

Case Study:

Response to Bridge Impacts – An Overview of State Practices

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Introduction

Bridges on U.S. highways, either over other highways or navigable waterways, are periodically struck by vehicles or errant vessels. These impacts can significantly affect the load carrying capacity of a bridge or may result in a partial or full collapse. While most of these bridge impacts are overhead collisions with bridge beams or truss elements, there truck or vessel impacts with bridge piers may cause a bridge to collapse. Examples of overhead impact damage are shown in Figure 1.

State department of transportation (State DOT) agencies have developed manuals and documented the desired procedures following an over height collision to ensure public safety, coordinate repairs, and maintain or restore traffic as quickly as possible. This case study provides an overview of the policies and procedures developed and followed by several State DOTs. For this process to be successful, it is important to classify the extent of the damage and address both short-term and long-term repairs in a timely manner. This case study provides examples from several State DOT practices for responding to bridge hits, making preservative and reconstructive repairs to the bridge and allowing return of the bridge to full service as quickly as possible.



Figure 1. Photos. Examples of Truck Impact Damage.

Background

According to data collected in 2018 for the National Highway Traffic Safety Administration's (NHTSA) annual report, "Traffic Safety Facts: A Compilation of Motor Vehicle Crash Data", there were 13,000 collisions recorded between motor vehicles and fixed bridge objects.⁽¹⁾ As shown in Table 1 below, the number of vehicle-bridge collisions has ranged from 18,000 to 13,000 from 2013 to 2018.

Table 1. Recorded Number of Collisions with a Fixed Object Bridge per Year

	2013	2014	2015	2016	2017	2018
Number of Collisions	18,000	14,000	16,000	15,000	15,000	13,000

Source: Data obtained from NHTSA's Traffic Safety Facts Annual Report Tables.⁽¹⁾

In Figure 2, the photos show examples of vehicle hits causing severe damage to bridges.



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Figure 2. Photos. Examples of Severe Truck Impact.

In general, when a bridge owner is made aware of a bridge hit, routine actions follow such as closing roads, inspecting the bridge, and erecting temporary shoring. However, most bridge owners have developed their own specific response policies and procedures. For an efficient and effective response, and due to FHWA's recognition of damage inspection as a type of a bridge inspection in 23 CFR 650.305, many State DOTs have dedicated a section of their bridge inspection manual or procedures to bridge damage inspection. These written procedures vary from a single page describing the actions to be undertaken to much more in-depth procedures and even stand-alone documents. A review of over 15 State DOT websites and discussions with many State Bridge Engineers resulted in selection of the policies, procedures, and action plans for in-depth review from:

- Iowa DOT (IowaDOT).
- Michigan DOT (MDOT).
- Minnesota DOT (MnDOT).

Overall, each reviewed resource prioritized safety as the overarching goal when responding to a bridge hit. The first responders generally include (a mix of) State and local police, fire and emergency medical technicians (EMTs) and State DOT maintenance personnel. Upon securing the safety of the motor vehicle drivers and passengers (primarily the responsibility of the police and the EMTs), State DOT procedures are typically initiated.

State DOT Approaches

IowaDOT

Among the agencies reviewed, IowaDOT is the only agency with a stand-alone document for an approach to bridge hit response, entitled Emergency Response Manual for Over Height Collisions to Bridges.⁽²⁾ The goal is to have a consistent, documented response which sets the following priorities:

- Preserving life, minimize injury and preserve public safety.
- Restoring essential services.

- Protecting property and the environment.
- Providing timely and accurate emergency communication to the public through media.

The focus of the manual is limited to steel beam/girder and concrete beam/girder bridges impacted by over-height vehicles, because the vast majority of the incidents reported in Iowa are this type of hit. However, the manual does include a chapter covering a wide variety of other types of bridge impact events. Regardless of the type of bridge hit, IowaDOT's priorities do not change.

It is important to note that Chapter 2 of the IowaDOT manual, which constitutes approximately half of the entire manual, is dedicated to discussing the emergency response plan, including State and local police, EMTs, HazMat personnel, etc.; public and media coordination; maintenance of traffic, including using existing Intelligent Transportation System dynamic and variable message signing (VMS) and portable VMS for incident reporting and alternative/detour routing; assessment procedures; and contract letting and funding procedures, including reimbursement policies. Chapters 3 and 4 extensively cover the issues involved with steel beam/girder repairs and concrete beam/girder repairs respectively. Chapter 5 provides a review of other bridge damage occurrences, including truss bridges, cast-in-place concrete bridges, bridge piers, and non-vehicle bridge impacts such as fire, flood scour, flood debris, and barge impact. Also included in the manual are flow charts and a wide variety of photos exhibiting typical damage, as well as photos showing repairs with various types of shoring and temporary supports. Examples of bridge hit damage reported by IowaDOT are shown in Figure 3.



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Figure 3. Photos. IowaDOT Examples of Bridge Damage.

Finally, the IowaDOT manual includes eight appendices which are dedicated to standard letter and report templates, examples of letters and reports, examples of temporary supports, examples of calculations, and examples of development and special provisions for contracting repairs.

MDOT

MDOT's damage inspection procedures are outlined in Chapter 9 of the Michigan Structure Inspection Manual, Bridge Inspection.⁽³⁾ Damage inspections are unscheduled inspections due to environmental factors, e.g., floods, or human actions, e.g., vehicle or vessel impacts. According to the manual, timely response is necessary to protect public safety, and accurate documentation will help expedite repairs so that impacts to the

traveling public are minimized. In addition, proper reporting of the damage helps when seeking reimbursement of the costs associated with the inspection and repair activities. Guidelines are provided to classify the damages into one of three types which will assist the bridge owner in defining the effort, anticipated requirements, and characteristics of the damage. Details regarding the three types of damage classified by MDOT follow.

Type I Damage Inspection

A Type I Damage Inspection is reserved for the least impactful damages, normally surface scraping of primary or secondary members, primary member distortions of 2 inches or less of the bottom flange, spalling of concrete less than 6 inches in width and without cracking. More often than not, this damage is not reported when it occurs, the impacting vehicle continues without stopping, and the damage is documented during the scheduled routine bridge safety inspection and recorded in the Bridge Safety Inspection Report (BSIR). However, if any concern exists upon completion of the bridge safety inspection, a Request for Action (RFA) is submitted to the bridge owner. The bridge owner is responsible for reviewing the RFA to determine if a Type II Damage Inspection or other actions are warranted. Examples of typical Type I damage are shown in Figure 4.



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Figure 4. Photos. MDOT Examples of Typical Type I Damage.

Type II Damage Inspection

A Type II Damage Inspection is classified when damage exceeds the damage noted for a Type I Damage Inspection, or when reported by law enforcement (on a State of Michigan Traffic Crash Report UD-10) to MDOT, or when engineering judgment dictates the need for a hands-on damage inspection. While the UD-10 requires the Type II Damage Inspection be completed within 180 days of the report, MDOT recommends that the inspection be completed by a qualified bridge inspection team leader immediately upon arrival at the scene. Additionally, an immediate assessment is made to determine if the damage affects the structural capacity of the bridge. Finally, detailed measurements and photographs are documented in the damage inspection report and an updated BSIR is compiled. However, if any concern exists upon completion of the bridge damage inspection, an RFA is submitted to the bridge owner. The bridge owner is responsible for reviewing the RFA to determine if a Type III Damage Inspection or other actions are warranted. Examples of typical Type II damage are shown in Figure 5.



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Figure 5. Photos. MDOT Examples of Typical Type II Damage.

Type III Damage Inspection

A Type III Damage Inspection takes place when critical damage to the primary structural elements causes concern for structural stability or loss of structural capacity. The majority of these inspections are initiated via a verbal request from law enforcement, but also may be the result of an RFA or a hands-on inspection and are completed as soon as the scene is safe for the inspectors and their equipment to inspect the affected component(s). As with all Damage Inspections, detailed measurements and photographs are documented; however, most times when a Type III Damage Inspection is requested, immediate repairs and other restrictions or activities are required to maintain safe passage of vehicles under and/or on the bridge. Traffic control set up to secure the scene and safely evacuate the driver and passengers will remain in place until the Type III Damage Inspection can be completed, including an assessment of whether the damage has reduced the safe load carrying capacity of the structure and if temporary shoring or supports are required. Upon stabilizing the structure and permanently providing lane/load restrictions as needed, an RFA is developed and plans for the permanent repair and restoration of the structure are developed for construction. Additionally, a narrative of activities completed is provided and included with the Type III Damage report in the bridge file. Examples of typical Type III damage are provided in Figure 6.

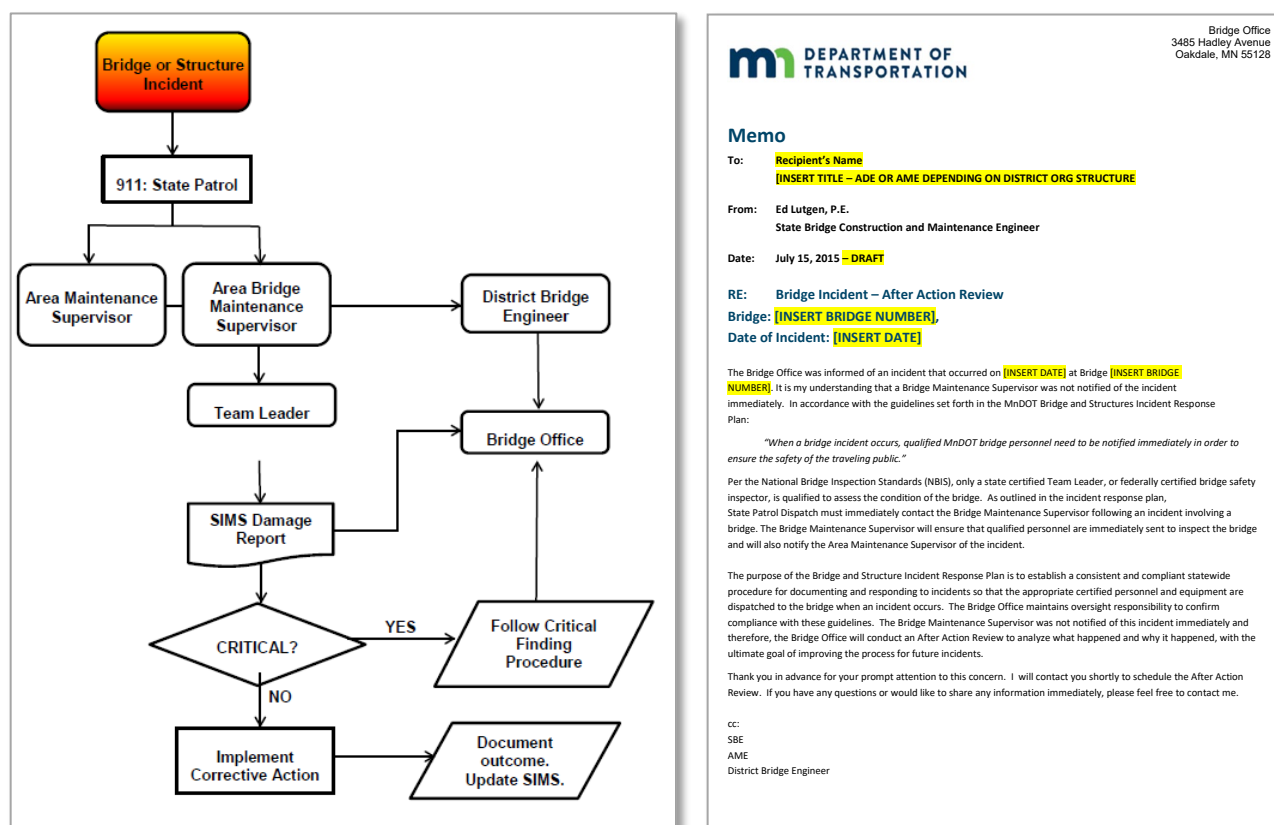


Figure 6. Photos. MDOT Examples of Typical Type III Damage.

The bridge owner is responsible for coordinating the immediate and intermediate actions that may be required; however, public safety is paramount in every action undertaken. The procedures include separate sections for: steel superstructures; concrete superstructures; concrete substructures; movable bridge and vessel impacts; and fire damage. Documenting the damage as described in the Type I, II or III Damage Inspection is of critical importance for maintaining a complete and accurate bridge file and for use in developing repair and reconstruction actions. This documentation is also used as the basis for seeking reimbursement from the party responsible for damaging the bridge. This claim for reimbursement process is outlined in the last section of the manual.

MnDOT

MnDOT's bridge damage procedures are outlined in Appendix J & K in the Bridge and Structure Inspection Program Manual.⁽⁴⁾ Appendix J, entitled Minnesota Bridge and Structures Incidence Response Plan, outlines the response, defines responsibilities and includes a flow chart. Appendix K provides a sample/format for the Bridge Incident – After Action Review, as shown in Figure 7.



© 2015 MnDOT

Figure 7. Chart. MnDOT Response Flowchart and Accompanying After Action Report.

The purpose of MnDOT's Appendix J is to establish and implement a mandatory statewide Bridge and Structures Incident Response Plan, so that the appropriate certified personnel and equipment are dispatched to the bridge or structure when an incident occurs, and to ensure the incident is properly investigated, documented, reported, and response/repair action plans are developed and implemented in a timely, complete and accurate manner. The response plan is framed around many of the FHWA's incident management resources and is combined with the National Bridge Inspection Standards (23 CFR 650.305) for an unscheduled inspection to assess structural damage resulting from environmental factors or human actions.⁽⁵⁻⁸⁾ According to MnDOT, a bridge incident is anything that affects, or could affect, the structural integrity of the asset and may include impact damage, critical deterioration, scour, or a public safety hazard such as falling deck concrete or damaged bridge parapets/railings. The Damage Report is performed and recorded in the Structure Information Management System, and if the damage results in critical findings, the critical finding reporting process in the Bridge and Structures Inspection Program Manual Section 6.2. In addition to bridges and culverts, this process is followed for ancillary structures such as overhead and cantilever sign structures, high mast tower lights, retaining walls, noise walls, etc. Examples of truck impact damage reported by MnDOT are shown in Figure 8 and Figure 9.



© 2015 MnDOT

Figure 8. Photo. MnDOT Example of Column Damage Due to Truck Impact.



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Figure 9. Photos. MnDOT Examples of Superstructure and Railing Damage Due to Truck Impact.

MnDOT's response to an incident includes:

- Immediately notifying and dispatching qualified bridge personnel so that they can assess the bridge or structure and take appropriate actions to ensure the safety of the traveling public.
- Activating the appropriate communication links and motorist information media as soon as there is a reasonable understanding of the incident and its impacts.
- Documenting and reporting findings.

- Preparing and implementing the necessary repair action plan.

Other State DOT Practices

In addition to the above three agencies, Pennsylvania DOT (PennDOT), Ohio DOT (ODOT), New Jersey DOT (NJDOT) and Maryland State Highway Administration (MSHA) have practices of interest. PennDOT and ODOT have sections in their Bridge Inspection Manuals which describe damage collisions, and each DOT has additional resources which augment and guide their responses. For example, in addition to Section 2.9 of PennDOT's Bridge Inspection Manual, PennDOT has a standard Bridge Problem Report (BPR) form found in Appendix IP 02-B that is required to be filled out by field staff (most often the bridge inspection team), as shown in Figure 10 on the next page.⁽⁹⁾ The BPR provides a concise "news" report (no longer than two pages, not including photographs) for the District Staff, Central Office Staff and ultimately the Deputy Secretary for Highway Administration to develop consistent meaningful messaging concerning a bridge incident. The BPR is an internal document and is amended as more information becomes available and repairs are undertaken. The BPRs are maintained in a database in the Bureau of Quality Assurance Division's database to facilitate follow-up reviews and develop improved response plans for future bridge incidents. PennDOT also has an appendix (Appendix IP 02-G) which illustrates a process, in an easy to follow flow chart format, for responding to barge hits. Lastly, PennDOT has an All-Hazards Incident Management Manual, which is aligned with several FHWA resources on Incident Management, for any incident PennDOT staff may be called upon to respond to which includes bridge hits, hazard material spill scenes, etc.⁽¹⁰⁾

Estimated Cost for Repairs

Similar to PennDOT, ODOT provides a description of Damage Inspections in Chapter 4 of the ODOT Bridge Inspection Manual.⁽¹¹⁾ ODOT also has standard detail sheets and standard payment items called “Insert Sheets” that discuss several items, including⁽¹²⁾:

- The differing maintenance of traffic requirements including the use of State or local law enforcement.
- The variety of work items to be included in the repair plans such as concrete repair including epoxy injection, the level of steel repair (section replacement, heating and straightening).
- Field welding procedures including drilling or coring of weld terminations, etc.
- Field painting of damaged/repaired steel.
- Jacking and temporary support of the superstructure.

The standardization of these details by ODOT provides for a cost effective and competitive environment for delivering the repairs in a rapid manner. Examples of truck impact damage reported by ODOT are shown in Figure 11.



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Figure 11. Photos. ODOT Examples of Pier and Median Damage Due to Truck Impact.

NJDOT and MSHA have a section in their respective Bridge Inspection Manuals for damage collisions, but then supplement that information with stand-alone internal procedures.^(13, 14) MSHA Office Procedure 11 requires an inspection of the traffic impact damage to a structure be performed by a NBIS-qualified bridge inspection team as soon as possible. The vertical clearance at the point of impact as well as the historic low clearance point of the bridge is measured and compared to what is in the existing bridge inspection report. All available information regarding the accident is documented: What hit the bridge? When was it hit? The police report incident number and their written report is included. Measurements with sketches of the damage to the structure include, but are not limited to:

- Sweep of the beam.
- Rotation and translation of the bottom flange and web.
- Deformations in the web.

- Gouges, tears, cracked welds.
- Scrapes in the web or bottom flange.
- Damaged diaphragms.

An example of damage due to truck impact as reported by MSHA is shown in Figure 12.



© 2017 MSHA

Figure 12. Photo. MSHA Example of Steel Truss Damage Due to Garbage Truck Impact.

All accident damage is measured, photographed, and documented. An assessment/analysis of the damaged structural elements, using the data collected from the inspection, is performed to determine which of the following repair options, or combination of repair options, are recommended as follows:

Steel Beams:

- Grinding gouges or scrapes along the impact areas.
- Grinding and drilling out cracks in welds or base metal.
- Removal of existing damaged diaphragms and installing new ones in new locations;
- Heat straightening of the member.
- Plating the web or bottom flange (or both) to supplement for the loss of steel due to the damage to the original member.
- Replacement of the member.
- Strengthen the beams/girders to resist future impacts.

Concrete Panels (Planks or Voided Slabs) and Girders:

- Patch impact areas.
- Splice reinforcing bars or post tensioning cables.
- Inject cracks less than 1/4 inch.

- External post tensioning cables or bars.
- Strengthen the concrete panels or girders to resist future impacts.

Additionally, an evaluation of potential actions to reduce future traffic impacts is assessed including the following: increasing the existing clearance at the bridge by removing additional wearing surface under the bridge; determining if there is a need for signing or additional signing, and at a minimum installing clearance signs if less than 14 ft 6 in; restricting truck traffic; and ultimately evaluating the overall condition of the bridge regarding its potential for rehabilitation, replacement, or planned/scheduled improvements to the roadway being carried or crossing under the bridge. This assessment/analysis is documented and included in a recommendation letter signed by the Director of the Office of Structures.

NJDOT has an internal Emergency Incident Response Procedure document for Bridge Engineering and Infrastructure Management staff to follow. An Emergency Incident is defined as a situation that affects the structure's or roadway's stability and could directly lead to, or has resulted in, the failure or collapse of a major portion of the structure or roadway, or a situation that creates, or can create, a safety hazard to the traveling public. Examples of emergency incidents could be, but are not limited to, the following:

- Collisions.
- Overloading.
- Scour or Undermining.
- Rock Fall Slope Failures.
- Seismic Events.
- Fires.
- Terrorism.

Immediately upon becoming aware of the existence of an emergency incident, the appropriate Manager or their designee within the Division of Bridge Engineering and Infrastructure Management is notified and provided with all the available information relating to the emergency incident. "Promptly investigating the reported problem is of the utmost importance."⁽¹³⁾ For emergency incidents involving bridges all applicable records such as bridge or roadway plans, bridge inspection reports, soil borings and other related information are reviewed and a field investigation of the structure with a NBIS qualified bridge inspection team is performed as quickly as the field situation allows. Additionally, a notification protocol is included with individuals' cell phone numbers provided for immediate (text or voice) contact. If the incident is expected to be of a long duration, the Emergency Management Coordinator may set up a Mobile Command Post for the engineers/leadership to operate from on-site.

Once the problem is investigated and identified, a required remedial action plan is determined. "Repairs or temporary/interim repairs to make the structure or roadway safe for the traveling public are of the utmost importance and must be undertaken as quickly as the situation demands."⁽¹³⁾ Temporary or interim solutions to the emergency incident are considered which could include complete or partial closing of the bridge or roadway, load posting, temporary shoring or repairs or other interim measures. The proposed permanent repairs to the structure are considered when identifying and developing the interim or temporary repairs. NJDOT has several resources to assist in investigating the emergency incident and developing a remedial action plan including in-house inspection and design staff and consultant on-call contracts. Similarly, the

construction of the temporary and permanent repairs can be performed by in-house maintenance staff, existing force-account maintenance contracts or emergency on-call contracts. Examples of superstructure damage due to truck impact as reported by NJDOT are shown in Figure 13.



Figure 13. Photos. NJDOT Examples of Superstructure Damage Due to Truck Impact.

Summary

The average number of recorded bridge hits across the nation is over 15,000 per year, as recorded in the NHTSA category entitled “Collision Fixed Object Bridge.” Most of these bridge impacts are overhead collisions with bridge stringers or girders. However, there are also some instances of truck impacts with bridge piers, causing bridges to collapse. Finally, there have also been vessel impact incidents which, while fewer in number, can be just as damaging to the bridge as truck impacts.

Based on these statistics and the potential for severe safety and economic impacts created by bridge impacts, State DOTs have developed a variety of response protocols. Although each State DOT’s specific response varies, every State DOT prioritizes safety as the overarching goal when responding to a bridge hit. The first responders generally include a mix of State and local police, EMTs and State DOT Maintenance personnel. Only after making sure safety of the motor vehicle drivers and passengers (primarily the responsibility of the police and the EMTs) is complete, then the State DOT procedures are activated. Based on a desire to respond efficiently and effectively, and FHWA’s recognition of damage inspection as a type of a bridge inspection (23 CFR 650.305), many State DOTs have largely included a section of their Bridge Inspection manual or procedures to bridge damage inspections. These written procedures vary from simply a page describing the actions to be undertaken when informed of a bridge hit to much more in-depth procedures and even standalone documents.

Resources

The resources utilized for this case study are provided below.

1. Traffic Safety Facts Annual Report Tables, found at <https://cdan.nhtsa.gov/tsftables/tsfar.htm>
2. Iowa DOT resources from the 2014 IOWADOT Office of Bridges and Structures Emergency Response Manual for Over Height Collisions to Bridges , Issue Date September 11, 2014, found at https://siims.iowadot.gov/IowaDOT_EmergencyResponseManualForBridges.pdf
3. Michigan DOT resources from the 2017 Michigan Structure Inspection Manual found at https://www.michigan.gov/mdot/0,4616,7-151-9625_24768_24773_59525-326737--,00.html
4. Minnesota DOT resources from the 2020 MnDOT Bridge and Structure Inspection Program Manual, found at <http://www.dot.state.mn.us/bridge/pdf/insp/bridge-and-structure-inspection-program-manual.pdf>
5. FHWA resources from the Simplified Guide to the Incident Command System for Transportation Professionals, found at https://ops.fhwa.dot.gov/publications/ics_guide/ics_guide.pdf
6. FHWA resources from National Traffic Incident Management Responder Training, Every Day Counts, found at <https://www.fhwa.dot.gov/innovation/everydaycounts/edc-2/tim.cfm>
7. FHWA resources from Emergency Transportation Operations, found at https://ops.fhwa.dot.gov/eto_tim_pse/about/tim.htm
8. FHWA resources from Procedures for Major Incidents, found at https://ops.fhwa.dot.gov/eto_tim_pse/about/pmi.htm
9. Pennsylvania DOT resources from the 2010 Bridge Safety Inspection Manual, found at <http://www.dot.state.pa.us/public/PubsForms/Publications/PUB%20238.pdf>
10. Pennsylvania DOT resources from <http://www.dot.state.pa.us/public/pubsforms/Publications/PUB%20911.pdf>
11. Ohio DOT resources from the 2014 ODOT Manual of Bridge Inspection, found at <http://www.dot.state.oh.us/Divisions/Engineering/Structures/bridge%20operations%20and%20maintenance/Manual%20of%20Bridge%20Inspection%202014%20v8/Complete%20Manual%20of%20Bridge%20Inspection%202014%20v8%20with%20Appendix.pdf>
12. Ohio DOT collision sheet, found at <http://www.dot.state.oh.us/Divisions/Engineering/Structures/standard/Bridges/Plan%20Insert%20sheets/Collision%20-%20Insert%20sheet.pdf>
13. New Jersey DOT resources from the Structural Evaluation and Bridge Management page, found at <https://www.state.nj.us/transportation/eng/structeval/downloads.shtm>
14. Maryland DOT resources from the Structure Inspection Section of the 2019 Office of Structures Guidelines and Procedures Memorandums <https://www.roads.maryland.gov/OBD/GPM-OOS-03-Inspection.pdf>



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