo of the ID placard and when possible take a second overall photo of the culvert. Photos taken at the site are preferably geo-tagged.
3. Examine traffic flow on the culvert and mark on the assessment form.
4. Make a quick visual inspection of the entire culvert.
   a. If the culvert is collapsed or non-functional (including totally or partially inundated), mark the culvert as UNSAFE.
   b. In the case of hydro-hazards (flooding, storm surge, debris backup), if the roadway above the culvert is partially or totally inundated, mark the culvert as UNSAFE.
   c. High water levels or high water velocities should be reported. (Note that some culverts may have high water level markings; others may require judgment).
   d. If deemed as UNSAFE, go to Step 10.
5. Begin PDA evaluation by reviewing the elements listed in Table 7-1. If scour is apparent, follow the procedure in the scour section of this manual (Section 4.9).

Table 7-1. Culvert inspection checklist.

Element	Check for:
1. Embankment	Depressions, settlement, slumps, voids
2. Roadway	Cracking, spalling, patches, potholes
3. Culvert condition	Visible damage, settlement, misalignment, separation, cracking, spalling
4. Headwall /wingwall	Offset, alignment, cracking, spalling, settlement
5. Invert	Cracking, spalling, corrosion, scaling, buckling
6. Scour	Undermining, erosion, settlement

6. Document all appropriate damages (none, minor, moderate, severe) in the assessment form for each culvert element after inspection. See Section 7.2 for specific guidance on elements and Chapter 12 for photographic examples. Provide comments and observations in the assessment form.
7. Take photos of observed damage. When necessary for scale indications, use a tape measure, person, clipboard, or other distinguishing object to relate size variations.
8. Determine an overall damage rating (0–100%) using Section 3.5.1.
9. Discuss the observations with the team members and come to a consensus for the culvert (INSPECTED or UNSAFE). In the case that team members are equally split on the decision, classify as UNSAFE.
10. If any element damage is severe, mark the culvert as UNSAFE.
11. If UNSAFE, notify the ME immediately.
12. Place and secure the placard and appropriate decal in the predetermined location, in accordance with Section 2.3.1 of this manual.
13. Proceed to the next site.

7.2 Culvert Damage States

Tables 7-2 through 7-9 provide damage states for culverts [modified from New York State DOT (NYSDOT 2006) and Trevis (2013)].

Table 7-2. Damage states for culvert embankment.

Minor	Moderate	Severe
Minor erosion away from the structure	Moderate erosion near the structure with no cracks on the headwall	Slope stability problem near the culvert and/or extensive hairline cracks near the headwall
Minor settlement and/or small depressions	Depressions, soil cracks, slumps, and/or voids along the embankment	Large depressions, soil cracks, slumps, and/or voids along the shoulder

Table 7-3. Damage states for roadway.

Minor	Moderate	Severe
Not more than minor settlement of the roadway with no cracks	Minor settlement of the roadway or major cracks	Heavy settlement of the roadway or major cracks
Minor misalignment of guardrail posts	Significant misalignment of several guardrail posts in a row	Extensive vertical or horizontal misalignment of several guardrail posts
Minor isolated cracking and spalled areas	Significant cracking, spalling, potholes, or maintenance patches affecting up to 20% of any single travel lane	Extensive cracking, spalling, potholes, or maintenance patches affecting up to 20% of any single travel lane

Table 7-4. Damage states for concrete culvert.

Minor	Moderate	Severe
Longitudinal cracks 0–⅛ inch in width	Longitudinal cracks between ⅛–¼ inch in width	Severe cracking and spall greater than ½ inch on culvert walls
Spalls 0–¼ inch deep	Spalls larger than ½ inch deep, and/or spalls have exposed rebar	Spalls greater than ½ inch on culvert walls
Minor separation of joints 0–1 inch	Significant separation of joints between 1–3 inches	Severe separation of joints greater than 3 inches
		Sections of culvert are partially collapsed
		Major corrosion of rebar

Table 7-5. Damage states for metal culvert.

Minor	Moderate	Severe
Minor cracking around bolt holes or seams at isolated sections	Significant cracking and/or deterioration along bolt holes and isolated seams of plates	Severe cracking and/or deterioration along bolt holes or plates
Minor corrosion, pitting, and/or isolated distortions	Significant deterioration and pitting with isolated section loss and holes	Large holes and/or section loss throughout barrel

Table 7-6. Damage states for plastic culvert.

Minor	Moderate	Severe
Minor isolated tear caused by debris 0–6 inches in length and 0–½ inch in width	Cracking, splits, or tears over 6 inches in length and up to ½–¾ inch in width	Cracking, splits, punctures, or tears over 6 inches in length and over 1 inch in width
Isolated perforations caused by abrasion	Perforations caused by abrasion	Loss of barrel material

Table 7-7. Damage states for headwall/wingwall.

Minor	Moderate	Severe
Minor spalls and cracks 0–⅛ inch in width	Significant spalls and cracks ⅛–¼ inch in width	Extensive spalls and cracks over ¼ inch in width
No exposed rebar or surface evidence of rebar corrosion	Exposed rebar with corrosion	Corrosion of rebar and extensive section loss
Minor differential or rotational settlement	Significant differential or rotational settlement	Extensive settlement of the wall
		Extensive deterioration with loss of concrete

Table 7-8. Damage states for inverts.

Minor	Moderate	Severe
Minor corrosion and abrasion	Moderate corrosion and abrasion	Heavy corrosion and abrasion
Minor waterway blockage due to debris	Moderate obstruction due to debris	Maximum waterway is blocked due to debris
No deformation		Ends totally/partially broken

Table 7-9. Damage states for scour.

Minor	Moderate	Severe
Minor undermining of the culvert barrel or top of footing is exposed	Significant undermining of the culvert barrel or undermining of the footing	Extensive undermining of the culvert barrel or footing resulting in a possible settlement
Culvert span to scour hole depth ratio is between 5 and 10	Culvert span to scour hole depth ratio is between 2 and 5	Culvert span to scour hole depth ratio is less than 2

7.3 Culvert Assessment Form

Figure 7-3 shows the PDA form for culverts.

Preliminary Damage Assessment (PDA) Form – Culverts

Inspector 1 Name/ID: ____________	Structure ID: ____________	**PDA Outcome:**
Inspector 2 Name/ID: ____________	Highway: ____________	☐ INSPECTED (Green)
Agency: ____________	Milepost: ____________	☐ UNSAFE (Red)
Date and time: ____________	Route Carried on: ____________	
Latitude/Longitude: ____________	Route Carried under: ____________	
Shape: ☐ Circular ☐ Arch	☐ Box ☐ Other ____________	
Material ☐ Concrete ☐ Metal	☐ Steel ☐ Plastic ☐ Other ________	

Damage Summary:	**Traffic Level:**	**Overall Comments:**
☐ 1 – None (0%)	☐ No traffic at all	
☐ 2 – Slight (0-1%)	☐ Traffic on all lanes	
☐ 3 – Light (1-10%)	☐ Traffic on some lanes	
☐ 4 – Moderate (10-30%)	**Scour:**	
☐ 5 – Heavy (30-60%)	☐ Unknown	
☐ 6 – Major (60-100%)	☐ Unlikely	
☐ 7 – Destroyed (100%)	☐ Likely, but cannot see	
	☐ Definitely	

Feature Description:					**Notes: (additional notes on back)**
1. Embankment	☐ None	☐ Minor	☐ Moderate	☐ Severe	
2. Roadway	☐ None	☐ Minor	☐ Moderate	☐ Severe	
3. Culvert condition	☐ None	☐ Minor	☐ Moderate	☐ Severe	
4. Headwall/ wingwall	☐ None	☐ Minor	☐ Moderate	☐ Severe	
5. Invert	☐ None	☐ Minor	☐ Moderate	☐ Severe	
6. Scour	☐ None	☐ Minor	☐ Moderate	☐ Severe	
Other__________	☐ None	☐ Minor	☐ Moderate	☐ Severe	
Other__________	☐ None	☐ Minor	☐ Moderate	☐ Severe	

Recommendations: Choose a recommendation based on the evaluation and team judgment. DDA evaluations should only be recommended with an UNSAFE posting. Provide comments on the recommendations below.

☐ None **☐ DDA (Low Priority)** **☐ DDA (High Priority)**

Record any recommendations:____________________________

(QR Code)

Figure 7-3. Culvert assessment form (page 1/2).

Sketch any areas of damage on the culvert:

Notes/Drawings/Comments continued:

Figure 7-3. (page 2/2).

8 Walls

For the purpose of this manual, walls are defined as any retaining, self-supported, or quay wall, regardless of height. In retaining walls, the primary function is to act as a retaining structure for embankments, fill slopes, or natural slopes. They can be externally stabilized structures, internally stabilized structures, fill-type retaining walls, cut-type retaining walls, mechanically stabilized earth walls, or other geotechnical structures depending on the geotechnical mechanism used to resist lateral loads. Table 8-1 provides a simplified classification of wall structural types.

Table 8-1. Classification of wall structural types.

Fill-constructed walls (built from the bottom up)	
Externally stabilized	**Internally stabilized**
Rigid gravity walls • Masonry gravity walls (stone, concrete, brick) • Cast-in-place (CIP) concrete gravity walls Rigid semi-gravity walls • CIP concrete cantilever T-wall or L-wall (including counterforted walls and buttressed walls) Prefabricated modular gravity walls • Crib wall • Bin wall • Gabion wall Rockeries	Mechanically stabilized earth (MSE) walls • Segmental, precast facing MSE wall • Prefabricated modular block facing • Flexible facing (geotextile, geogrid, or welded-wire facing) Reinforced soil slopes

Cut-constructed walls (built from the top down)	
Externally stabilized	**Internally stabilized**
Non-gravity cantilevered (embedded) walls • Sheet-pile wall (steel, concrete, timber) • Soldier pile and lagging wall • Slurry (diaphragm) wall • Tangent/secant pile walls • Soil-mixed wall (SMW) Anchored walls* • Ground anchor (tieback) • Deadman anchor	In-situ reinforced walls • Soil-nailed wall • Root-pile wall • Insert pile wall

Self-Supporting Walls		
• Quay walls	• Sea walls	• Noise walls

*Anchors are often used in combination with embedded walls of various types and may also be used in combination with semi-gravity cantilever walls.
Source: Modified from Sabatini et al. (1997).

Basic elements of a highway wall structure include the foundation system, sub-drainage system, and material. Walls themselves are made up of concrete, masonry, wood, or steel and are supported by gravity, piles, or ties to resist the geotechnical elements behind the wall.

Table 8-2 provides a condition checklist breaking down primary and secondary exterior wall elements. This checklist was reproduced from the FHWA and the National Park Service Retaining Wall Inventory Field Guide. Used in conjunction with Table 8-3, the appropriate wall elements that should be given inspection ratings can be identified. Prior to arriving at the inspection site, PDARs should determine the wall type and appropriate primary and secondary elements using Table 8-3.

Table 8-2. Primary and secondary wall elements.

Primary element condition ratings	
Piles and shafts	Soldier piles, sheet piles, micropiles or drilled shafts, as well as supplemental structures such as walers, comprising part or all of the visible wall
Lagging	Structural lagging between piles and walers
Anchor heads	All visible parts of tieback anchor, including pad (generally observed without removing cap)
Wire/Geosyn. Facing Elements	Visible facing/basket wire, soil reinforcing elements, hardware cloth, geotextile/geogrids and facing stone
Bin or crib	Visible portion of cellular gravity wall
Concrete	Visible precast or cast-in-place concrete wall and footing elements (does not include piles, lagging, crib blocks, manufactured block/brick, and architectural facing)
Shotcrete	Visible shotcrete (does not include piles, lagging, architectural facing, or other specific elements)
Mortar	Visible mortar used between uncut or masoned rock, manufactured blocks or brick, or used for wall repairs
Manufactured block/brick	Manufactured blocks and bricks, including concrete masonry unit's segmental blocks, large gravity blocks, etc. (does not include concrete lagging or crib wall components)
Placed stone	Dry-laid or mortar-set uncut rock
Stone masonry	Dry-laid or mortar-set cut rock
Wall foundation material*	Soil or rock immediately adjacent to and supporting the wall
Other primary wall element	Any primary wall element not listed
Secondary element condition ratings	
Wall drains*	Function and capacity of visible drain holes, pipes, slot drains, etc., that provide wall subsurface drainage
Road/Sidewalk/ Shoulder	Road and/or sidewalk surface above or below a wall, and within the influence of the wall
Upslope	Groundslope area above a wall affecting wall condition and/or performance
Downslope	Groundslope area below the wall, distinct from the wall foundation material, affecting wall condition and/or performance
Lateral slope*	Groundslope laterally adjacent to a wall affecting wall condition and/or performance

*Wall elements that should always be rated for all wall types
Source: DeMarco et al. (2010).

Table 8-3. Wall elements that should be rated based on the wall structural type.

	Wall Type	PRIMARY ELEMENTS	Piles and Shafts	Lagging	Anchor Heads	Wire/Geosyn.Facing Elements	Bin or Crib	Concrete	Shotcrete	Mortar	Manufactured Brick Block	Placed Stone	Stone Masonry	Wall Foundation Material	Other Primary Element	SECONDARY ELEMENTS	Wall Drains	Architectural Facing	Traffic Barrier/Fence	Road/Sidewalk/Shoulder	Upslope	Downslope	Lateral Slope	Vegetation	Culvert	Curb/Beam/Ditch	Other Secondary Element	WALL PERFORMANCE	Performance
Anchor	(AH) Anchor Tieback H-Pile		X	X	X									X			X			O	O	O	X						X
	(AM) Anchor Micropile		X		X									X			X			O	O	O	X						X
	(AS) Anchor, Tieback Sheet Pile		X		X									X			X			O	O	O	X						X
Bin	(BC) Bin, Concrete						X							X			X			O	O	O	X						X
	(BM) Bin, Metal						X							X			X			O	O	O	X						X
Cantilever	(CL) Cantilever, Concrete							X						X			X			O	O	O	X						X
	(CP) Cantilever, Soldier Pile		X	X										X			X			O	O	O	X						X
	(CS) Cantilever, Sheet Pile		X											X			X			O	O	O	X						X
Crib	(CC) Crib, Concrete						X							X			X			O	O	O	X						X
	(CM) Crib, Metal						X							X			X			O	O	O	X						X
	(CT) Crib, Timber						X							X			X			O	O	O	X						X
Gravity	(GB) Gravity Concrete Block Brick									X	X			X			X			O	O	O	X						X
	(GC) Gravity, Mass Concrete							X						X			X			O	O	O	X						X
	(GD) Gravity, Dry Stone											O	O	X			X			O	O	O	X						X
	(GG) Gravity, Gabion					X								X			X			O	O	O	X						X
	(GM) Gravity, Mortared Stone									X		O	O	X			X			O	O	O	X						X
MSE	(MG) MSE, Geosyn. Wrapped Face					X								X			X			O	O	O	X						X
	(MP) MSE, Precast Panel							X						X			X			O	O	O	X						X
	(MS) MSE, Segmental Block										X			X			X			O	O	O	X						X
	(MW) MSE, Welded Wire Face					X								X			X			O	O	O	X						X
Other	(SN) Soil Nail								X					X			X			O	O	O	X						X
	(TP) Tangent Secant Pile		X											X			X			O	O	O	X						X
	(OT) Other, User Defined													X			X			O	O	O	X						X

Notes:

X = Wall element that should always be rated for the given wall type (others may also apply)

O = 1 of 2 primary wall elements required depending on material observed

= 2 of 3 secondary wall elements requried depending on wall location relative to roadway.

Road/Sidewalk Shoulder: Rate only when these elements lie within the influence of the wall. The shoulder is generally defined as extending no greater than 5 ft horizontally from the roadway sidewalk and less than -5 ft vertical offset.

Upslope: Rate the upslope condition for all walls above roadway grade, regardless of slope ratio. Rate the upslope condition for all walls below roadway grade, regardless of slope ratio, when the vertical offset to the wall from the roadway shoulder is greater than 5 ft. Otherwise evaluate the condition of the upslope under the "Road/Sidewalk/Shoulder" element.

Downslope: Rate the downslope conditions for all walls below roadway grade, regardless of slope ratio. Rate the downslope condition for all walls above roadway grade, regardless of slope ratio, when the vertical offset to the wall from the roadway shoulder is greater than 5 ft (otherwise, evaluate the condition of the downslope under the "Road/Sidewalk/Shoulder" element.

Source: Modified from DeMarco et al. (2010).

8.1 PDA Procedure for Walls

1. Review the general PDA procedures detailed in Section 3.4.
2. Arrive at the inspection site and determine the traffic level surrounding the wall. Document PDARs' names, IDs, structure identification number, and arrival time.
3. Identify whether any wall damage or debris:
   a. Presents an immediate safety hazard or impedes traffic (UNSAFE)
   b. Poses an impending hazard to the roadway (UNSAFE)
   c. Could be cleaned up by maintenance crews relatively quickly (UNSAFE—make a note of maintenance needs on the assessment form)
   d. Is self-contained on the side of the road (INSPECTED, but make a note that repairs are needed).
4. Determine the structural type.
   a. If the wall type is known, use Table 8-3 to determine the appropriate primary and secondary elements to inspect.
   b. If the wall type is not known, inspect at minimum, the wall foundation material, wall drains, and wall performance. Inspect any other wall elements based on judgment.
5. Take a photo of the ID placard and when possible take a second overall photo of the wall. Photos taken at the site are preferably geo-tagged.
6. Begin PDA according to the initial wall items listed in the assessment form (wall performance, corrosion/weathering, cracking/breaking, distortion/deflection, and lost bearing/missing elements) as well as the primary and secondary elements (Table 8-2) defined using Step 4.
7. Document all appropriate damages (none, minor, moderate, severe) in the assessment form for each wall element after inspection. See Section 8.2 for specific guidance on elements and Chapter 13 for photographic examples. Provide comments and observations in the assessment form.
8. Determine an overall damage rating (0–100%) using Section 3.5.1.
9. Code and mark the structure as INSPECTED or UNSAFE after completing the assessment form.
10. If UNSAFE, notify the ME immediately.
11. Place and secure the placard and appropriate decal in the predetermined location, in accordance with Section 2.3.1 of this manual.
12. Proceed to the next site.

8.2 Wall Damage States

Tables 8-4 through 8-9 provide information on damage states of walls, as modified from DeMarco et al. (2010).

Table 8-4. Damage states for wall performance.

Minor	Moderate	Severe
Observation of minor distress	Observations of element distress combinations that indicate wall component problems	Combined element distresses indicating serious stability problems with components or global wall stability
		Global wall rotation, settlement, and/or overturning

Table 8-5. Damage states for corrosion/weathering.

Minor	Moderate	Severe
Evidence of minor corrosion/staining, contamination, or cracking/spalling	Moderate corrosion/ staining, contamination or cracking/spalling	Metallic elements are corroded
Minor weathering/ weakening of bedrock, softening of soil, or saturated ground conditions	Significant weathering/ weakening of bedrock, softening of soil, or saturated ground conditions	Extensive weathering/ weakening of bedrock, softening of soil, or saturated ground conditions
Minor impacts from vegetation within the wall or within adjacent elements	Moderate impacts from vegetation are evident within the wall adjacent elements	Severe impacts from vegetation are evident within the wall or within adjacent elements
		Concrete/shotcrete is extensively spalled, cracked, and/or weakened

Table 8-6. Damage states for cracking/breaking.

Minor	Moderate	Severe
Evidence of minor element cracking, breaking, or damage	Localized element cracking, breaking, abrasion, and/or drainage	Extensive severe element cracking, breaking, abrasion or damage
Concrete, shotcrete, and mortar is still sound, durable, and shows little or no signs of shrinkage, cracking, or spalling	Concrete, shotcrete, and mortar is occasionally soft or drummy, has lost durability, and shows cracking and/or spalling	Concrete, shotcrete, and mortar is consistently soft, drummy, or missing and shows pervasive cracking and/or spalling intercepting corroding reinforcement
Drains are open and in working order but contain minimal debris	Drains not fully operational	Drainage is missing, damaged, or clogged

Table 8-7. Damage states for distortion/deflection.

Minor	Moderate	Severe
Small, localized soil displacements but no signs of significant settlement, bulging, bending, heaving, or distortion/deflection	Significant localized settlement, bulging, bending, heaving, misalignment, distortion, deflection, and/or displacement	Excessive settlement, bulging, bending, heaving, distortion, misalignment, deflection, and/or displacement

Table 8-8. Damage states for lost bearing/missing elements.

Minor	Moderate	Severe
No wall elements are missing but may have minor cosmetic defects	Some wall elements are missing (e.g., chinking, lagging, brickwork) or non-functional	Many of key wall elements are missing (e.g., placed wall stone, chinking, lagging), no longer bearing, or non-functional
Foundation soils/rock are more than adequate to support the wall, consistently dense, drained, and strong but slight soil displacements may be apparent	Foundations susceptible to erosion, scour, or vegetation impacts	Foundation soils/rock show signs of failure, excessive settlement, scour, erosion, substantial voids, bench failure, or slope over-steepening or may be adversely affected by vegetation
No slope failures have occurred but surficial erosion may be present	Isolated slope failures have occurred	Substantial slope failures have occurred
Wall elements are still fully bearing against retained soil/rock units but may show slight damage	Localized open voids exist along the back and top of the wall	

Table 8-9. Damage states for primary and secondary wall elements.

Minor	Moderate	Severe
Low extent of low severity stress	High extent of low severity stress	Medium-to-high extent of high severity stress
Distress does not significantly compromise the element function	Distress does not compromise element function, but lack of treatment may lead to impaired function	Element is no longer serving intended function
Distress present over a modest amount of the wall	Elements will need to be mitigated in order to avoid significant repairs or element replacement	Marginally functioning, severely distressed wall element in jeopardy of failing without element repair

8.3 Wall Assessment Form

Figure 8-1 shows the PDA form for walls.

Preliminary Damage Assessment (PDA) Form – Walls

Inspector 1 Name/ID: ____________ Structure ID: ____________
Inspector 2 Name/ID: ____________ Highway: ____________
Agency: ____________ Milepost: ____________
Date and time: ____________ Latitude/Longitude: ____________
Wall type: ☐ Masonry gravity ☐ Crib wall ☐ Sheet-pile wall
☐ Cast-in-place gravity ☐ Bin wall ☐ Soldier pile wall
☐ T-wall or L-wall ☐ Gabion wall ☐ Other ____________

PDA Outcome:
☐ INSPECTED (Green)
☐ UNSAFE (Red)

Damage Summary:
☐ 1 – None (0%)
☐ 2 – Slight (0-1%)
☐ 3 – Light (1-10%)
☐ 4 – Moderate (10-30%)
☐ 5 – Heavy (30-60%)
☐ 6 – Major (60-100%)
☐ 7 – Destroyed (100%)

Wall debris or damage:
☐ Presents a safety hazard or impedes traffic
☐ Poses a hazard if the structure is further damaged
☐ Can be cleaned by maintenance quickly
☐ Self contained

Overall Comments:

Feature Description:					**Notes: (additional notes on back)**
1. Wall performance	☐ None	☐ Minor	☐ Moderate	☐ Severe	
2. Corrosion/ weathering	☐ None	☐ Minor	☐ Moderate	☐ Severe	
3. Cracking/ breaking	☐ None	☐ Minor	☐ Moderate	☐ Severe	
4. Distortion/ deflection	☐ None	☐ Minor	☐ Moderate	☐ Severe	
5. Lost bearing/ missing elements	☐ None	☐ Minor	☐ Moderate	☐ Severe	
6. Primary ____________	☐ None	☐ Minor	☐ Moderate	☐ Severe	
7. Primary ____________	☐ None	☐ Minor	☐ Moderate	☐ Severe	
8. Primary ____________	☐ None	☐ Minor	☐ Moderate	☐ Severe	
9. Secondary ____________	☐ None	☐ Minor	☐ Moderate	☐ Severe	
10. Secondary ____________	☐ None	☐ Minor	☐ Moderate	☐ Severe	
Other ____________	☐ None	☐ Minor	☐ Moderate	☐ Severe	

Recommendations: Choose a recommendation based on the evaluation and team judgment. DDA evaluations should only be recommended with an UNSAFE posting. Provide comments on the recommendations below.

☐ None **☐ DDA (Low Priority)** **☐ DDA (High Priority)**

Record any recommendations: ____________

(QR Code)

Figure 8-1. Wall assessment form (page 1/2).

Sketch any areas of damage on the wall:

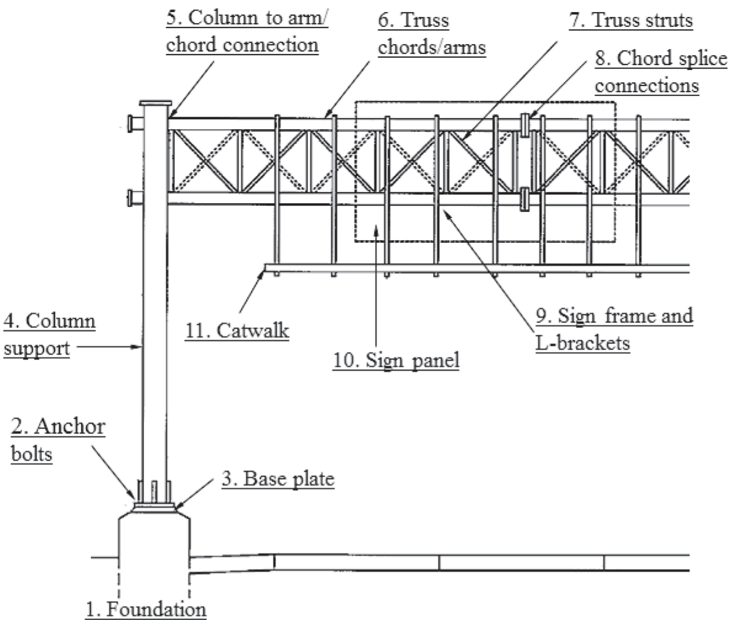
Notes/Drawings/Comments continued:

Figure 8-1. (page 2/2).

9 Overhead Signs

Overhead signs play a vital role in communicating messages to safely direct traffic. They can be sign bridges, cantilever sign structures, or mast arm structures.

The nomenclature used in Figure 9-1 is consistent with AASHTOWare™ Bridge Management software (formerly, Pontis) based systems and the nomenclature developed by Garlich and Thorkildsen (2005).



Source: Modified from Garlich and Thorkildsen (2005).

Figure 9-1. Overhead sign schematic.

9.1 PDA Procedure for Overhead Signs

1. Review the general PDA procedures detailed in Section 3.4.
2. Examine the surrounding traffic and determine if inspection is safe.
3. Identify whether any sign damage or debris:
   a. Presents an immediate safety hazard or impedes traffic (UNSAFE)
   b. Poses an impending hazard to the roadway (UNSAFE)
   c. Could be cleaned up by maintenance crews relatively quickly (UNSAFE, make a note of maintenance needs on the assessment form)
   d. Is self-contained on the side of the road (INSPECTED, but make a note that repairs are needed).
4. Take a photo of the ID placard and when possible take a second overall photo of the wall. Photos taken at the site are preferably geo-tagged.
5. Begin inspecting elements in numerical order starting from the foundation and working skyward (use Table 9-1 for reference).
6. Document all appropriate damages (none, minor, moderate, severe) in the assessment form for each sign element after inspection. See Section 9.2 for specific guidance on elements and Chapter 14 for photographic examples. Provide comments and observations in the assessment form.
7. Determine an overall damage rating (0–100%) using Section 3.5.1.
8. Code and mark the structure as INSPECTED or UNSAFE after completing assessment form.
9. If UNSAFE, notify the ME immediately.

Table 9-1. Overhead sign inspection checklist.

Elements	Check for:
1. Foundation	Cracking, spalling, and/or exposed rebar. Rust, surface pitting, and corrosion.
2. Anchor bolts	Corrosion, misalignment, loose bolts, cracking, sheared bolts, and missing.
3. Base plate	Corrosion, failed protective coating, and section loss.
4. Column support	Corrosion, section loss, water, and plumbness.
5. Column to arm/chord connection	Corrosion, section loss, and misalignment.
6. Truss chord/arms	Corrosion, section loss, and misalignment.
7. Truss struts	Corrosion, section loss, misalignment, and cracking.
8. Chord splice connections	Corrosion, section loss, misalignment, and element defects.
9. Sign frame and L-brackets	Loose connections, missing connections, deterioration, and cracking.
10. Sign panel	Loose connections, deterioration, or loss of legibility.
11. Catwalk	Deterioration, loose connections, misalignment, and damaged gratings.

Source: Modified from Garlich and Thorkildsen (2005).

10. Place and secure the placard and appropriate decal in the predetermined location, in accordance with Section 2.3.1 of this manual.
11. Proceed to the next site.

9.2 Overhead Sign Damage States

Tables 9-2 through 9-12 provide more detailed information on damage states for overhead signs, as modified from Garlich and Thorkildsen (2005).

Table 9-2. Damage states for foundation.

Minor	Moderate	Severe
Concrete foundation: Minor cracks and spalls but no exposed reinforcing	Concrete foundation: Some delaminations and/or spalls and some reinforcing exposed	Concrete foundation: Corrosion of reinforcement and/or loss of concrete
Steel foundation: Surface rust and/or surface pitting	Steel foundation: Corrosion of rebar present but loss of section is incidental and doesn't affect serviceability	Steel foundation: Sufficient section loss of steel
		Advanced deterioration

Table 9-3. Damage states for bolts.

Minor	Moderate	Severe
Minor corrosion of the element present	Moderate corrosion of the element present	Heavy corrosion of the element present
	Anchor nuts misaligned or not fully engaged	Bolts are cracked/sheared or multiple anchor nuts are loose/missing
	One or two loose nuts, but doesn't affect serviceability	

Table 9-4. Damage states for base plate.

Minor	Moderate	Severe
Minor surface corrosion present	Any protective coating present has failed	Cracks present on the base plate to column support connection weld
	Surface pitting present but any section loss from corrosion is measurable	Section loss is sufficient to limit serviceability

Table 9-5. Damage states for column support.

Minor	Moderate	Severe
Minor damage or corrosion is present with no section loss	Moderate damage or corrosion is present	Heavy damage or corrosion of elements with localized section loss
Handhole covers or post caps are missing	Standing water observed inside the post	Misaligned or have severe impact damage
	Column supports out of plumb	

Table 9-6. Damage states for column to arm/chord connection.

Minor	Moderate	Severe
Minor corrosion with no section loss	Moderate corrosion or damage is present to one or more components	Major or multiple element defects
Minor misalignments	Significant misalignment of components	

Table 9-7. Damage states for truss chords/arms.

Minor	Moderate	Severe
Minor corrosion with no section loss	Moderate corrosion or damage is present to one or more components	Major or multiple element defects or section loss
Minor misalignments	Significant misalignment of components	Cracks propagating into any truss member

Table 9-8. Damage states for truss struts.

Minor	Moderate	Severe
Minor corrosion with no section loss	Moderate corrosion or damage is present to one or more components	Major or multiple element defects or section loss
Minor misalignments	Significant misalignment of components	Cracks propagating into any chord

Table 9-9. Damage states for chord splice connections.

Minor	Moderate	Severe
Minor corrosion with no section loss	Moderate corrosion or damage is present to one or more components	Major or multiple element defects or section loss
Minor misalignments	Significant misalignment of components	

Table 9-10. Damage states for sign frame and L-brackets.

Minor	Moderate	Severe
An occasional loose connection nut	Multiple loose/missing backing strip nuts	Connection components cracked, sheared, or missing nuts
	Significant deterioration or impact damage	Cracks observed on the welds

Table 9-11. Damage states for sign panel.

Minor	Moderate	Severe
A few loose or missing backing strip nuts	Moderate deterioration	Significant deterioration
Minor loss of element legibility	Collision damage present but not affecting legibility	

Table 9-12. Damage states for catwalk.

Minor	Moderate	Severe
Minor damage or deterioration	Moderate deterioration of the connections	Heavy deterioration of the connections
Connections have loose nuts	Handrails and locking pins misaligned	Sections of grating or handrails misaligned, unstable, damaged, or missing
	Safety chains missing or deteriorated	

9.3 Overhead Sign Assessment Form

Figure 9-2 shows the PDA form for overhead signs.

Preliminary Damage Assessment (PDA) Form – Overhead Signs

Inspector 1 Name/ID:	______	Structure ID:	______	**PDA Outcome:**
Inspector 2 Name/ID:	______	Highway:	______	☐ INSPECTED (Green)
Agency:	______	Milepost:	______	☐ UNSAFE (Red)
Date and time:	______	Latitude/Longitude:	______	
Structure type:	☐ Span	☐ Cantilever	☐ Other ______	

Damage Summary:	**Impeding traffic:**	**Overall Comments:**
☐ 1 – None (0%)	☐ Presents a safety hazard or impedes traffic	______
☐ 2 – Slight (0-1%)	☐ Poses a hazard if the structure is further damaged	______
☐ 3 – Light (1-10%)	☐ Can be cleaned by maintenance quickly	______
☐ 4 – Moderate (10-30%)	☐ Self-contained	______
☐ 5 – Heavy (30-60%)		______
☐ 6 – Major (60-100%)		______
☐ 7 – Destroyed (100%)		______

Feature Description:					**Notes: (additional notes on back)**
1. Foundation	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
2. Anchor bolts	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
3. Base plate	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
4. Column support	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
5. Column to arm/chord connection	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
6. Truss chord/arms	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
7. Truss struts	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
8. Chord splice connections	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
9. Sign frame and L-brackets	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
10. Sign panel	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
11. Catwalk	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Other______	☐ None	☐ Minor	☐ Moderate	☐ Severe	______
Other______	☐ None	☐ Minor	☐ Moderate	☐ Severe	______

Recommendations: Choose a recommendation based on the evaluation and team judgment. DDA evaluations should only be recommended with an UNSAFE posting. Provide comments on the recommendations below.

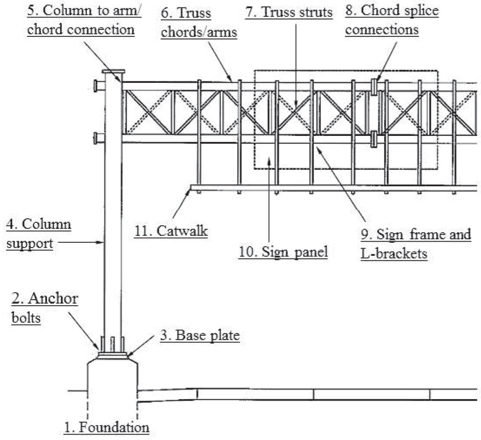
☐ None **☐ DDA (Low Priority)** **☐ DDA (High Priority)**

Record any recommendations______

(QR Code)

Figure 9-2. Overhead sign assessment form (page 1/2).

Mark any areas of damage on the sign structure:



Notes/Drawings/Comments continued:

Figure 9-2. (page 2/2).

PART III

Damage Photos

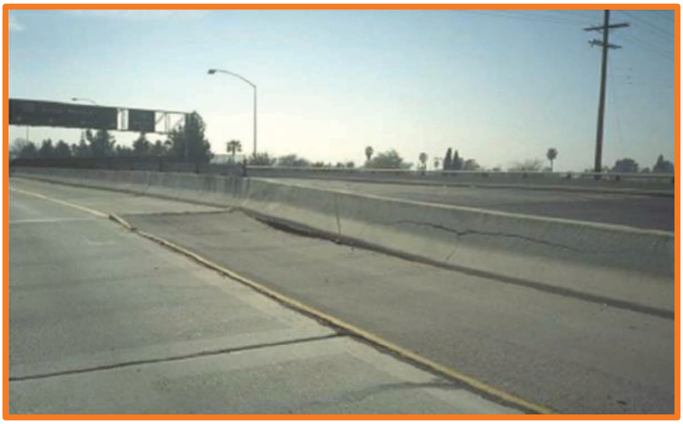
This part of the field manual contains example damage photos that can be used to help rate the damage level for each element of the structure. Pictures are included for bridges, tunnels, culverts, walls, and overhead signs. Classification examples are provided for minor, moderate, and severe damage, when applicable. In some cases, there may not be photos of all three damage states. For these instances, some judgment will be required when selecting a damage rating.

10 Bridge Damage Photos

The figures in this chapter depict minor, moderate, or severe damage to bridge elements:

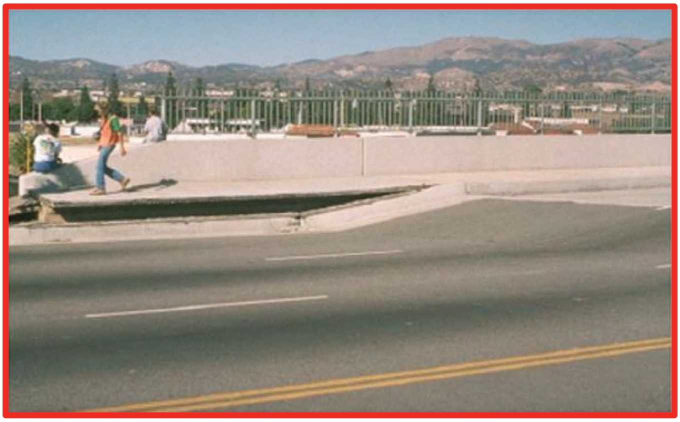
- Figures 10-1 and 10-2: approaches/embankments
- Figures 10-3 through 10-5: parapets, handrails, and curb lines
- Figures 10-6 and 10-7: decks
- Figures 10-8 through 10-10: expansion joints
- Figures 10-11 through 10-14: abutments and wingwalls
- Figures 10-15 through 10-20: girders
  - Figures 10-15 through 10-17: concrete girders
  - Figures 10-18 through 10-20: steel girders
- Figures 10-21 through 10-24: bearings
- Figures 10-25 through 10-27: bent caps and columns
- Figures 10-28 through 10-30: foundations
- Figures 10-31 through 10-34: geotechnical problems

10.1 Approach/Embankment



Source: NISEE (2011).

Figure 10-1. Moderate damage—Approach settlement between 1 and 6 inches.



Source: NISEE (2011).

Figure 10-2. Severe damage—Settlement of the bridge approach slab over 6 inches.

10.2 Parapets, Handrails, and Curb Line

Source: NISEE (2011).

Figure 10-3. Minor damage—Parapet crushing/ spalling.

Source: Missouri DOT (2004).

Figure 10-4. Moderate damage—Bowing of parapet and railing.

Source: Padgett et al. (2008).

Figure 10-5. Severe damage—Bridge parapet failure due to storm surge.

10.3 Deck

Source: NISEE (2011).

Figure 10-6. Moderate damage—Vertical offset between decks.

Source: NISEE (2011).

Figure 10-7. Severe damage—Severe deck cracking and collapse.

10.4 Expansion Joint

Source: Missouri DOT (2004).

Figure 10-8. Minor damage—Misaligned finger joint.

Source: National Center for Research on Earthquake Engineering (1999).

Figure 10-9. Moderate damage—Movement of expansion joints between 1 and 6 inches.

Source: KOERI (2015).

Figure 10-10. Severe damage—Excessive transversal movement at joint over 6 inches.

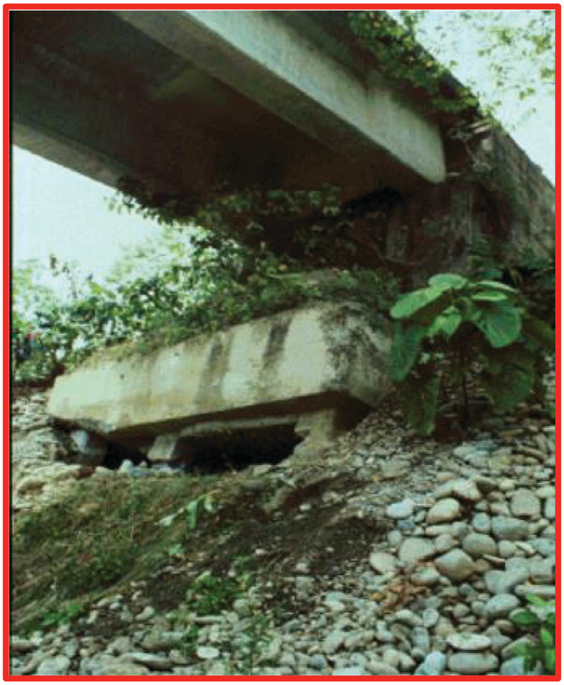
10.5 Abutments and Wingwalls

Source: Sardo et al. (2006).

Figure 10-11. Minor damage—Shearing cracking at the abutment backwall and wingwall.

Source: Simek and Murugesh (1999).

Figure 10-12. Moderate damage—Longitudinal displacement at the abutment seat.



Source: Sardo et al. (2006).

Figure 10-13. Severe damage—Foundation movement, longitudinal displacement, and rotation of the abutment footing.

Source: Padgett et al. (2008).

Figure 10-14. Moderate damage—Abutment damage from scour and erosion.

10.6 Girder

10.6.1 Concrete Girder

Source: NISEE (2011).

Figure 10-15. Minor damage—Shear cracks beginning to develop near the supports.

Source: Sardo et al. (2006).

Figure 10-16. Moderate damage—Flexural cracks in a concrete box girder bridge.

Source: NISEE (2011).

Figure 10-17. Severe damage—Excessive damage to the superstructure and substructure causing partial collapse.

10.6.2 Steel Girder

Source: Sardo et al. (2006).

Figure 10-18. Minor damage—Sheared rivets at the steel truss plate.

Source: Sardo et al. (2006).

Figure 10-19. Moderate damage—Buckled flanges and webs of the steel girders and bearing failure.

Source: NISEE (2011).

Figure 10-20. Severe damage—Buckling of the steel girders.

10.7 Bearings

Source: Simek and Murugesh (1999).

Figure 10-21. Minor damage—Cracks induced by steel bearing.

Source: NISEE (2011).

Figure 10-22. Moderate damage—Crushed bearing assembly and slightly elongated bolts.

Source: Missouri DOT (2004).

Figure 10-23. Severe damage—Displacement of the steel girder off the bearing support.

Source: Hoshikuma (2011).

Figure 10-24. Severe damage—Deformation/pulling out of anchor bolts.

10.8 Bent Cap and Column

Source: Sardo et al. (2006).

Figure 10-25. Minor damage—Torsional/ shear cracking throughout the column length.

Source: Sardo et al. (2006).

Figure 10-26. Moderate damage—Shear failure of the column with cracking propagating into the core concrete.

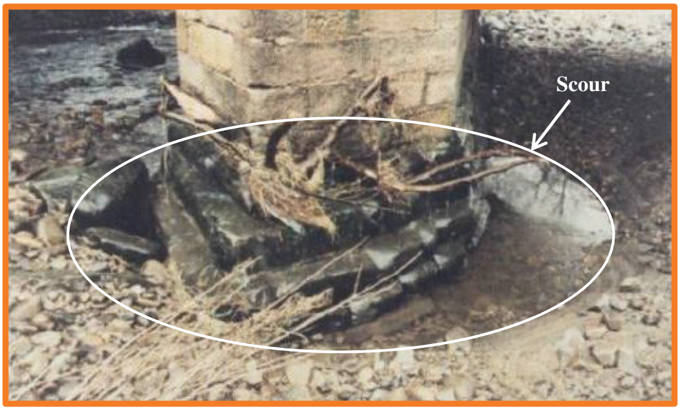
Source: NISEE (2011) (left); Sardo et al. (2006) (right).

Figure 10-27. Severe damage—Shear failure in column **(left)** ***and reinforcement cage and core concrete confinement failure*** **(right).**

10.9 Foundation

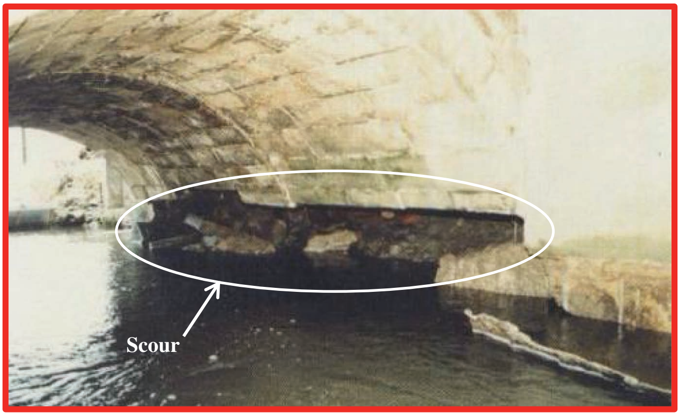
Source: Highways Agency (2007).

Figure 10-28. Minor damage—Minor scour adjacent to wing wall.



Source: Highways Agency (2007).

Figure 10-29. Moderate damage—Scour around base of pier.



Source: Highways Agency (2007).

Figure 10-30. Severe damage—Scour to masonry arch, causing loss of voussoirs at arch springing.

10.10 Geotechnical Problems

Source: O'Connor (2010).

Figure 10-31. Minor damage—Ground movement indicating possible foundation movement.

Source: NISEE (2011).

Figure 10-32. Moderate damage—Disturbed soil at the base of a column.

Source: NISEE (2011).

Figure 10-33. Moderate damage—Separation of soil at column base of pier.

Source: KOERI (2015).

Figure 10-34. Moderate damage—Soil failure due to fault movement through reinforced concrete bridge piers.

11 Tunnel Damage Photos

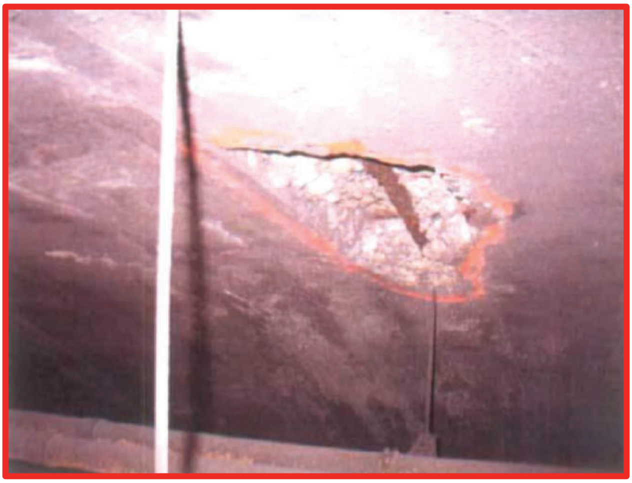
The figures in this chapter depict minor, moderate, or severe damage to tunnel elements:

- Figures 11-1 through 11-4: ceiling/roof slabs
- Figures 11-5 and 11-6: roadway slabs
- Figures 11-7 through 11-10: walls
- Figures 11-11 through 11-13: safety walks and railings

11.1 Ceiling/Roof Slab (Roadway, Upper Plenum, and/or Lower Plenum)

Source: FHWA (2010).

Figure 11-1. Moderate damage—Spalling with section loss in the exposed reinforcing steel on underside of roof ceiling.



Source: FHWA (2010).

Figure 11-2. Severe damage—Significant spalling of tunnel roof.

Source: FHWA (2010).

Figure 11-3. Severe damage—Damaged ceiling panels with misalignment, holes, and surface deterioration.

Source: FHWA (2010).

Figure 11-4. Severe damage—Bowed ceiling hangers.

11.2 Roadway Slab

Source: FHWA (2010).

Figure 11-5. Minor damage—Minor spall in the concrete wearing surface.

Source: FHWA (2010).

Figure 11-6. Moderate damage—Moderate map cracking in the concrete wearing surface.

11.3 Walls

Source: FHWA (2010).

Figure 11-7. Minor damage—Damaged and missing tiles on wall.

Source: FHWA (2010).

Figure 11-8. Moderate damage—Spall with section loss to the exposed reinforcing steel.

Source: FHWA (2010).

Figure 11-9. Severe damage—Large area of missing and delaminated tile with water seeping through wall joint.

Source: FHWA (2010).

Figure 11-10. Severe damage—Spall with up to 100% section loss to the exposed reinforcing steel.

11.4 Safety Walks and Railings

Note: Although this damage is not likely caused by a hazard, it is for illustrative purposes and can be caused by debris impact.
Source: FHWA (2010).

Figure 11-11. Minor damage—Minor misalignment in railing.

Source: FHWA (2010).

Figure 11-12. Moderate damage—Missing section of mid-height rail.

Source: FHWA (2010).

Figure 11-13. Severe damage—Large full-depth hole with 100% section loss to reinforcing steel.

12 Culvert Damage Photos

Figures 12-1 through 12-22 are photographs of minor, moderate, or severe damage to culvert elements:

- Figures 12-1 and 12-2: embankments
- Figures 12-3 and 12-4: roadways
- Figures 12-5 through 12-13: culvert conditions
  - Figures 12-5 through 12-7: concrete culvert conditions
  - Figures 12-8 through 12-10: metal culvert conditions
  - Figures 12-11 through 12-13: plastic culvert conditions
- Figures 12-14 through 12-16: headwalls/wingwalls
- Figures 12-17 through 12-19: inverts
- Figures 12-20 through 12-22: scour

12.1 Embankment

Source: NYSDOT (2006).

Figure 12-1. Moderate damage—Roadway embankment raveling and sloughing away and guide rail posts being undermined.

Source: NYSDOT (2006).

Figure 12-2. Severe damage—Roadway embankment eroding, guide rail posts completely exposed, and roadway slab undermined.

12.2 Roadway

Source: NYSDOT (2006).

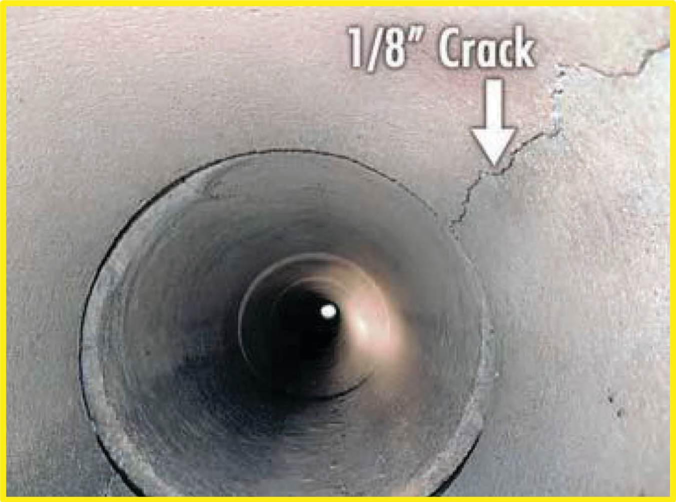
Figure 12-3. Moderate damage—Asphalt pavement settled 3 inches with respect to concrete slab.

Source: NYSDOT (2006).

Figure 12-4. Severe damage—Asphalt settled 1–2 inches along full length of joint angle.

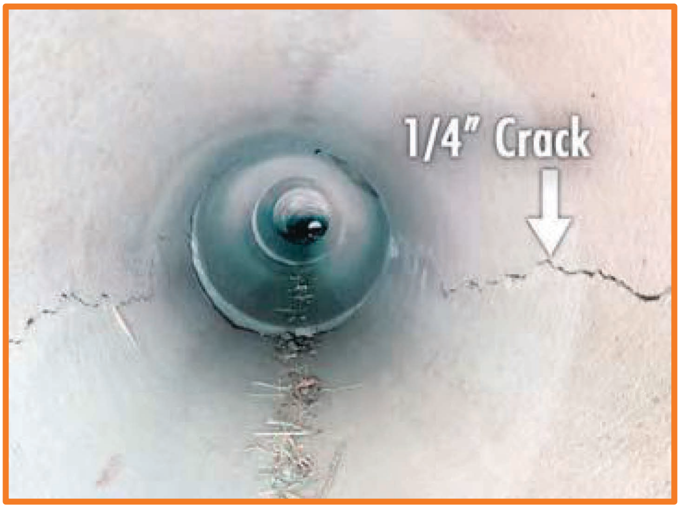
12.3 Culvert Condition

12.3.1 Concrete Culvert Condition



Source: Trevis (2013).

Figure 12-5. Minor damage—⅛-inch longitudinal crack.



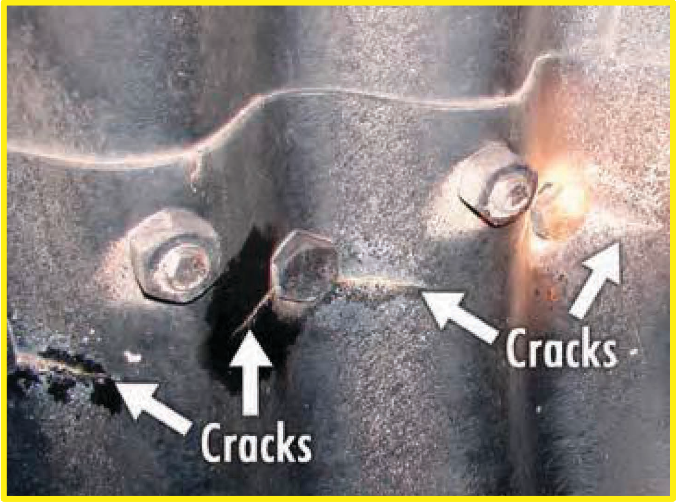
Source: Trevis (2013).

Figure 12-6. Moderate damage—¼-inch longitudinal crack.

Source: Trevis (2013).

Figure 12-7. Severe damage—Partial collapse of culvert.

12.3.2 Metal Culvert Condition

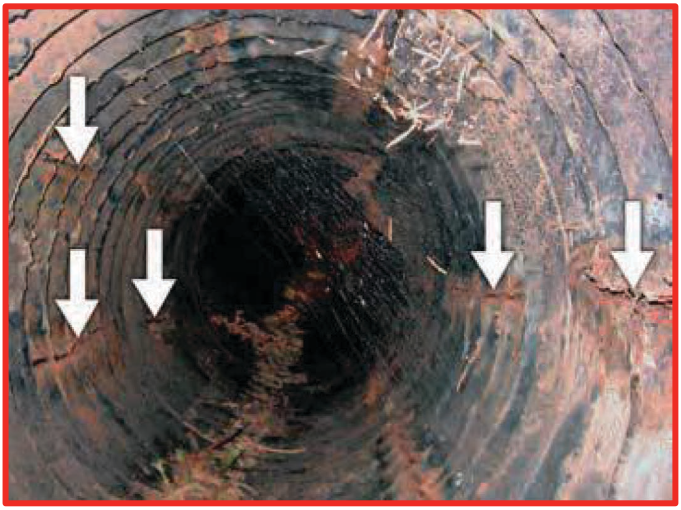


Source: Trevis (2013).

Figure 12-8. Minor damage—Minor cracking around bolt holes.

Source: Trevis (2013).

Figure 12-9. Moderate damage—Deterioration along bolt holes.



Source: Trevis (2013).

Figure 12-10. Severe damage—Severe deterioration along seams.

12.3.3 Plastic Culvert Condition

Source: Trevis (2013).

Figure 12-11. Minor damage—Minor isolated tears.

Source: Trevis (2013).

Figure 12-12. Moderate damage—Multiple tears along culvert.

Source: Trevis (2013).

Figure 12-13. Severe damage—Large tear over 1 inch in width.

12.4 Headwall/Wingwall

Source: NYSDOT (2006).

Figure 12-14. Minor damage—Erosion at the end of the wingwall.

Source: NYSDOT (2006).

Figure 12-15. Moderate damage—Wingwall is heavily spalled.

Source: NYSDOT (2006).

Figure 12-16. Severe damage—Wingwall is cracked and deeply spalled full height.

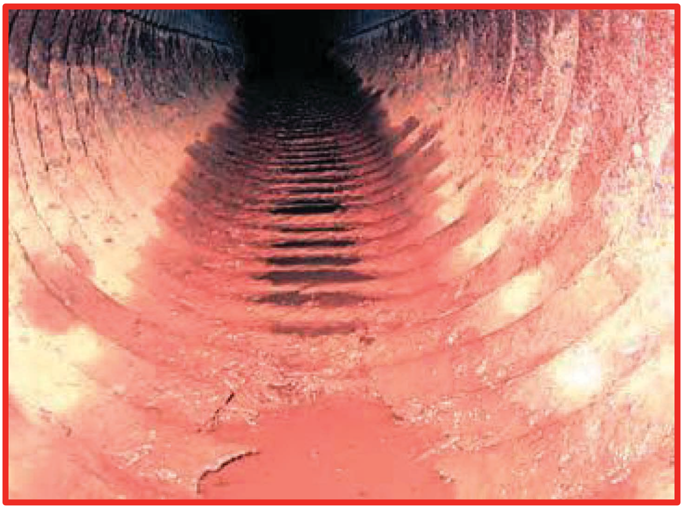
12.5 Invert

Source: Trevis (2013).

Figure 12-17. Minor damage—Minor corrosion and pitting.

Source: Trevis (2013).

Figure 12-18. Moderate damage—Significant deterioration, pitting, and holes developing along the invert.



Source: Trevis (2013).

Figure 12-19. Severe damage—Loss of invert material, holes developed in invert, and buckling along invert.

12.6 Scour

Source: NYSDOT (2006).

Figure 12-20. Minor damage—Section of rip-rap bank protection has sloughed into stream.

Source: NYSDOT (2006).

Figure 12-21. Moderate damage—Channel scouring along abutment and wingwall. Vertical face of footing exposed.

Source: NYSDOT (2006).

Figure 12-22. Severe damage—Deep scour pocket under end section at outlet.

13 Wall Damage Photos

Figures 13-1 through 13-3 are photographs of severe damage to wall elements.

Source: Di Capua et al. (2009).

Figure 13-1. Severe damage—Partially collapsed wall.

Source: Di Capua et al. (2009).

Figure 13-2. Severe damage—Ruptured retaining wall.

Source: Ansal et al. (1999).

Figure 13-3. Severe damage—Collapsed reinforced earth wall.

14 Overhead Sign Damage Photos

The figures in this chapter depict minor, moderate, or severe damage to overhead sign elements:

- Figures 14-1 through 14-3: foundations
- Figures 14-4 through 14-6: anchor bolts
- Figures 14-7 through 14-9: base plates
- Figures 14-10 through 14-12: column supports
- Figures 14-13 through 14-15: column to arm/chord connections
- Figures 14-16 through 14-18: truss chords/arms
- Figures 14-19 through 14-20: truss struts
- Figures 14-21 through 14-23: chord splice connections
- Figures 14-24 through 14-26: sign frame and L-brackets
- Figure 14-27: sign panel
- Figures 14-28 through 14-29: catwalk

14.1 Foundation

Source: NYSDOT (2013).

Figure 14-1. Minor damage—Minor cracking with concrete rings.

Source: NYSDOT (2013).

Figure 14-2. Moderate damage—Radial cracking at anchor bolt.

Source: Garlich and Thorkildsen (2005).

Figure 14-3. Severe damage—Deteriorated grout pad.

14.2 Anchor Bolts

Source: NYSDOT (2013).

Figure 14-4. Minor damage—Minor corrosion. No washer under the turned element.

Source: NYSDOT (2013).

Figure 14-5. Moderate damage—Anchor bolt is misaligned.

Source: NYSDOT (2013).

Figure 14-6. Severe damage—Fractured anchor bolt.

14.3 Base Plate

Source: NYSDOT (2013).

Figure 14-7. Minor damage—Minor corrosion.

Source: NYSDOT (2013).

Figure 14-8. Moderate damage—Corrosion and surface pitting.

Source: NYSDOT (2013).

Figure 14-9. Severe damage—Cracked aluminum base plate.

14.4 Column Support

Source: NYSDOT (2013).

Figure 14-10. Minor damage—Poor post alignment.

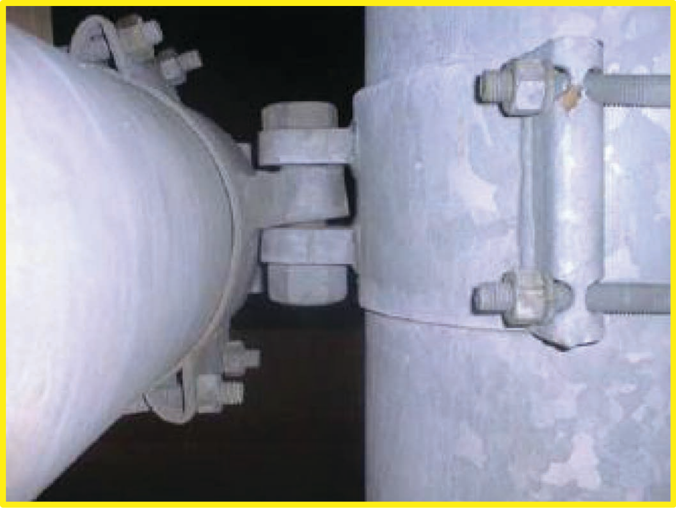
Source: Garlich and Thorkildsen (2005).

Figure 14-11. Moderate damage—Corrosion at base of post.

Source: NYSDOT (2013).

Figure 14-12. Severe damage—Cracked post.

14.5 Column to Arm/Chord Connection



Source: NYSDOT (2013).

Figure 14-13. Minor damage—Minor misalignment or fit-up at hinge.

Source: Garlich and Thorkildsen (2005).

Figure 14-14. Moderate damage—Gap between upper chord.

Source: NYSDOT (2013).

Figure 14-15. Severe damage—Fractured U-bolts.

14.6 Truss Chords/Arms

Source: Garlich and Thorkildsen (2005).

Figure 14-16. Minor damage—Minor surface corrosion.

Source: Garlich and Thorkildsen (2005).

Figure 14-17. Moderate damage—4-inch diameter ding in lower chord and right rear end cap missing.

Source: NYSDOT (2013).

Figure 14-18. Severe damage—Missing secondary member.

14.7 Truss Struts

Source: Garlich and Thorkildsen (2005).

Figure 14-19. Minor damage—~2-inch diameter defect in aluminum strut.

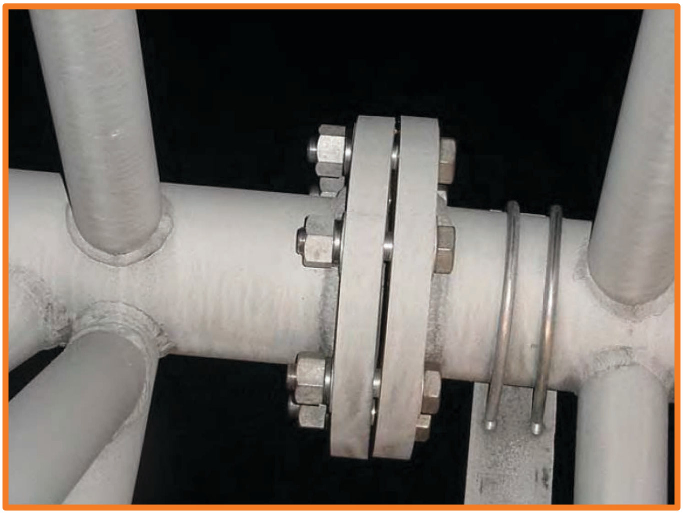
Source: Garlich and Thorkildsen (2005).

Figure 14-20. Severe damage—1.5-inch and 2.5-inch tears in strut member.

14.8 Chord Splice Connections

Source: NYSDOT (2013).

Figure 14-21. Minor damage—Corrosion on bolt threads.



Source: Garlich and Thorkildsen (2005).

Figure 14-22. Moderate/severe damage—Gap in chord splice.

Source: Garlich and Thorkildsen (2005).

Figure 14-23. Severe damage—Severely deteriorated splice bolt.

14.9 Sign Frame and L-brackets

Source: Garlich and Thorkildsen (2005).

Figure 14-24. Minor damage—Missing one U-bolt at the lower chord to vertical sign member.

Source: NYSDOT (2013).

Figure 14-25. Moderate damage—Cracked hanger at wind-beam connection.

Source: Garlich and Thorkildsen (2005).

Figure 14-26. Severe damage—Severe impact damage with missing members and hardware.

14.10 Sign Panel

Source: Garlich and Thorkildsen (2005).

Figure 14-27. Severe damage—Severe impact damage with approximately half the lower section of the sign panel missing.

14.11 Catwalk

Source: Garlich and Thorkildsen (2005).

Figure 14-28. Moderate damage—Moderate impact damage.

Source: Garlich and Thorkildsen (2005).

Figure 14-29. Portion exhibits severe impact damage and has been removed from this section.

15 Scour Damage Photos

Figures 15-1 through 15-4 are photographs of severe scour damage.

Source: Pennsylvania DOT (2014).

Figure 15-1. Water is flowing against the bridge superstructure and water levels may continue to rise and flow over the bridge, causing overtopping.

Source: Pennsylvania DOT (2014).

Figure 15-2. Severe debris buildup of tree branches, caught against the bridge blocking more than 25% of the span opening.

Source: Pennsylvania DOT (2014).

Figure 15-3. Extreme settlement damage in the abutment.

Source: Pennsylvania DOT (2014).

Figure 15-4. Settlement damage in the abutment due to scour underneath the bridge abutment.

Appendix A: PDA Equipment List

Inspection Equipment					
Clipboard	☐	Inspection forms	☐	100’ measuring tape	☐
Flashlight	☐	Notepad	☐	25’ pocket tape	☐
Red paint marker and ribbon	☐	Yellow paint marker and ribbon	☐	Green paint marker and ribbon	☐
Pens and pencils	☐	Hammer	☐	Keel/crayon	☐
Binoculars	☐	Cellular phone	☐	Flagging tape	☐
Duct tape	☐	Portable ladder	☐	Digital camera	☐
Pliers	☐	Micrometer	☐	Wire brush	☐
Chipping hammer	☐	Pocket knife	☐	Scraper	☐
Traffic control equipment	☐	Rope	☐	Shovel	☐
Boat*	☐	Waders*	☐	Underwater probe*	☐
Electronic and Communication Equipment					
State or local maps	☐	Laptop computer with charger	☐	Copies of latest structure inspection files	☐
Flash drives	☐	Identification badges	☐	Walkie-talkies or state-wide radio	☐
Traffic cones	☐	Satellite phone	☐		
Safety Equipment					
Hard hat	☐	Work boots	☐	Safety vest	☐
Ear plugs	☐	Safety glasses	☐	Rubber boots	☐
Rain gear	☐	Work gloves	☐	Rubber gloves	☐
Dust mask	☐				
Personal Supplies					
First aid kit	☐	Drinking water	☐	Toilet paper	☐
Food	☐				

*Specialized PDAR teams for evaluating scour-critical structures

Appendix B: Field Safety

Be sure that you are fully aware of and follow your agency's safety policies and procedures as well as OSHA regulations. You should also have contact information for your department's safety representatives and key contacts for emergency and medical treatment.

Performing reconnaissance after emergency events can be stressful and exhausting. It is particularly important to take time to think about your personal health and alleviate stress.

Basic considerations include the following:

- Always work in teams and stay within visual distance of each other.
- Wear a hard hat and personnel protective equipment for safety and identification.
- Be alert for falling hazards.
- Be aware of your surroundings including traffic, terrain, steep slopes, and confined space.
- Have a first aid kit ready.
- Drink plenty of water.
- Eat healthy foods and have additional food with you in case you are working in areas where there are no stores, they are not open, or where supplies are limited. (It is best to purchase food outside the impacted area, if possible, to not compete with residents in the area for limited supplies).
- Be sure to get plenty of rest before (if possible) and after each day performing PDA.
- When returning home or to lodging after PDA inspections, take time to relax and alleviate stress.
- Take brief breaks from the work, as needed.
- Frequently talk with others to help alleviate stress.
- Keep a vigilant eye out for debris all around you while walking (above, below, and to the sides).
- Do not fill out forms or look at the smart tablet (or other device) while walking.

Appendix C: Contact List Form

The following emergency call down contact list is modified from Utah DOT (2014).

Updated: __/__/____

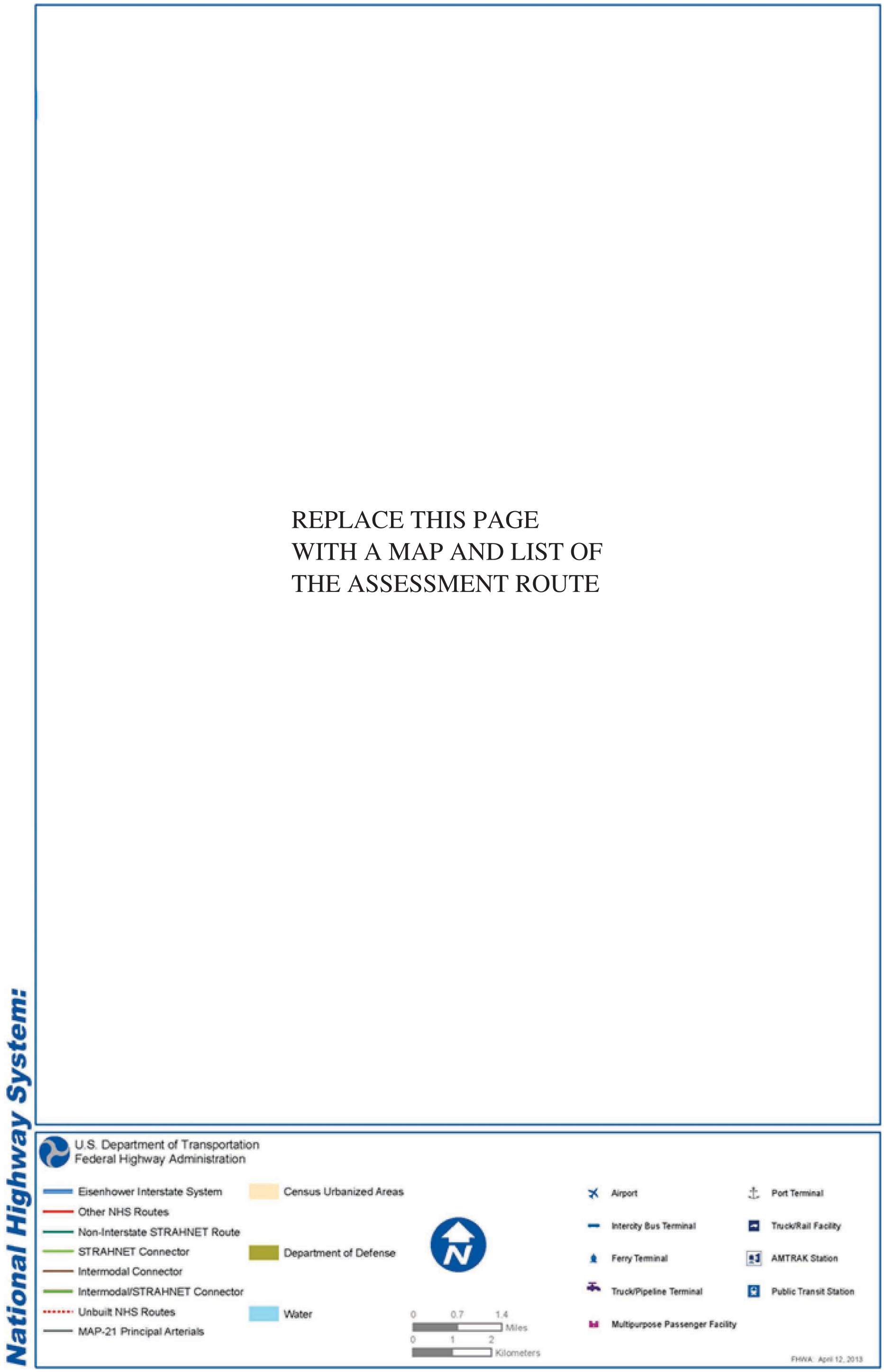
General		
Structures Division (Main number)	Phone #	( ) -
Structures Division (FAX)	Phone #	( ) -
Traffic Operations Center (TOC)	Phone #	( ) -
State Emergency Command Center	Phone #	( ) -
______ Region 1	Phone #	( ) -
______ Region 2	Phone #	( ) -
______ Region 3	Phone #	( ) -
______ Region 4	Phone #	( ) -
______ Region 5	Phone #	( ) -
______ Region 6	Phone #	( ) -
______ Region 7	Phone #	( ) -
______ Region 8	Phone #	( ) -
Seismology Station	Phone #	( ) -
FHWA contact	Phone #	( ) -

PRIMARY CALL LIST		
(Bridge Operations Group - Notify for all Response Levels II, III, & IV)		
Bridge Emergency/Maintenance Coordinator	Phone #	( ) -
	Cell #	( ) -
Structures Bridge Management Engineer	Phone #	( ) -
	Cell #	( ) -
Structures Project Engineer	Phone #	( ) -
	Cell #	( ) -
Structures Design Manager	Phone #	( ) -
	Cell #	( ) -
Chief Structural Engineer	Phone #	( ) -
	Cell #	( ) -

MANAGEMENT CALL LIST		
(Notify immediately on all Emergency Levels III & IV)		
Region 1 Director	Phone #	( ) -
	Cell #	( ) -
Region 2 Director	Phone #	( ) -
	Cell #	( ) -
Region 3 Director	Phone #	( ) -
	Cell #	( ) -
Region 4 Director	Phone #	( ) -
	Cell #	( ) -
Region 5 Director	Phone #	( ) -
	Cell #	( ) -
Region 6 Director	Phone #	( ) -
	Cell #	( ) -
Other		
Geotechnical Design Manager	Phone #	( ) -
	Cell #	( ) -
Geotechnical Engineer	Phone #	( ) -
	Cell #	( ) -
Geotechnical Engineer	Phone #	( ) -
	Cell #	( ) -
Senior Hydraulic Engineer	Phone #	( ) -
	Cell #	( ) -
R&D Engineer	Phone #	( ) -
	Cell #	( ) -
Hydraulic Engineer	Phone #	( ) -
	Cell #	( ) -
Other DOT's		
_____________ State Bridge Eng.	Phone #	( ) -
_____________ State Bridge Eng.	Phone #	( ) -
_____________ State Structural Eng.	Phone #	( ) -
_____________ State Structural Eng.	Phone #	( ) -
_____________ Emergency Response Eng.	Phone #	( ) -
_____________ Emergency Response Eng.	Phone #	( ) -

CONTINGENCY BRIDGE INSPECTOR LIST		
(For Backup, or Widespread Emergencies)		
Bridge Groups:		
Bridge Inspection Supervisor	Phone #	( ) -
	Cell #	( ) -
Bridge Inspector	Phone #	( ) -
	Cell #	( ) -
Bridge Inspector	Phone #	( ) -
	Cell #	( ) -
Bridge Inspector	Phone #	( ) -
	Cell #	( ) -
Senior Design Engineer	Phone #	( ) -
	Cell #	( ) -
Design Engineer	Phone #	( ) -
	Cell #	( ) -
Bridge Program Manager	Phone #	( ) -
	Cell #	( ) -
Bridge Planning Engineer	Phone #	( ) -
	Cell #	( ) -
Structures Construction Engineer	Phone #	( ) -
	Cell #	( ) -
Senior Design Engineer	Phone #	( ) -
	Cell #	( ) -
Design Engineer	Phone #	( ) -
	Cell #	( ) -
Design Engineer	Phone #	( ) -
	Cell #	( ) -
Design Engineer	Phone #	( ) -
	Cell #	( ) -
Design Engineer	Phone #	( ) -
	Cell #	( ) -
Load Rating Engineer	Phone #	( ) -
	Cell #	( ) -
Engineering Technician	Phone #	( ) -
	Cell #	( ) -

Appendix D: Emergency Routes



Route prioritization map template

Appendix E: Example of a Completed Assessment Form

Preliminary Damage Assessment (PDA) Form – Bridges

Inspector 1 Name/ID:	J. CLOUSEA/12345	Structure ID:	BR. No. 53 0730	**Final Posting:**
Inspector 2 Name/ID:	H. POIROT/54321	Structure Name:	SAN FERNANDO RD. OH	☐ INSPECTED (Green)
Agency:	CALTRANS	Highway:	I5	
Date and time:	5/23/15 10:22 AM	Milepost:	43.84	☒ UNSAFE (Red)
Latitude:	34°20'07.42 N	Route Carried on:	I5 NB	
Longitude:	118°30'31.29 W	Route Carried under:	SAN FERNANDO RD.	
Structure material:	☐ Steel ☒ Concrete ☐ Other			

Damage Summary:	**Traffic Level:**	**Overall Comments:**
☐ 1 – None (0%)	☒ No traffic at all	DAMAGE CONCENTRATED @ A1, B2
☐ 2 – Slight (0-1%)	☐ Traffic on all lanes	B3, B4, B5, A6 APPEAR UNDAMAGED
☐ 3 – Light (1-10%)	☐ Traffic on some lanes	POUNDING + BEARING DAMAGE @ A1
☒ 4 – Moderate (10-30%)	**Scour:**	SHEAR CRACKS @ B2 COLUMNS
☐ 5 – Heavy (30-60%)	☐ Unknown	
☐ 6 – Major (60-100%)	☒ Unlikely	
☐ 7 – Destroyed (100%)	☐ Likely, but cannot see	
	☐ Definitely	

Feature Description:					**Notes: (additional notes on back)**
1. Approach/ Embankments	☒ None	☐ Minor	☐ Moderate	☐ Severe	
2. Parapets, Handrail, and Curb Line	☐ None	☒ Minor	☐ Moderate	☐ Severe	HANDRAIL MISALIGNMENT + SEPARATIONS @ A1
3. Deck	☐ None	☒ Minor	☐ Moderate	☐ Severe	MINOR CRUSHING + SPALLING @ A1 EXP. JT.
4. Expansion Joint	☐ None	☐ Minor	☐ Moderate	☒ Severe	7" VERT. + 5" HORIZ. OFFSET @ A1
5. Abutments and Wingwalls	☐ None	☐ Minor	☐ Moderate	☒ Severe	LG. CRACK ON S. SIDE OF A1 WINGWALL
6. Girder	☐ None	☐ Minor	☒ Moderate	☐ Severe	CLOSED FLEXURAL CRACKS NEAR B2 (TOP) + LOCALIZED SPALLING OF COVER (BOT)
7. Bearings	☐ None	☐ Minor	☐ Moderate	☒ Severe	UNSEATING OF A1 BEARINGS
8. Bent Cap and Column	☐ None	☐ Minor	☐ Moderate	☒ Severe	LG. STEEP CRACKS @ B2 COLUMNS
9. Foundation	☒ None	☐ Minor	☐ Moderate	☐ Severe	
10. Geotechnical	☒ None	☐ Minor	☐ Moderate	☐ Severe	
Other________	☐ None	☐ Minor	☐ Moderate	☐ Severe	

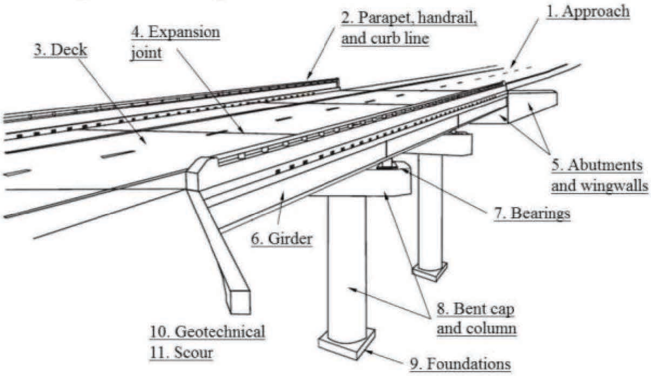
Recommendations: Choose a recommendation based on the evaluation and team judgment. DDA evaluations should only be recommended with an UNSAFE posting. Provide comments on the recommendations below.

☐ **None** ☐ **DDA (Low Priority)** ☒ **DDA (High Priority)**

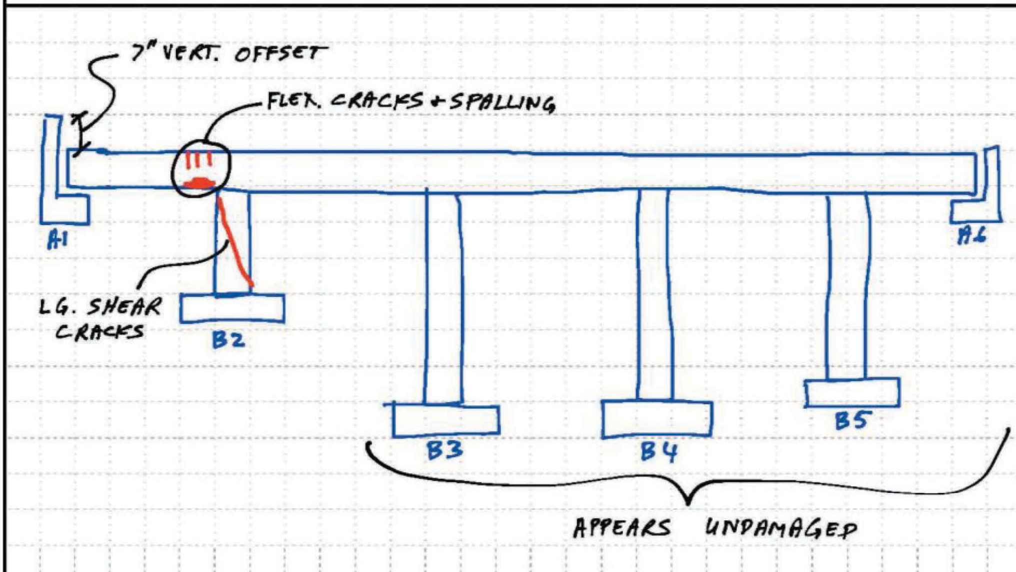
Record any recommendations:____________________

(QR Code)

Mark any areas of damage on the bridge:



Notes/Drawings/Comments continued:



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Acronyms and Abbreviations

CIP	Cast-in-Place
DDA	Detailed Damage Assessment
EI	Extended Investigation
FEMA	Federal Emergency Management Agency
FR	Fast Reconnaissance
GIS	Geographic Information System
GPS	Global Positioning System
MBE	Manual for Bridge Evaluation
ME	Managing Engineer
MSE	Mechanically Stabilized Earth
NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
PDA	Preliminary Damage Assessment
PDAR	Preliminary Damage Assessment Responder
QR	Quick Response
SHA	State Highway Agency

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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