Office of Bridges and Structures

Emergency Response Manual for Over Height Collisions to Bridges

Issue Date: September 11, 2014

Developed By:

DISCLAIMER

THIS EMERGENCY RESPONSE MANUAL FOR RESPONDING TO OVER HEIGHT COLLISIONS TO BRIDGES IS PUBLISHED TO PROVIDE INFORMATION AND GUIDANCE TO IOWA DOT PERSONNEL WHO ARE EITHER DIRECTLY OR INDIRECTLY RESPONDING TO AN EMERGENCY SITUATION INVOLVING IMPACT DAMAGE TO A BRIDGE ON THE STATE OR U.S. HIGHWAY SYSTEM WITHIN THE STATE OF IOWA. THIS MANUAL IS ISSUED TO SECURE, SO FAR AS POSSIBLE, UNIFORMITY OF PRACTICE AND PROCEDURE IN METHODS DEVELOPED BY EXPERIENCE. BUDGETARY LIMITATIONS, VOLUMES AND TYPES OF TRAFFIC, LOCAL CONDITIONS AND OTHER FACTORS MAY RENDER COMPLETE COMPLIANCE WITH THE GUIDELINES SET FORTH IN THIS MANUAL IMPOSSIBLE OR IMPRACTICAL. THIS MANUAL IS NOT PURPORTED TO BE A COMPLETE GUIDE IN ALL AREAS OF BRIDGE IMPACT EMERGENCY RESPONSE AND IS NOT A SUBSTITUTE FOR SOUND ENGINEERING JUDGMENT.

TABLE OF CONTENTS

CHAPTER 1 OVERVIEW AND DEFINITIONS 1-1

1.1 Purpose of Manual 1-1
1.2 Definitions, Abbreviations, and Acronyms 1-1
1.2.1 Definitions 1-1
1.2.2 Abbreviations and Acronyms 1-2
1.3 Common Types of Bridge Damage 1-2
1.3.1 Impact Damage to Steel Beam or Girder Bridges 1-2
1.3.2 Impact Damage to Prestressed Concrete Beam Bridges 1-3

CHAPTER 2 RESPONSE PROCEDURES 2-1

2.1 Emergency Response Variables 2-1
2.2 Emergency Response Flowcharts 2-1
2.3 State of Iowa and Iowa DOT Emergency Response Plan for Major Events 2-4
2.3.1 State of Iowa Emergency Response Plan 2-4
2.3.2 Iowa DOT Systems Operations Bureau, Traffic Operations Center 2-5
2.4 State Patrol, Rescue Personnel, HazMat Personnel, and Local Police/Sheriff Coordination 2-6
2.5 Second-party Bridge Owner or Agency Coordination 2-7
2.6 Reporting Hazardous Materials Spills 2-7
2.7 Public and Media Coordination 2-8
2.7.1 Iowa 511 2-8
2.7.2 Iowa DOT Office of Strategic Communications 2-8
2.7.3 Communication Coordination with District Staff 2-8
2.8 Maintenance of Traffic Operations and Procedures 2-9
2.8.1 Initial Clean-up and Restoration of Traffic 2-9
2.8.2 Use of Statewide Intelligent Transportation Systems and Variable Message Signs 2-11
2.8.3 Incident Management Routes 2-11
2.8.4 Use of Temporary Detour Bridge 2-11
2.9 Assessing Damage and Determining Follow-up Procedures 2-11
2.9.1 Field Inspection of Collision Damage 2-12
2.9.2 Beam and Girder Damage Levels 2-15
2.9.3 Repair/Replacement Options Tied to Levels and Types of Damage 2-16
2.10 Assessing Bridge Repair vs. Bridge Replacement 2-26
2.11 Contract Letting Options 2-26
2.11.1 Regular Letting Process 2-26
2.11.2 Special Lettings 2-26
2.11.3 Emergency Lettings 2-26
2.11.4 Use of Incentives and Disincentives 2-27
2.12 Funding Repairs and Reimbursement to Iowa DOT for Repairs 2-27
2.12.1 Iowa DOT Project Number for Inspection/Design Services 2-28
2.12.2 Federal Aid Considerations 2-28

CHAPTER 3 STEEL BEAM OR GIRDER BRIDGE REPAIR 3-1

3.1 Use of Temporary Strong Backs 3-1
3.2 Partial Removal and Replacement of Steel Beam Bottom Flange and Web 3-2
3.3 Steel Beam Strengthening Angle 3-3
3.4 Temporary Shoring Towers 3-4

3.4.1 Loads 3-5
3.4.2 Geometric Constraints 3-5
3.4.3 Protection from Traffic 3-6
3.5 Local Repairs to Prevent Stress Risers 3-6
3.6 Heat Straightening 3-6
3.7 Cold Jacking 3-8
3.8 Steel Beam Repair Concept Statement 3-8

CHAPTER 4 PRESTRESSED CONCRETE BEAM BRIDGE REPAIR 4-1

4.1 Temporary Shoring Towers 4-1
4.2 Carbon Fiber and Fiber Reinforced Polymer Wrap Repairs 4-1
4.3 Grouted Steel Sleeve Repairs 4-2
4.4 Prestressed Strand Splicing 4-3
4.5 Prestressed Concrete Beam Repair Concept Statement 4-3

CHAPTER 5 RELATED TYPES OF BRIDGE DAMAGE AND OTHER BRIDGE TYPES 5-1

5.1 Other Types of Damage 5-1
5.1.1 Fire Damage 5-1
5.1.2 Impact to Bridge Pier Columns 5-3
5.1.3 Flood Debris Damage 5-3
5.1.4 Flood Scour Damage 5-4
5.1.5 Barge Impact 5-4
5.2 Other Bridge Types 5-5
5.2.1 Truss Bridges 5-5
5.2.2 Cast-in-Place Concrete Bridges 5-5

List of Tables

Table 1.2.2. Abbreviations and Acronyms 1-2

List of Figures

Figure 2.2-1. Initial Emergency Response Flow Chart 2-2
Figure 2.2-2. Detailed Bridge Assessment Flow Chart 2-3
Figure 2.2-3. Repair Design and Contract Letting Flow Chart 2-4
Figure 2.9.3.1-1. Steel Gouge and Paint Scrape 2-16
Figure 2.9.3.1-2. Moderately Bent Bottom Flange with Some Web Distortion 2-17
Figure 2.9.3.1-3. Damaged Diaphragm Member 2-18
Figure 2.9.3.1-4. Out of Plane Bending with Web Tear 2-19
Figure 2.9.3.1-5. Bottom of Deck Spalling with Crack at Girder-to-Deck Interface 2-19
Figure 2.9.3.2-1. Installation of Drape to Catch Loose Debris 2-20
Figure 2.9.3.2-2. Minor Bottom Flange Spalling 2-21
Figure 2.9.3.2-3. Bottom Flange Damage with Mild Reinforcing and Prestressing Strands Intact 2-22
Figure 2.9.3.2-4. Cracking Along Web-to-Top Flange Interface 2-23
Figure 2.9.3.2-5. Heavy Damage with Web Cracking and Severed Mild Reinforcing and Prestressing Strands 2-24
Figure 2.9.3.2-6. Severe Prestressed Beam Damage with Excessive Concrete Section Loss 2-25
Figure 2.9.3.2-7. Multiple Prestressed Beams with Severe Damage 2-25
Figure 3.1. Temporary Strong Back Beam 3-1

Figure 3.2. Partial Steel Beam Removal and Replacement 3-3
Figure 3.4-1. Shoring Towers on Each Side of Damage 3-4
Figure 3.4-2. Shoring Tower Providing End Span Support 3-5
Figure 4.2. Fiber Reinforced Polymer Wrapped Repair 4-1
Figure 4.3. Grouted Steel Sleeve Repair 4-2
Figure 5.1.1. Collapse of I-880 Bridge in San Francisco from Fire Damage 5-2
Figure 5.1.2. Truck Collision with Bridge Pier 5-3
Figure 5.1.4. Bridge Pier Scour Damage 5-4
Figure 5.1.5. Barge Lodged Across the Mississippi River Channel Parallel to IA-9 Lansing Bridge 5-5
Figure 5.2.2. Continuous Concrete Slab Overpass 5-6

List of Appendices

Appendix A – Sample Concept Statements for Steel I-Beam and Prestressed Concrete Beam Bridge Repairs
Appendix B – Critical Findings Report
Appendix C – Damage Inspection Notes - Template
Appendix D – Strong Back and Support Beam Details for Damaged Bridges
Appendix E – Calculations for Strong Back Beam, Support Beam, and Steel Beam Web Splice
Appendix F – Sample Developmental and Special Provisions
Appendix G – Partial Reference List of Past Iowa DOT Over Height Vehicle Collision Repairs
Appendix H – References

CHAPTER 1
OVERVIEW AND DEFINITIONS

1.1 PURPOSE OF MANUAL

On a fairly regular basis, bridges spanning State of Iowa (State) or U.S. highways in Iowa are struck by vehicles that exceed the vertical clearance envelope under the bridge or by vehicles that have unsecured loads or components encroaching into the vertical clearance envelope. This second classification of vehicles might include trucks hauling a flatbed trailer loaded with an over height backhoe or excavator, dump trucks with their payload bed raised, flatbed trailers on which the payload has not been secured, or other over height configurations. As a result, beams or girders supporting the overhead bridge may be impacted, causing various degrees of damage to the bridge.

The purpose of this manual is to define and document the desired procedures following an over height collision to be followed by emergency and Iowa Department of Transportation (Iowa DOT) personnel to ensure public safety, coordinate repairs, and maintain or restore traffic as quickly as possible. 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. Thus, this manual is intended to ensure consistency in the response, keeping in mind the following priorities: 1) preserving life, minimizing injury, and preserving public safety; 2) restoring essential services; 3) protecting property and the environment; and 4) providing timely and accurate emergency communication to the public through media.

The scope of this manual is intentionally limited to emergency responses for either steel beam/girder bridges or prestressed concrete beam bridges impacted by over height vehicles. Although other types of bridges may be subject to impact by over height vehicles, the vast majority of incidents involve these two types of bridges; therefore, this manual is intended to focus on these structures. However, many of the emergency response procedures contained in this manual may apply to other types of bridges or to damage caused by other means. Damage caused by events other than over height vehicle collisions or damage to other bridge types besides steel beam/girder bridges or prestressed concrete beam bridges are addressed in Chapter 5.

1.2 DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

1.2.1 Definitions

The following terms in this manual are used as defined below:

- *Critical Finding* – A structural or safety-related deficiency for a bridge requiring immediate follow-up inspection or action.
- *Incident Commander* – The most senior ranking emergency response official responding to an emergency who shall become the individual in charge of a site-specific incident command system. The senior emergency response official is the most senior official on site who has the responsibility for controlling the operations at the site. Initially, it is the senior officer on the first piece of responding emergency apparatus to arrive on the incident scene. As more senior officers arrive, the position is passed up the line of authority.
- *Three-Level Guidelines for Emergency Incident Notification* – Decision criteria used by the Iowa DOT Traffic Operations Center to prioritize the notification requirements to Iowa DOT and other

state personnel depending on the severity of an incident on the state transportation system, the level of disruption or lane closures, and whether the incident involves a hazardous materials spill.

1.2.2 Abbreviations and Acronyms

The abbreviations and acronyms used in this manual are defined in Table 1.2.2.

Table 1.2.2. Abbreviations and Acronyms

Abbreviation	Term
AASHTO	American Association of State Highway and Transportation Officials
AWS	American Welding Society
°C	temperature on the Centigrade scale
CFR	Critical Findings Report
CMS	changeable message signs (typically a portable trailer-mounted sign)
DOD	U.S. Department of Defense
ER	Emergency Relief
ESF	Emergency Support Function
ETO	emergency transportation operations
°F	temperature on the Fahrenheit scale
FHWA	Federal Highway Administration
FRP	fiber reinforced polymer
HazMat	hazardous materials
HAZWOPER	Hazardous Waste Operations and Emergency Response
HMR	Hazardous Materials Regulations
ITS	intelligent transportation systems
Iowa DOT	Iowa Department of Transportation
LRFD	Load and Resistance Factor Design
NDT	non-destructive testing
NRC	U.S. Nuclear Regulatory Commission
OBS	Iowa DOT Office of Bridges and Structures
OSHA	Occupational Safety and Health Administration
SIIMS	Structure Inventory and Inspection Management System
TBR	temporary barrier rail
TIM	traffic incident management
TOC	Traffic Operations Center of the Iowa DOT Systems Operations Bureau
VMS	variable message sign

1.3 COMMON TYPES OF BRIDGE DAMAGE

1.3.1 Impact Damage to Steel Beam or Girder Bridges

Impact damage to steel beam or steel plate girder bridges can range from minor paint scrapes and gouges of the steel beams to major damage requiring repair or partial replacement of damaged members. Damage to secondary members, such as steel diaphragms, and damage to field splices connecting adjoining sections of steel beams along a beam line are also common. In rare cases, the bridge damage could be so severe as to warrant partial/full superstructure replacement or total bridge replacement.

In addition to damage to the steel members themselves, impact damage can affect the concrete deck. Concrete cracking or spalling along the interface between the top flanges of the steel beams and the bottom of the bridge deck should be investigated. Additionally, it is important to inspect the top of the concrete deck to determine whether any cracking has propagated through the deck.

1.3.2 Impact Damage to Prestressed Concrete Beam Bridges

Impact damage to prestressed concrete beam bridges may range from minor spalling to the bottom flange of a prestressed concrete beam to severe damage of the beam, including severed prestressing tendons and/or web cracking. As with steel beams, the damage can also be manifested by cracking or spalling at the interface between the top of the beam and the bottom of the bridge deck or cracks propagating through the bridge deck. For prestressed concrete beam bridges, another weak point that may show cracking is the juncture of the web and top flange of the beam.

The range of repairs for damage to prestressed concrete beam bridges may included patching of beam spalls, splicing of broken prestressing tendons, adding fiber reinforced polymer (FRP) wraps around damaged areas of beams, constructing a steel sleeve around damaged areas and injecting epoxy between the beam and the steel sleeve, epoxy injecting concrete cracks, and partial deck removal coupled with complete replacement of severely damaged prestressed concrete beams.

CHAPTER 2
RESPONSE PROCEDURES

2.1 EMERGENCY RESPONSE VARIABLES

A wide range of variables could affect the type and magnitude of response that is associated with an over height vehicle impact. The initial response and clean-up stage could be affected by whether personal injury, fire, or hazardous materials spills are involved with the collision. The initial response could also be affected by whether any other agencies need to be contacted, such as the Iowa Department of Environmental Quality for hazardous spills, the Iowa Department of Natural Resources for issues affecting natural waterways, affected railroads for a collision affecting an overhead railroad bridge, or the U.S. Department of Defense (DOD) or U.S. Nuclear Regulatory Commission (NRC) should one of their vehicles be involved in the collision.

The extent of bridge damage may also trigger the type of response needed. If an over height impact causes only inconsequential paint scrapes in a steel beam or minor concrete spalling to a prestressed concrete beam, the damage may not warrant reporting to the Office of Bridges and Structures (OBS) by the District Bridge Crew Leader, but should be documented in the next scheduled routine inspection of the bridge. However, if the impact causes permanent deformation, tears in tension members, ruptured prestressing strands or mild reinforcing steel, cracked steel members, an unstable condition, or the potential for added property damage or injury from falling debris, then a higher level of response would be warranted.

2.2 EMERGENCY RESPONSE FLOWCHARTS

Three flowcharts presented in this section of the manual outline the emergency response procedures for an over height collision to a bridge. Figure 2.2-1 shows the procedures for the initial emergency response. This phase of the response is focused on addressing the immediate needs at the bridge site, including preserving life, minimizing injury, preserving public safety, minimizing hardship and suffering, restoring essential services, protecting property and the environment, and providing timely and accurate emergency communication to the public through media. The process outlined also addresses conducting an initial assessment of the damaged bridge based on as-built information available to OBS and information supplied by the on-site District Bridge Crew Leader or other authorized District staff as designated by the District Engineer or Assistant District Engineer.

The flowchart in Figure 2.2-2 addresses the steps to be taken to further assess the damaged bridge once the initial emergency is over. The procedures involve a detailed inspection of the bridge damage and a load rating analysis to determine whether the structure can remain in service while repairs are designed and prepared for contract. This assessment may result in the use of temporary measures to help support the bridge or it may result in a decision to close the bridge to traffic.

Figure 2.2-3 shows the steps involved with designing repairs, preparing a contract letting for repairs, and completing the bridge repairs so that full traffic function and operation can be returned to the overhead route as well as the route below the bridge.

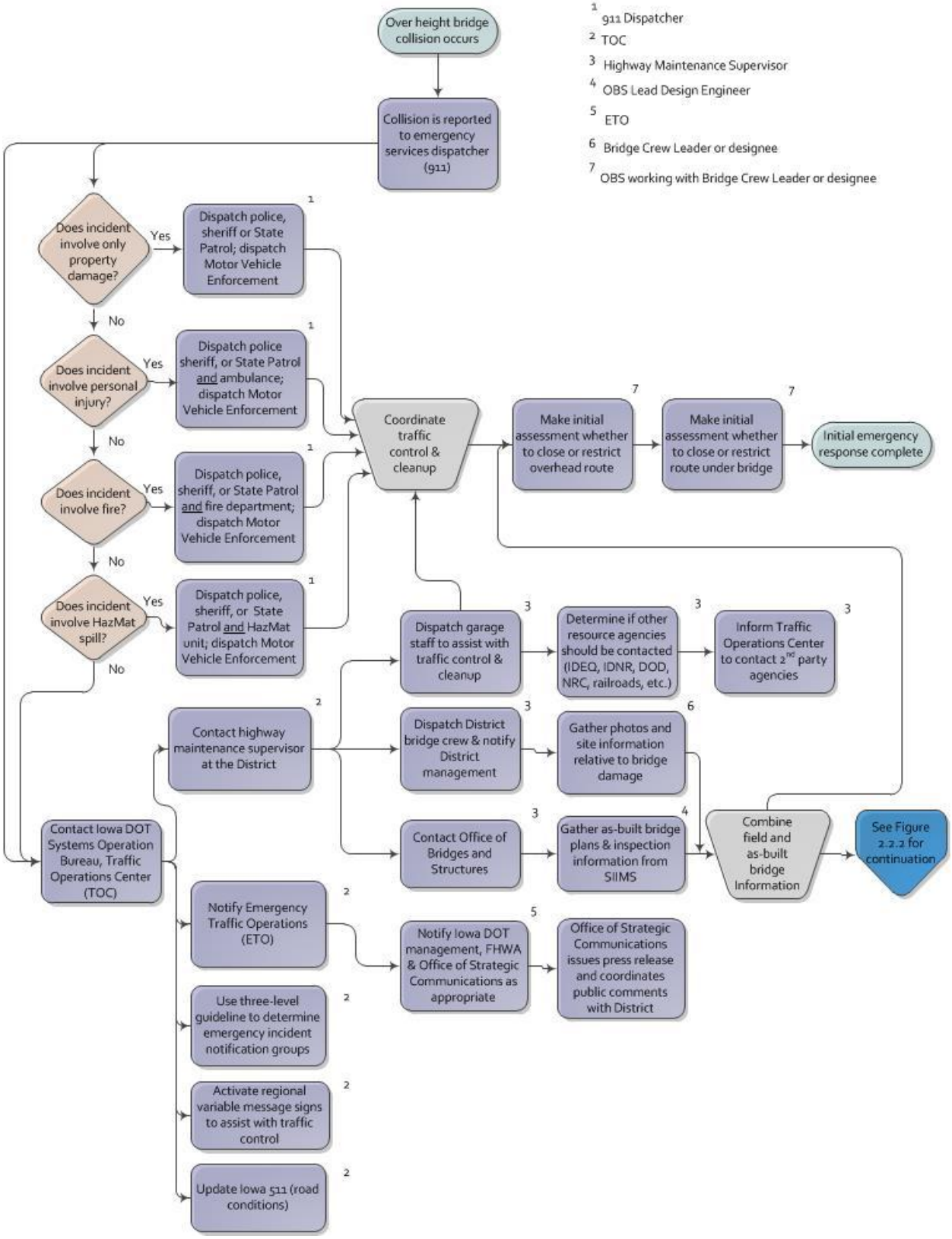


Figure 2.2-1. Initial Emergency Response Flow Chart

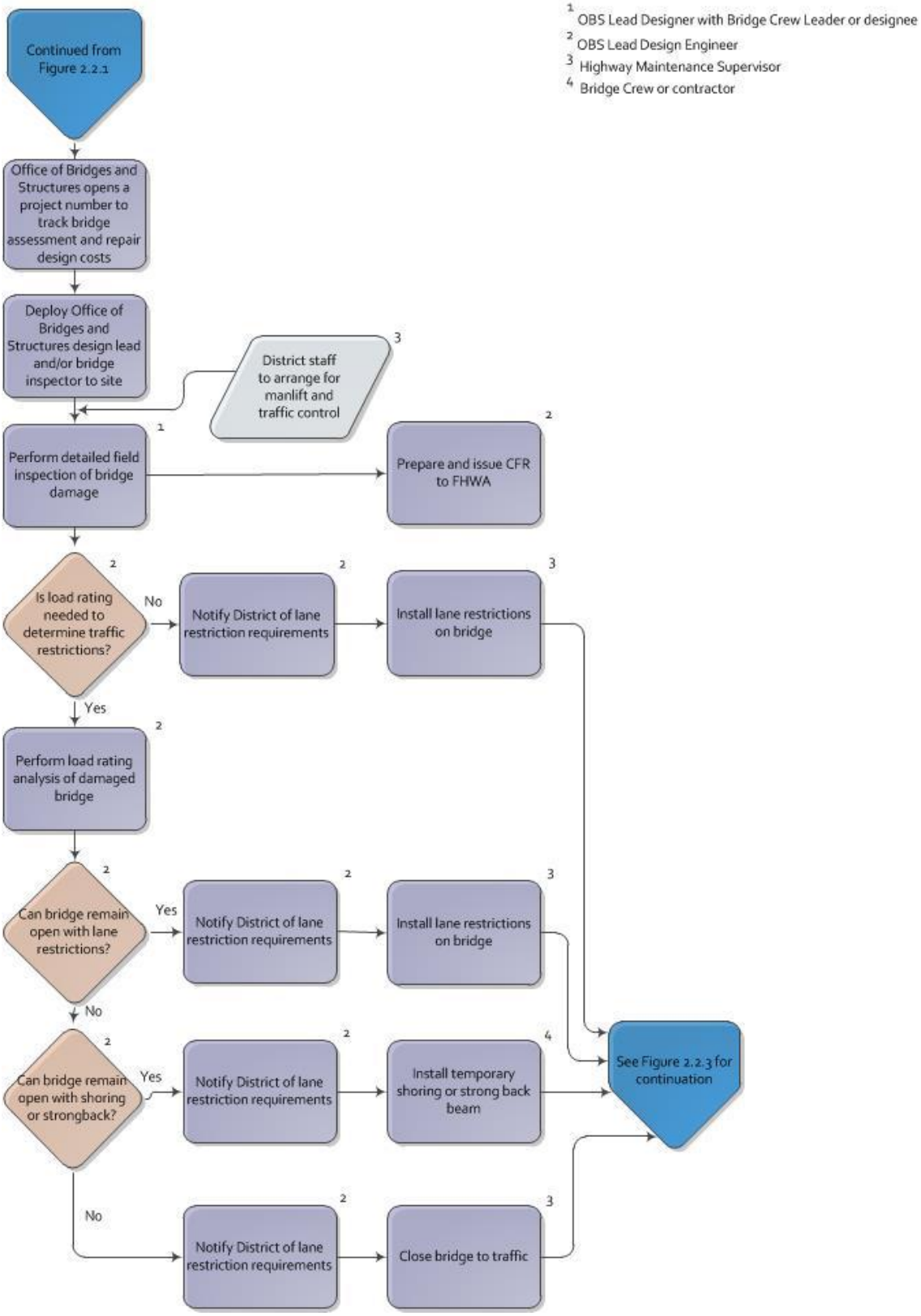


Figure 2.2-2. Detailed Bridge Assessment Flow Chart

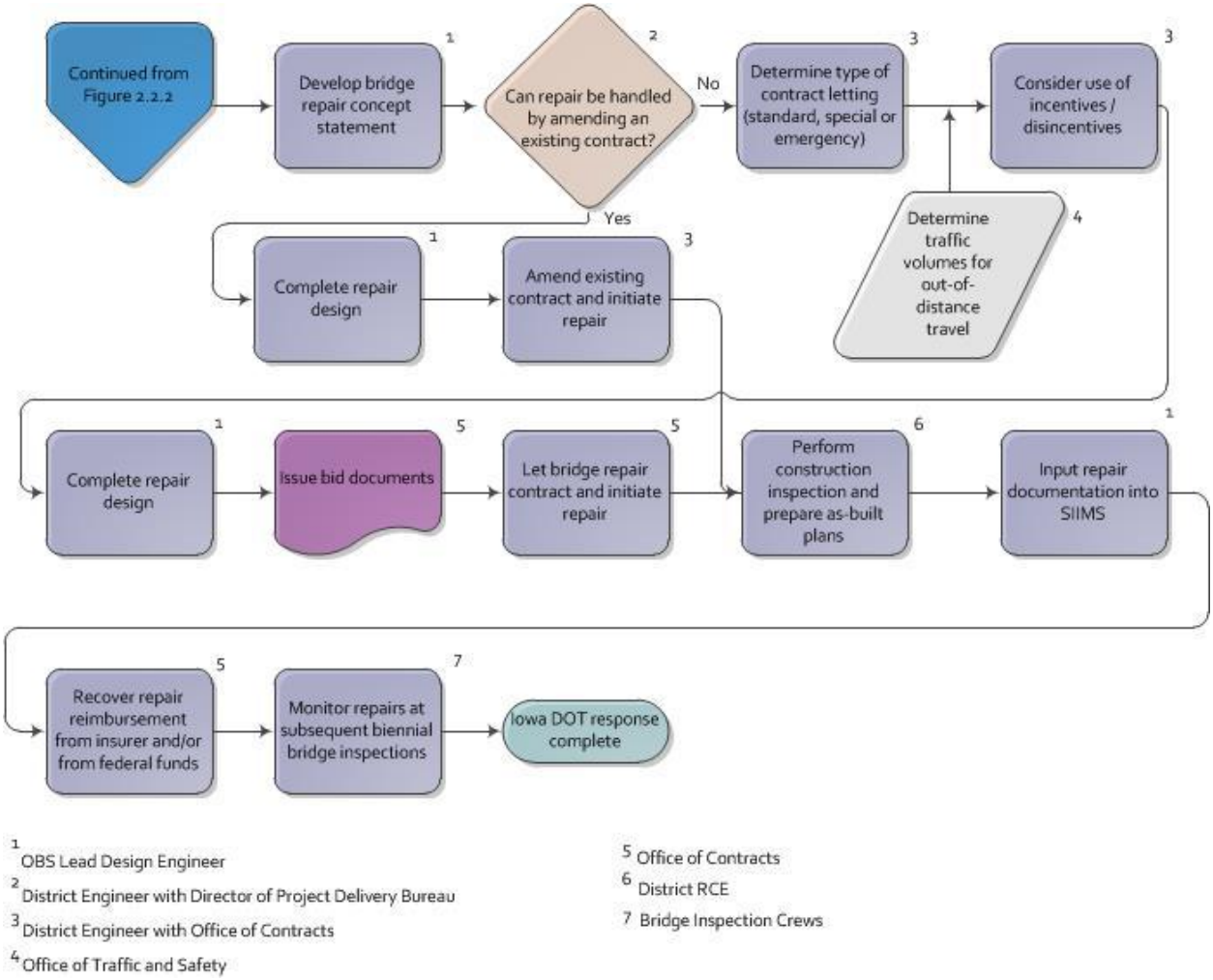


Figure 2.2-3. Repair Design and Contract Letting Flow Chart

2.3 STATE OF IOWA AND IOWA DOT EMERGENCY RESPONSE PLAN FOR MAJOR EVENTS

2.3.1 State of Iowa Emergency Response Plan

The Iowa Homeland Security and Emergency Management Division has developed an overall Iowa Emergency Response Plan (Plan) to provide instructions, policies, and explanatory information related to many or all of the agencies and entities involved in emergency/disaster response. This Plan also provides information about the legal and administrative foundations for the Plan, the State's characteristics and significant hazards, lines of succession for the State's chief executive, Plan activation requirements, and the structure of the response organization. This Plan provides a mechanism for delivering State resources and other assistance to local governments and State agencies during and after an emergency or disaster. This Plan is based on the premise that the preservation of life, health, safety, and property and the minimization of human suffering are the top priorities during an emergency/disaster response.

In addition to a basic emergency response plan, the overall Plan addresses 15 Emergency Support Functions (ESFs) essential to State operations. The first ESF listed in the Plan is Transportation, which addresses the availability and satisfactory condition of the transportation infrastructure and capabilities required to support the response to an emergency or disaster. Therefore, the Transportation ESF coordinates transportation infrastructure restoration and recovery activities. Although incidents of over height vehicle impacts may require temporary closure of State and U.S. routes, the duration of the closure generally would be expected to be limited. If, however, an incident requires a longer duration closure of a major interstate, such as I-80, the Iowa Emergency Response Plan would be activated to provide assistance in the recovery effort to reopen the route.

2.3.2 Iowa DOT Systems Operations Bureau, Traffic Operations Center

For the majority of over height vehicle impacts affecting State and U.S. highway routes and interstates, the Traffic Operations Center (TOC) of the Iowa DOT Systems Operations Bureau provides the primary coordination of response and recovery efforts. The TOC ensures the mobility and safe operation of the transportation system through coordination and collaboration with transportation stakeholders by:

- Management of the day-to-day traffic operations on the highway system through the statewide Traffic Operations Center
- Management of the emergency transportation operations response efforts on behalf of Iowa DOT
- Management and maintenance of the 511 Travel Information System
- Deployment and maintenance of intelligent transportation systems (ITS) on the highway system
- Development and maintenance of a coordinated, comprehensive statewide traffic incident management (TIM) response plan

Once the TOC is notified of an over height bridge impact by Emergency Services (911) or by Iowa DOT local District staff, the TOC notifies the area Highway Maintenance Supervisor and would have the Highway Maintenance Supervisor notify and determine the necessary support from District Management, the District Bridge Crew, on-scene responders, and District garage staff. The area Highway Maintenance Supervisor would also stay in contact with the TOC to ensure that the TOC maintains situational awareness.

Based on incident details, the TOC would notify the Emergency Transportation Operations (ETO) staff within the Office of Traffic Operations. ETO staff will determine the need for and notify as appropriate Iowa DOT management, the Federal Highway Administration, and the Iowa DOT Office of Strategic Communications.

A three-level guideline to incident notification (based on varying severities) is used to also notify Emergency Incident Notification groups. Email notifications are sent based on Level 1, 2, or 3 criteria, and notifications are updated as needed if conditions should change. A current listing of personnel and email addresses for the Emergency Incident Notification groups can be obtained by contacting the Office of Traffic Operations.

A Priority Level 1 emergency incident is the highest level incident and requires the greatest level of notifications. A Level 1 incident also requires a call to the Iowa DOT's Director of Statewide Emergency Operations. Level 1 notifications are triggered by one of the following events:

- Closure of all lanes in either direction of an interstate route or a four-lane primary road with an expected duration greater than 4 hours

- Full closure of both lanes for a two-lane primary road with an expected duration greater than 8 hours
- A hazardous materials (HazMat) incident that is a risk to public safety (evacuation)
- Damage to system infrastructure causing a disruption of service
- An incident requiring activation of the State Emergency Operations Center

A Priority Level 2 incident has a lower level of required notifications. Level 2 notifications are triggered by one of the following events:

- Closure of all lanes in either direction of an interstate route or a four-lane primary road with an expected duration less than or equal to 4 hours
- Full closure of both lanes for a two-lane primary road with an expected duration less than or equal to 8 hours
- A HazMat cargo shipping release
- A multi-casualty crash
- Fatalities
- Incidents crossing District jurisdictional lines

Priority Level 3 incidents have the lowest level of required notifications. If a Level 3 incident occurs in a metropolitan area during rush hour, lasts less than 30 minutes, and does not create a significant impact on traffic, then no Emergency Incident Notification is required. Otherwise, Level 3 notifications would be triggered by:

- Any road/lane closure reported in a District with either short term or local impacts
- Any HazMat release reported in a District
- Any accident on the primary highway system that is reported in a District

2.4 STATE PATROL, RESCUE PERSONNEL, HAZMAT PERSONNEL, AND LOCAL POLICE/SHERIFF COORDINATION

An emergency response for an over height vehicle impact would be initiated, in most cases, from a 911 call to emergency services from a motorist on the scene of the incident. For the immediate emergency response after an over height vehicle impact, local law enforcement, the Iowa State Patrol, or a local fire department would control the site and would coordinate rescue and recovery efforts. The most senior ranking emergency response official responding to an emergency would be designated as the incident commander. Initially, this would be the senior officer on the first piece of responding emergency apparatus to arrive on the incident scene. As more senior officers would arrive, the position would be passed up the line of authority. Emergency responder personnel would be responsible for tending to the injured, fighting any fires, conducting initial (HazMat) containment, and restricting traffic from the site to allow for the rescue efforts. Iowa DOT local District personnel should make themselves available in a support role under the direction of the incident commander to assist with traffic control, route closures, and cleanup as needed to facilitate rescue operations.

The area Highway Maintenance Supervisor or designee should first determine who is the on-site incident commander and should establish a working relationship with that individual. After determining with the incident commander the course of action to be taken, the area Highway Maintenance Supervisor or

designee should determine if the road is to be closed or detoured, if a HazMat spill is involved, if additional signing is needed, if field personnel are needed for cleanup operations, if other assistance is needed of District personnel by the incident commander, and what notifications are to be made.

Once the site is secured, immediate rescue operations are concluding, and efforts begin to transition to recovery and a return to restricted or normal traffic operations, it would be expected that control of the site would transition to Iowa DOT personnel, specifically the area Highway Maintenance Supervisor. Iowa DOT personnel should be aware of ongoing accident investigation operations by law enforcement personnel and should not impede these investigation procedures because a thorough accident report is important to assist in Iowa DOT recovery and repair operations. Toward this end, removal or clearing of debris and vehicle wreckage should not proceed prior to direction from local law enforcement. If a driver refuses to move his or her vehicle, District field personnel should not remove the vehicle until directed to do so by law enforcement personnel.

Once access to the damaged bridge is available, it will be important for District staff to examine and photograph the damage to the bridge. The Bridge Crew Leader or other district staff member, as designated by the District Engineer or Assistant District Engineer, will need to share this information with OBS so decisions can be made as to whether the bridge can be opened to traffic and whether it is safe to allow traffic to pass under the damaged bridge.

2.5 SECOND-PARTY BRIDGE OWNER OR AGENCY COORDINATION

In some situations, an over height vehicle impact could affect second-party bridge owners or users. For example, if the overhead structure that is impacted is owned by a railroad company, that railroad should be contacted immediately to coordinate recovery efforts, especially if there is damage to the bridge that could affect railroad traffic.

Similarly, if the vehicle that has impacted the bridge is owned or operated by an agency such as DOD or NRC, the affected agency should be contacted immediately. If a DOD shipment with escorts is involved, Iowa DOT local District personnel should withdraw from the area and provide the assistance requested by the escort person, who will serve as the incident commander.

Finally, if the bridge impact involves a HazMat spill, the Iowa Department of Environmental Quality should be contacted, and if the incident involves a spill in a regulated waterway, the Iowa Department of Natural Resources should be contacted.

Generally, it will not be known whether these second-party agencies are affected by the incident until District personnel arrive on the scene. At that point, after assessing the site, the TOC can be notified as to whether it will need to contact any second-party agencies.

2.6 REPORTING HAZARDOUS MATERIALS SPILLS

Reporting of HazMat spills is governed through Federal regulations, specifically the Hazardous Materials Regulations (HMR) at 49 Code of Federal Regulations Parts 171-180. The HMR requires certain types of HazMat incidents to be reported to the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration. HMR Section 171.15 requires an immediate report (that is, within 12 hours) to the National Response Center by phone or through an online form.

HMR Section 171.16 requires a written report for certain types of HazMat incidents within 30 days of the incident and a follow-up written report within 1 year of the incident based on certain circumstances. Additionally, Incident Report Form 5800.1 is a guidance document for preparing incident reports and includes tabular summaries of HazMat incidents by mode, year, state, hazard class, etc.

The Statewide Operations Center should be made aware of any hazardous spill so that they can notify the proper authorities, such as the Iowa Department of Natural Resources or the United States Environmental Protection Agency. Any follow-up incident reports to comply with Federal regulations would then be generated by the Iowa DOT Office of Location and Environment.

2.7 PUBLIC AND MEDIA COORDINATION

The task of informing the public and media regarding an over height vehicle impact to a bridge requires a coordinated effort between the TOC, the Office of Strategic Communications, and the local District. Iowa DOT employs a number of methods to communicate with the public and media, including use of the 511 system for reporting road conditions, press releases, social media, and direct comments to the press by local Iowa DOT staff.

2.7.1 Iowa 511

Upon receiving a notice of an over height vehicle impact to a bridge, the TOC will issue a CARS alert, which will update the Iowa 511 Road Conditions report. In addition, the CARS alert will automatically generate a Tweet and update Facebook with detour information or lane restriction information. Depending on the severity of the incident and various threshold criteria, the TOC may also notify the Office of Strategic Communications.

2.7.2 Iowa DOT Office of Strategic Communications

2.7.2.1 Press Releases

Depending on the severity of the incident and the impact on traffic, the Office of Strategic Communications may be notified about the incident by the TOC, ETO or District so that a press release can be generated. The factors that may be addressed might include whether any injury or loss of life occurred as a result of the incident, whether a HazMat spill occurred as a result of the incident, and the expected duration of the traffic restrictions, detours, or closures.

2.7.2.2 Iowa DOT Website

If a press release is issued, it will be automatically posted on the Iowa DOT website.

2.7.2.3 Social Networking

With the issuance of a press release, a Tweet is automatically generated and Facebook would be automatically updated if appropriate.

2.7.2.4 Notification of the Governor's Office

In the event that a section of an interstate must be closed due to an over height vehicle collision with a bridge, the Governor's office may be informed. This notification is typically made through the Office of the Director for Iowa DOT.

2.7.3 Communication Coordination with District Staff

An important part of communicating with the public is having the most up-to-date information regarding the status of the incident and cleanup. Because District staff will have the most direct knowledge of the incident, they are responsible for providing updates to the TOC and the Office of Strategic Communications so that all Iowa DOT personnel are working from the same baseline information.

For major incidents in which the Office of Strategic Communications is involved, personnel from that office will work with the local District Engineer to identify who at the District level is authorized to communicate directly with the press. This function may be handled directly by the District Engineer or may be designated to the District Field Service Coordinator or possibly an area Highway Maintenance Supervisor who may be on site. The Office of Strategic Communications will coordinate with the local District spokesperson to provide specific talking points and to provide direction on what should be communicated to the media.

2.8 MAINTENANCE OF TRAFFIC OPERATIONS AND PROCEDURES

Handling traffic flow as a result of an over height vehicle impact consists of handling the immediate traffic congestion during accident cleanup and long-term maintenance of traffic until the bridge is returned to service.

2.8.1 Initial Clean-up and Restoration of Traffic

2.8.1.1 Considerations for District Staff at Accident Scene

Typically, emergency responders will be the first ones on the scene of an over height vehicle collision. Their first priority is to preserve life, minimize injury, and preserve public safety. More than likely, traffic will be initially halted from passing under the damaged bridge because of debris on the roadway. An immediate decision must also be made whether to halt traffic on the overhead bridge.

Upon being dispatched to the accident scene, District garage staff should immediately coordinate with the on-scene incident commander and assist law enforcement personnel with traffic control operations. For four-lane divided highways and interstate routes passing under the damaged bridge, this may include directing traffic off the route at the first exit before the accident site or using alternative routes and side roads. District garage staff should also assist in diverting traffic from the route that would normally be using the damaged bridge.

Portable changeable message signs (CMS), flagmen, Type II barricades, traffic barrels, and small emergency detour signs may be used by District staff to manage traffic. Field personnel shall use appropriate approved safety apparel, including nighttime apparel if applicable.

In the event of a HazMat spill to which local HazMat response teams have responded, Iowa DOT local District personnel should make the local responders aware of materials and equipment available from Iowa DOT. Iowa DOT personnel should not be involved with any spill response activities and in the rare event that they are, any Iowa DOT personnel involved with HazMat spill response must be fully trained to the Hazardous Waste Operations and Emergency Response (HAZWOPER) operations level as defined by the Occupational Safety and Health Administration (OSHA).

Once the accident investigation is complete, District garage staff should assist in accident and debris cleanup and, if the extent of bridge damage allows it, restore traffic operations.

2.8.1.2 Guidelines for Restoring Traffic

The purpose of this section is to provide general guidelines for evaluating bridge damage so that decisions can be made with respect to traffic restrictions. Short-term and long-term decisions include keeping a route open to traffic, open with traffic restriction, or completely closed to traffic. The primary interest of this section pertains to short-term decisions that generally are made immediately or within a few days of the incident. Ultimately, safety of the travelling public is the primary concern in determining whether to restrict traffic both on and under the bridge. These guidelines can only be general in nature and are not a substitute for the sound engineering judgment required for particular collision incidents.

Considerations for restricting traffic on the bridge:

- Extent of damage to supporting girder(s)
- Location of damaged girder(s) with respect to traffic lanes
- Structural redundancy (for example, the number of girders)
- Ability to strengthen/stabilize structure
- Ability to safely shift traffic lanes considering lane widths, average daily traffic, speed limit, and traffic direction
- Availability of detour routes
- Importance of traffic route

Considerations for closing traffic lanes under the bridge:

- Vehicles or payloads blocking lanes or impeding traffic flow
- Debris on the road from vehicles/payloads
- Debris on the road from the bridge
- Damage to the road surface under the bridge
- Potential for additional debris to fall from the structure onto traffic
- Instability of bridge or compromised structural integrity of the bridge
- Potential of future over height collisions to cause collapse of damaged structure
- Structure having the appearance of being unsafe so as to distract the travelling public
- Displaced bridge members that intrude on vertical and/or horizontal clearance requirements

In general, a route (either on the overhead bridge or under it) may remain open without traffic restriction if the damage is minor to one or more beams.

For routes carried on the overhead bridge, if there is moderate damage to a single exterior beam, closure of the bridge would not be required. Traffic will need to be moved away from the damaged beam such that undamaged beams encompass all traffic lanes, and then the route may remain open. In such cases it will be necessary to install appropriate traffic control devices (for example, cones, barrels, or temporary barrier rails (TBRs) depending on the characteristics of the road and traffic) over the next undamaged beam to restrict traffic from travelling over the moderately damaged beam near the edge of the bridge. In situations where traffic may be maintained, moderate damage is often confined to the exterior beam on bridges with larger shoulder widths. In cases where more than one beam is moderately damaged, a bridge rating analysis may need to be performed to ensure that the structure can carry the loads. The above guidelines generally apply to bridges with straight prestressed concrete beams or straight steel beams. Bridges with curved steel girders rely on a system interaction between the curved girders and the intermediate diaphragms so, what may appear to be moderate damage to a curved steel girder bridge, may require more restrictions than a typical straight beam bridge.

For routes passing under the damaged bridge, if the damage to the bridge is moderate such that it is deemed safe to maintain restricted traffic on the overhead route, then it should be safe to reopen traffic under the bridge. This assumes the damaged vehicle, payload, and debris can be adequately removed from the roadway and the road surface is not adversely damaged. If there is the potential for additional debris to fall from the bridge, either temporary traffic restrictions (for example, cones, barrels, or TBR) should

be employed to restrict lanes under the bridge or a canvas diaper or debris net should be installed under the damaged area to catch any additional falling concrete debris.

Severe damage to one or more beams will typically necessitate closing the overhead bridge and the route under the bridge. In some instances it may be possible to keep an overhead bridge open, or reopen an overhead bridge and re-establish traffic under the bridge by stabilizing and/or strengthening the bridge, possibly in combination with traffic shifting or traffic restrictions.

For further discussion of the levels of damage that would constitute minor, moderate, and severe levels of collision damage, see Section 2.9.2.

2.8.2 Use of Statewide Intelligent Transportation Systems and Variable Message Signs

Emergency Services (that is, a 911 Operator) should be responsible for contacting the TOC. For urban interstate routes, variable message signs (VMS) may be available in the vicinity of the accident scene that TOC could activate, thereby assisting in informing motorists of the accident and rerouting traffic. Likewise, the Iowa 511 Road Conditions report would be updated by the TOC, with automatic Tweets and Facebook updates to inform the public of road closures and restrictions.

2.8.3 Incident Management Routes

The District Maintenance Manager or designee is responsible for planning for freeway incident management. As such, a detour route should be developed for each segment of freeway/interstate, and updated annually or as needed. Plans are to be coordinated with cities, counties, county emergency coordinators, fire departments, local hazardous response teams, sheriff departments, police departments, the Iowa State Patrol, the Department of Public Defense (Emergency Management Division), railroads, regional offices of the Iowa Department of Natural Resources, and other state Departments of Transportation. As a result, designated Incident Management Routes should be preplanned for each segment of freeway/interstate. In addition, for non-interstate primary roads, Iowa DOT will work with local jurisdictions to compile information to use in establishing emergency detours prior to or at the time of an incident.

2.8.4 Use of Temporary Detour Bridge

Iowa DOT has one modular temporary detour bridge in storage at the Williams maintenance garage that could potentially be used to return a damaged bridge to service. However, the temporary detour bridge is configured for only small stream crossings and would not be suitable for a multispan overpass, particularly a damaged continuous-span steel girder bridge. If a bridge carrying a critical route must be removed from service due to an over height vehicle collision, it may be possible to use a rented bridge for a temporary detour. Providers of temporary bridges for rental include Acrow Corporation and Bailey Bridges.

2.9 ASSESSING DAMAGE AND DETERMINING FOLLOW-UP PROCEDURES

Assessment of a damaged bridge typically would be a two-phase process. At the time of the initial emergency response, an initial assessment must be made as to whether traffic can be allowed on the damaged bridge and whether traffic can pass below the damaged bridge without the potential for debris falling. Once the initial decision is made and traffic operations are either detoured, resumed, or resumed with restrictions, a detailed inspection and assessment of the damage can be made and a load rating performed. This detailed assessment would be used to confirm the initial disposition of the bridge and then to initiate repair design and a contract for repairs.

If the damage is severe or possibly severe, the District should immediately report the damage by telephone to the Bridge Maintenance and Inspection Engineer or the State Bridge Engineer in OBS to make an initial decision whether to allow traffic on the damaged bridge and whether to allow traffic below the bridge. OBS would then assign a lead design engineer for the repairs and begin to assemble information for the existing structure based on as-built plans and past inspection records stored in the Structure Inventory and Inspection Management System (SIIMS). This would include:

- Reviewing the bridge maintenance folder to determine if there is a history of over height collisions to the bridge, whether there have been repairs to collision damage, or whether there is current damage that has not been repaired.
- Determining the current vertical clearance at the bridge site.
- Making copies of the bridge plans to take to the bridge site.

Concurrently, once the accident site is cleared to the point where District staff can begin to assess the damage, typically the District Bridge Crew would photograph the damage, email the photographs to OBS, and provide an initial assessment of the damage. Ideally, based on the photographs of the damage and consultation between OBS and either the District Bridge Crew Leader or other designated District engineering staff, a decision can be made whether to reopen the bridge, maintain traffic on the bridge with restrictions, close the bridge, and/or close the route below the bridge, as well as whether supplementary support (such as a falsework towers or a strong back beam) would be needed for the damaged bridge. Another corrective action, especially for a damaged prestressed concrete beam bridge, might be to install a temporary protective diaper or netting to prevent debris from falling on the road below. If a decision is made to close a bridge or restrict lanes on a bridge, a Critical Findings Report (CFR) must be completed by OBS for the bridge documenting the action taken and the reasons for the action.

Once the initial disposition of the bridge is determined, a detailed assessment and analysis of the bridge would follow. Typically, the lead design engineer and/or bridge inspection staff would travel to the site to gather detailed information of the bridge condition. This data gathering phase would consist of additional photographs, detailed measurements, field sketches, and possible non-destructive testing of damaged areas, such as magnetic particle testing of damaged steel members, to determine if there are any cracked or torn steel members. For prestressed concrete beam bridges, the inspectors would also look for broken mild reinforcing and/or prestressing strands, and micro-cracking of the concrete. For both steel and concrete bridges, secondary members would also be examined, and the condition of the bond interface between the girders and the bottom of the bridge deck would be examined for separation.

Following collection of the field data, a load rating of the bridge would be performed if necessary to confirm the load carrying capacity of the damaged bridge and to confirm the initial disposition of the bridge. The field-collected data would also be used to help determine whether to repair or replace the bridge. If it is determined that the bridge must be closed or traffic restricted on the bridge due to the impact damage, the Bridge Maintenance and Inspection Unit shall complete a CFR to document with FHWA the restrictions and the action plan for reopening the bridge. A copy of the CFR can be found in Appendix B.

2.9.1 Field Inspection of Collision Damage

Equipment to be gathered for use in the field should include a digital camera, hard hats, safety vests, flashing emergency light for vehicle, clipboard, flashlight, tape measure, level, ruler, chipping hammer, visual crack gauge, and stringline. In addition, if the damaged bridge is a steel beam or steel girder bridge, it may be helpful to take along non-destructive test equipment so that a qualified bridge inspector can determine the limits of any cracked steel members using either die penetrant or magnetic particle testing. The repair designer should coordinate with the District office in advance of the field inspection to arrange for lift equipment to provide access to the damaged area.

A key element of assessing the condition of the bridge and extent of damage includes thoroughly documenting the damage with digital photography. The following guidelines should be used for providing effective damage photographs.

- Verify the camera is set to the current date and time.
- For most cameras, to focus the camera on the subject, the shutter must be partially depressed to lock the camera onto the subject and then fully depressed to take the picture.
- Extremely high resolution photographs are not necessarily needed for most bridge inspection tasks. A 3 megapixel resolution for a 4 inch by 6 inch photograph is usually adequate and will allow multiple photographs to upload quickly to a web-based program such as SIIMS.
- Close up photographs should be accompanied with a second wider view photograph to orient the person viewing the photograph and provide perspective.
- For wider view photographs, consider whether a straight-on view or an oblique view provides a better depiction of the subject.
- The macro function on digital cameras is an excellent tool for documenting fatigue cracks since this function allows for a close focus mode. Although the macro function will allow the camera lens to be positioned within a few inches of the crack, it does limit the depth of field. Therefore, the actual crack might be in focus but member components at different distances from the lens may be out of focus. The macro setting is usually depicted as a flower on the settings dial of a digital camera.
- Key all photographs to a plan view location sketch. Photograph logs should be kept for all photographs and the descriptions for each photograph should document location, component, and defect (in that order).
- Study the lighting from different angles when composing a photograph. At times ambient light can benefit the photograph. Avoid shooting directly into sunlight since the camera will base its exposure on the brighter light, resulting in dark areas where you are attempting to capture damage details. Do not always rely on the auto flash mode; in cases as described above when shooting into the sun, the flash may not trigger.
- The flash may reduce or magnify effects of shadows. When in doubt, take the photograph with the flash off and the same photograph with the flash on.
- Review photographs before leaving the site to make sure all details desired have been captured. Download photograph files daily.

It is important to take adequate notes and make some sketches when documenting collision damage. Appendix C includes a template for Damage Inspection Notes to be used in the field to document collision damage.

2.9.1.1 Field Inspection of Damaged Steel Beam or Girder Bridges

The following are guidelines for the field inspection of damaged rolled steel beam or welded plate girder bridges:

- Note torn members and missing pieces of the superstructure.
- Using a level or stringline, measure the horizontal and vertical displacement of each damaged beam or girder at the impact location and at any kinks or angular displacements at other locations.
- Measure locations of damaged members.

- If no cracks are visible, but may be suspected, perform nondestructive testing (NDT) of the damaged area to check for non-visible cracks.
- Inspect each damaged beam or girder at restrained locations, such as diaphragms. Check for cracks or broken welds where the diaphragm connection stiffener is connected to the beam/girder and check diaphragm connections at adjacent girders where the impact force may have been absorbed.
- Check for damage to the slab at beam-to-slab interface.
- Check for buckling of diaphragms or other diaphragm damage.
- Check for weld or bolt damage at diaphragm connections.
- Note any existing collision damage from past collisions.
- Measure vertical clearance at point of impact.
- Sketch plan and elevation views of each damaged beam or girder.
- Take extensive photographs. Include dimension references such as magnetic rulers or an extended tape measure.
- If available, obtain a copy of the collision report from the Iowa State Patrol, local police, or sheriff.
- Review traffic restrictions to make sure they are adequate and whether it is necessary to continue traffic restrictions.

2.9.1.2 Field Inspection of Damaged Prestressed Concrete Beam Bridges

The following are guidelines for the field inspection of damaged prestressed concrete beam bridges:

- Check for cracks or severe section loss in the lower flange or in the web of each damaged beam; estimate the section loss.
- Check for severed prestressing strands that are visibly deformed. Record the number and location of severed strands.
- Check for an open horizontal crack at the junction of the web and top flange in each damaged beam.
- Determine any displacement between cracked sections.
- Determine if cracks extend completely through each cracked member by correlating cracks on one side of the member with cracks on the opposite side.
- Inspect diaphragms.
- Inspect slab-to-beam interface.
- Inspect beams adjacent to obviously damaged members to make sure all damage has been found.
- Note any existing collision damage from past collisions.
- Measure vertical clearance at point of impact.
- Sketch plan and elevation views of each damaged beam or girder.
- Take extensive photographs and include dimension references such as an extended tape measure. Key photographs to a reference sketch.
- If available, obtain a copy of the collision report from the Iowa State Patrol, local police, or sheriff.

- Review traffic restrictions to make sure they are adequate and whether it is necessary to continue traffic restrictions.
- Recommend whether a diaper or net should be installed to protect motorists from loose concrete.

2.9.2 Beam and Girder Damage Levels

The goal here is to establish general guidance on levels of damage. In situations involving minor damage, it may still be desirable to repair the damage at some point even if the structural capacity is not affected in the short-term. In cases of moderate beam damage, it may be possible to leave the bridge open with some level of traffic restrictions until repair or replacement is performed. In cases of severe damage, it is generally advisable to close the bridge at least until additional strengthening or stability measures are taken.

Steel girder damage levels:

- Minor damage – no repair or minimal repair required
  - Paint scrapes
  - Small nicks or gouges in bottom flange or minor bottom flange bends
  - Alignment of girder web less than 1inch out of plumb
- Moderate damage – repair required or partial beam section replacement required
  - Moderate flange bends
  - Alignment of girder web greater than 1 inch out of plumb
  - Bottom flange gouging
  - Tearing of web that is confined to the lower 25 percent of the web depth
- Severe damage – partial or full depth beam section replacement
  - Significant flange and web bends/misalignment
  - Bottom flange nicks and gouges too extensive to be ground out
  - Tearing of bottom flange (although minor flange tearing could possibly be repaired using a bolted flange splice)
  - Alignment of girder web considerably out of plumb with cracking or tearing of the web at diaphragm locations, particularly above the lower 25% of the web depth

Prestressed girder damage levels:

- Minor damage – no repair or minimal repair required
  - Minor concrete spalling of bottom flange
  - Mild reinforcing steel or prestressing strand may be partially exposed due to loss of cover concrete only; mild reinforcing steel or prestressing strand are not damaged and remain embedded in concrete
  - Concrete cracks are difficult to see from the ground and do not reflect from one side of the beam to the other
- Moderate damage – repair required
  - Moderate concrete spalling is typically limited to the bottom flange and includes exposed stirrups and strands
  - Through cracking of bottom flange and/or lower half of web

  - Horizontal crack at the junction of the web and the top flange of a prestressed concrete beam narrower than 1/16 inch
  - Up to 2 of the bottom flange strands are severed or partially severed
- Severe damage – beam replacement
  - Severe concrete spalling including exposed stirrups and strands
  - Through cracking of bottom flange extending into the upper half of the web
  - Horizontal crack at the junction of the web and the top flange of a prestressed concrete beam wider than 1/16 inch
  - Excessive loss of concrete section
  - More than 2 of the bottom flange strands are severed or partially severed

2.9.3 Repair/Replacement Options Tied to Levels and Types of Damage

The following subsections include photographs depicting various levels of impact damage that could be expected for both steel beam/girder bridges and for prestressed concrete beam bridges. Repair options are presented for each level of damage.

2.9.3.1 Steel Beam and Girder Repair Options

Figure 2.9.3.1-1 shows minor damage to a steel beam bridge consisting of paint scrapes and gouging of the bottom flange. Typically this type of damage should be repaired in a timely manner by removing the gouges by grinding as outlined in Section 3.5 of this manual. In most cases, the bridge may remain open without traffic restrictions if the gouging is not excessive.

Figure 2.9.3.1-1. Steel Gouge and Paint Scrape

Figure 2.9.3.1-2 shows a moderately bent bottom flange with some web distortion. If this type of damage did not include any fractures or tears to the steel members and if the extent of the distortion was not too severe, often this type of damage would be repaired with heat straightening, which would combine controlled heat with some internal or external restraining forces to return the member to its original geometry. In general, heat straightening should only be used on the same damaged area of a beam for two heat straightening operations because of the tendency to reduce the ductility of the base metal with more than two heat straightening operations. Often heat straightening repair will require supplemental support of the steel beam during repair. In these cases, a strong back beam may be placed on the deck of the bridge to help support the damaged beam or temporary shoring towers may be employed during heat straightening operations.

Figure 2.9.3.1-2. Moderately Bent Bottom Flange with Some Web Distortion

Figure 2.9.3.1-3. Damaged Diaphragm Member

Figure 2.9.3.1-3 shows a damaged and distorted diaphragm member. Although primary girder damage may need to be heat straightened or repaired by some other means, typically it is easiest to just replace damaged diaphragm members with the girder repairs rather than trying to repair or straighten them.

Figure 2.9.3.1-4 shows severe damage to an exterior beam line that has resulted in tearing and fracture of the steel beam. For this type of damage, often a strong back beam or temporary shoring towers would be used to support the damaged beam during repairs. Since the damage involves fracture to the beam, some level of beam replacement would be needed. One option would be to cut out and remove the bottom flange and the distorted and torn lower portion of the girder web between field splices and replace it in kind with a spliced section of web and a new bottom flange. Alternatively, if the damage also includes extensive cracking and spalling of the bridge deck, it may be necessary to remove portions of the deck above the damaged beam, remove and replace the entire steel beam between field splices, and replace the section of bridge deck that was removed.

Figure 2.9.3.1-4. Out of Plane Bending with Web Tear

Figure 2.9.3.1-5 shows spalling to the underside of the bridge deck in the cantilevered section of the deck and cracking along the interface between the top flange of the steel beam and the bottom of the bridge deck. If no surface spalling to the top surface of the bridge deck is involved, a possible repair would be to epoxy inject the crack at the top flange/bottom of bridge deck interface and then repair the spall damage to the underside of the bridge deck. If extensive damage in the form of either cracking or spalling has occurred at the top surface of the deck, removal and replacement of a portion of the bridge deck may be needed.

Figure 2.9.3.1-5. Bottom of Deck Spalling with Crack at Girder-to-Deck Interface

2.9.3.2 Prestressed Concrete Beam Repair Options

Figure 2.9.3.2-1. Installation of Drape to Catch Loose Debris

Over height vehicle damage to prestressed concrete beam bridges inevitably results in some degree of concrete spalling with loose concrete that could provide a hazard to traffic below. Figure 2.9.3.2-1 shows a typical drape that would be used to catch loose debris.

Figure 2.9.3.2-2 depicts typical minor spalling that may occur along the bottom flange of a prestressed concrete beam. In a case such as this, no mild reinforcing steel or prestressing strands have been exposed or damaged. Iowa DOT does not typically patch this type of damage to restore the original cross section of the beam due to the potential for the patch to come loose and drop on traffic. However, it is recommended to seal these types of spalls with a grey paint-type sealer in order to better identify any future hits to the same area.

Figure 2.9.3.2-2. Minor Bottom Flange Spalling

As impact damage to a prestressed concrete beam bridge becomes more substantial, it can be expected that larger spalls may occur, often exposing mild reinforcing steel or prestressing strands as shown in Figure 2.9.3.2-3. Iowa DOT employs a few repair strategies for these types of damage to restore the damaged beam to its original properties.

One such repair would involve first patching the spalls to return the beam to its original cross section. Often, following spall repair, a FRP wrap would be placed around the bottom flange of the beam in the damaged area and up the sides of the beam web. The FRP wrap can provide added shear strength to the beam, but generally it also serves to confine and contain the spall repairs to prevent them from separating from the beam and falling onto traffic below.

A second repair strategy, and one that is often employed for exterior beams that may be subjected to repeated impacts by over height vehicles, is to repair the spalled areas, but then encase the bottom of the beam with a two-piece steel sleeve. The steel sleeve is anchored with concrete anchors into the beam and then the space between the concrete beam and the inside of the steel sleeve would be injected with epoxy to bind the sleeve to the concrete beam. The steel sleeve serves to armor the bottom of the beam and thus provide a greater degree of protection from future vehicle strikes.

Figure 2.9.3.2-3. Bottom Flange Damage with Mild Reinforcing and Prestressing Strands Intact

Over height vehicle impacts to prestressed concrete beam bridges may be severe enough to initiate displacement of a concrete beam. Often when the beam tries to displace, a crack may form at the interface of the beam web with the top flange of the beam as show in Figure 2.9.3.2-4. With this type of damage, the inspector should look at the top of bridge deck to determine if any cracking or spalling has occurred in the actual bridge deck. If not, and if the cracking is limited to the interface between the beam web and the top flange, or possibly the interface of the top of the beam and the bottom of the bridge deck, the crack can be epoxy injected to seal the crack from moisture intrusion. Other web cracking in the beam may be evident, such as diagonal cracking in the web that radiates downward from the terminus of the web-to-top-flange crack. These web cracks should also be epoxy injected to seal the cracks from moisture intrusion.

Figure 2.9.3.2-4. Cracking Along Web-to-Top Flange Interface

Generally, the most severe damage to prestressed concrete beam bridges involves extensive spalls and girder cracking that severs mild reinforcing steel and prestressing strands as shown in Figure 2.9.3.2-5. If beam damage involves severing of two or more prestressing strands, a possible temporary repair alternative may involve patching of the beam spalls, epoxy grouting beam cracks, and either splicing the severed prestressing strands or supplementing the damaged strands with external prestressing. However, these types of repairs should only be considered temporary until the beam or the entire bridge can be replaced.

Figure 2.9.3.2-5. Heavy Damage with Web Cracking and Severed Mild Reinforcing and Prestressing Strands

Severe damage to prestressed concrete beam bridges might also involve excessive loss of concrete section as shown in Figure 2.9.3.2.6 or severe damage to multiple beams as shown in Figure 2.9.3.2.7. In most of these cases, the extents of the prestressed beam and bridge deck damage is so severe that removal of the bridge deck above the damaged beam and replacement of the beam is warranted or total span replacement is needed.

Figure 2.9.3.2-6. Severe Prestressed Beam Damage with Excessive Concrete Section Loss

Figure 2.9.3.2-7. Multiple Prestressed Beams with Severe Damage

2.10 ASSESSING BRIDGE REPAIR VS. BRIDGE REPLACEMENT

Several factors would be considered to determine whether to repair or replace the damaged bridge. The most important factor would be the severity of the damage. Other factors would include the age of the structure, bridge repair history, an evaluation of the available clearance envelope, past inspection issues, and whether the bridge is scheduled or programmed for replacement.

2.11 CONTRACT LETTING OPTIONS

The importance of the State or U.S. highway routes affected will often affect the type of contracting mechanism used for repair or replacement of the damaged bridge. In addition, the extent of the design work required may impact the type of contracting used if repair plans cannot be prepared in time for a regular contract letting.

2.11.1 Regular Letting Process

A regular contract letting is a scheduled upcoming letting. Typically, regular lettings are scheduled for the third Tuesday of the month and include a 1-month advertising period. Plan turn in lead times may or may not be reduced. This process is best suited for when the 1-month advertising period is acceptable, and the contract documents will be completed in time to advertise the emergency work simultaneously with the rest of the projects in the letting.

2.11.2 Special Lettings

A special letting is a contract letting on a day of the month other than the regularly scheduled lettings. A special letting would use the same advertisement period as would be used for a regular letting. The plan turn in lead time may or may not be reduced. This process is best suited for when the 1-month advertising period is acceptable or desirable; however, the development of the contract documents will not be completed in time to advertise the emergency work simultaneously with the next regular letting, and it is not acceptable to wait until a later regular letting.

2.11.3 Emergency Lettings

The District Engineer, in consultation with the Contracts Engineer, will make the determination / decision whether emergency letting procedures will be used.

An emergency letting is a non-scheduled letting performed with little or no advertising for bids. Iowa Code Section 313.10 provides that:

- The emergency was caused by an unforeseen event causing failure of the highway, bridge, or other highway structure so that the highway is unserviceable, or where immediate action is needed to prevent further damage or loss.
- The department solicits written bids from three or more contractors engaged in the type of work needed.
- The necessary work can be done for less than $1 million.

If possible, Iowa DOT shall notify the appropriate Iowa highway contractor's associations of the proposed work.

Iowa Code Section 313.11 also allows Iowa DOT to contract for specialized construction work for beam straightening, beam replacement, and beam repair on bridges without advertising for bids as required under Iowa Code Section 313.10 if all of the following conditions are met:

- The work is of a specialized nature in which fewer than five contractors engage.
- Iowa DOT solicits written bids from all available contactors engaged in the specialized work.
- The work can be done for less than $40,000.

In any situation, Iowa DOT will make every effort to:

- Solicit bids from all qualified contractors who have shown interest in similar work in the same general location in the past.
- Offer all qualified bidders the opportunity to submit bids.
- Notify the Associated General Contractors of Iowa.

The bid deadline is established as early as possible to accommodate development of the contract documents and contractors bid preparation. It may be at the same time as a previously scheduled letting, if convenient, as long as it meets the desired time frame.

This process is best suited for when the advertising period must be less than 1 month.

2.11.4 Use of Incentives and Disincentives

Due to the time-sensitive nature of completing repairs and restoring traffic operations, Iowa DOT may elect to incorporate the use of incentive and disincentive provisions in a repair contract to encourage the contractor to expedite repair. Typically, this type of contract provision would provide financial incentives or bonuses for completing the work or a phase of the work ahead of a set milestone date. Conversely, the contractor would be assessed a financial disincentive for the damages incurred if the actual duration of the work exceeds a set milestone date.

In order to determine the appropriate bonus for early completion of work or the liquidated damage for work not completed on time, an analysis of user costs is performed to determine the financial impact on the travelling public for undue delays.

2.11.4.1 Traffic Volumes

Because user cost is the primary inconvenience caused by a closed route, the Iowa DOT Office of Traffic and Safety may be asked to provide traffic volumes for the affected routes.

2.11.4.2 Out-of-Distance Travel

The out-of-distance travel caused by a closed route would be established to determine the additional miles required due to detours and subsequently the added costs for drivers.

2.12 FUNDING REPAIRS AND REIMBURSEMENT TO IOWA DOT FOR REPAIRS

No funds are typically programmed for emergency repairs and contingency funding must be approved to accomplish repairs. Discussions with the District at the concept stage help determine if the repairs will be done by Iowa DOT forces or by contract. Necessary funding usually is obtained with staff action for contingency funds written by OBS.

Reimbursement to Iowa DOT for repairs to a bridge due to an impact by an over height vehicle may come from two different sources. First, assuming the damage is due to the negligence of the vehicle's driver, reimbursement for the cost of repairs would be sought from the insurance carrier of the driver or trucking company. Second, Federal emergency repair funds may be available through the Federal government for some or the entire damage repair cost.

2.12.1 Iowa DOT Project Number for Inspection/Design Services

In an effort to capture in-house costs for the design effort to repair a damaged bridge, an Iowa DOT project number should be opened as early in the process as possible to track costs for the repair project.

2.12.2 Federal Aid Considerations

Federal Emergency Relief (ER) funds are only available upon declaration of an emergency event by the Federal government. The scope of this manual is limited to emergency responses for either steel beam/girder bridges or prestressed concrete beam bridges impacted by over height vehicles. It is unlikely that an isolated over height vehicle impact incident will meet the criteria to be declared an emergency event, and therefore use of ER funds is unlikely.

Use of other Federal aid requires a planning and programming process that typically cannot be accomplished in an emergency situation.

CHAPTER 3
STEEL BEAM OR GIRDER BRIDGE REPAIR

3.1 USE OF TEMPORARY STRONG BACKS

Over height vehicle collisions to steel beam or steel plate girder bridges may result in damage to the steel beams or girders that may compromise the load carrying capacity of the bridge. This may be due to steel members being torn or members being severely bent such that the strong axis moment of inertia is compromised. In these cases, it may be necessary to install a temporary strong back member to provide supplemental support to relieve load from the damaged member(s). An example of a temporary strong back beam in use is shown in Figure 3.1

Figure 3.1. Temporary Strong Back Beam

Iowa DOT has two steel beam components in storage that can be bolted together to provide auxiliary strong back support to a damaged steel beam. The 58-foot-long and 45-foot-long strong back beam components typically would be bolted together and supported on top of a bridge deck of a damaged steel beam/girder bridge to provide auxiliary support for a damaged beam/girder. With the strong back beam supported on timber cribbing near pier locations, threaded rods would be extended through holes in the bridge deck and connected to a secondary member under the deck. By tightening the hanger rods, load would be incrementally relieved from the damaged beam until the damaged beam/girder is supported adequately by the strong back beam. Then, repairs such as heat straightening or cutting out and replacing damaged portions of the beam could be made to the damaged beam.

As part of the development of this manual, Iowa DOT's strong back beam that splices together a 58-foot, W36 x 230 rolled beam and a 45-foot, W36 x 231 rolled beam has been analyzed to determine its load carrying capacity. These strong back beam sections are depicted on Iowa English Bridge Standard Sheets

1090 and 1091. The combined strong back beam was computed to have a factored bending and shear resistance of 2,113 kip-feet and 532 kips, respectively, based on the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications. These values were calculated considering the following assumptions:

- The W36x230 beam controlled
- Grade 36 steel was assumed
- Timber lateral bracing was assumed to be spaced at 25 feet on center

It should be noted that lateral torsional buckling of the section controlled the analysis, so a slightly larger resistance may be possible for a tighter spacing of the timber lateral bracing. However, it would be the responsibility of the engineer using the strong back beam to determine the capacity increase. Also, the splice connecting the 58-foot W36x230 beam to the 45-foot W36x231 beam was deemed to be adequate for loading not exceeding 93 percent of the above mentioned bending resistance for the controlling W36x230 beam. Since the current bolted splice is not located at the center of the combined beam, this may not be a concern, however the engineer using the strong back beam design should confirm the location of the splice within the loaded span to ensure the resistance of the splice is not exceeded. Details for the two strong back beam components currently in storage at the Ames maintenance yard are provided in Appendix D and supporting calculations for the analysis of the strong back beam are in Appendix E.

Also included in Appendix D are details for two other 51-foot-long support beams that may be used as part of a shoring system to support a damaged bridge from below. A typical use for these 51-foot support beams might be to provide end span support to a continuous beam bridge while portions of the center span are being repaired or replaced. These support beams were analyzed to determine their factored bending and shear resistance based on the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications and assuming they were unbraced for their full 51-foot length. The computed factored bending resistance was computed to be 1,155 kip-feet and the factored shear resistance was computed to be 813 kips. Supporting calculations for the analysis of these support beams can be found in Appendix E.

3.2 PARTIAL REMOVAL AND REPLACEMENT OF STEEL BEAM BOTTOM FLANGE AND WEB

Severe damage to the bottom flange and lower web of a steel beam or girder may require portions of the bottom flange and web to be removed and replaced. Generally, to facilitate the removal and replacement, a strong back beam or temporary shoring towers would be used to provide auxiliary support while the repairs are being made.

Once a strong back beam or shoring towers are in place to provide auxiliary support, often a guide angle is bolted to the web of the damaged beam to provide a straight guide surface to provide a uniform cut line for the girder web. Generally, the portion of beam removed will often extend between existing field splices. Since some areas of distortion may still remain in the portion of the girder web that remains, cold jacking against an adjacent beam line may be required to return distorted portions of the web that remains to a straight, uniform alignment. Continuous web splice plates are then bolted in place to connect the web of the existing beam with the new replacement web. In addition, the web and bottom flange are fully bolted into place at field splices. Typically, this type of repair will require replacement of damaged diaphragm members that fall within the impact zone.

A photograph of a completed steel beam removal and replacement is shown in Figure 3.2.

Figure 3.2. Partial Steel Beam Removal and Replacement

For the longitudinal web splice depicted in Figure 3.2 that connects the existing top and the new bottom portions of the beam web, the spacing of 7/8-inch diameter A325 bolts in double shear was analyzed to satisfy horizontal shear of the beam at various locations. Iowa Department of Transportation English Bridge Standards (40-foot Roadways – 3 Span Rolled Steel Beam Bridges) were used for all sectional and geometrical properties in the analysis. Only the center span between field splices (that is, positive moment region) of each bridge was considered, as this is the most likely location that a steel beam would be damaged from traffic below. Minimum and maximum conditions were examined to develop an envelope of possible bolt spacings. The minimum condition examined was a minimum standard bridge length of 160 feet, which carried a 64-foot center span. The maximum condition examined was a 240-foot standard bridge length, which carried a 96-foot center span. This span length was deemed the maximum length for which Iowa DOT's 103-foot-long strong back beam could be utilized.

The beam was loaded with the HL-93 vehicle in accordance with AASHTO LRFD Bridge Design Specifications, and the longitudinal connection was treated as a web splice. For either condition, the maximum allowable bolt spacing at any location between field splices was determined to be 5.0 inches, which also satisfied sealing pitch requirements for 3/8-inch splice plates. Supporting calculations for the analysis of the longitudinal web splice can be found in Appendix E.

3.3 STEEL BEAM STRENGTHENING ANGLE

In the past, Iowa DOT has also provided temporary repairs for a damaged bridge that was programmed for replacement. If a bridge is programmed for replacement or major rehabilitation, it may not make financial sense to put a sizable amount of work into the bridge if temporary repairs are acceptable. An example of this type of repair is the work done to original Design No. 7456 in Polk County (former Douglas Avenue Bridge over I-35).

For this continuous steel I-beam bridge, the south exterior beam previously had been damaged and strengthening plates previously had been bolted to the web and bottom flange at a diaphragm location adjacent to the new impact location. The new impact created a tear in the bottom flange of the beam and also caused out-of-plane distortion to the web plate in the lower one-third to one-half of the web depth. The new repairs included adding a second set of bottom flange strengthening plates at the location of the flange tear and also the addition of a pair of bolted longitudinal stiffening angles to the web of the beam near the top of the web distortion.

The intent of the temporary repairs was to restore the moment of inertia/ section modulus of the beam, and the repairs were considered adequate until the scheduled bridge replacement project was let for contract. Typically, it is the expectation of Iowa DOT that a damaged beam shall be restored to its original condition. Therefore, if the bridge had not been programmed for replacement, permanent repairs would have been required even if it required partial deck removal and replacement of the damaged beam.

3.4 TEMPORARY SHORING TOWERS

As a general policy, Iowa DOT does not stockpile or store materials for temporary shoring towers because the requirements for shoring towers, including the loads that they would be subjected to, can vary from case to case. However, because contractors may maintain a supply of tower components or may have supply sources readily available to provide stock components with little advance notice, Iowa DOT relies on private contractors to supply any needed temporary shoring towers or tower components.

To obtain shoring components from contractors on short notice, Iowa DOT will need to provide critical information, including the estimated loads that the tower will support, geometric constraints for positioning the shoring towers, and whether temporary barriers will be needed between the shoring towers and active traffic lanes to protect traffic.

Figure 3.4.1 shows two shoring towers that have been placed on either side of the damaged section of the exterior beam line, thus shortening the distance that the damaged beam must span and reducing the bending moment. In this particular case, the lower portion of the damaged steel beam (that is, bottom flange and lower half of the web) were removed between the towers and replaced with a new section of beam.

Figure 3.4-1. Shoring Towers on Each Side of Damage

Figure 3.4-2 shows a shoring tower placed to support the end span of a three-span continuous steel beam bridge. In this particular case, a portion of the bridge deck in the damaged center span had to be removed to allow total replacement of the positive moment field sections for several damaged beam lines.

Figure 3.4-2. Shoring Tower Providing End Span Support

3.4.1 Loads

To obtain an adequately sized shoring tower, Iowa DOT will need to estimate the required loads that the tower is expected to support. In general, it is assumed that temporary shoring towers will be sized to support some level of the dead load that a damaged beam normally would carry; due to impact damage, a damaged beam typically would not be relied on to continue to support live loads. In this case, active traffic normally would be shifted away from the damaged beam.

Following an impact by an over height vehicle, OBS staff would be responsible for estimating required shoring tower dead loads based on an analysis of the existing bridge geometry and the observed structural damage. Most falsework components are sized by the manufacturer for a safe working load by designing the components for a factor of safety above and beyond a given service load. Therefore, OBS staff should provide the service level dead load for which the towers are to be designed. Unless a minimum factor of safety is specified by OBS, it will be the contractor's responsibility to ensure that the support towers are sized with an appropriate factor of safety.

A review of existing soil borings that are part of the as-built bridge plans will provide information about the soils that will be supporting the shoring tower. Iowa DOT Soils Section should review the soil borings to provide a recommended maximum soil bearing pressure for the shoring tower legs. This determination could control the size of cribbing or a mat foundation needed to support the tower legs.

3.4.2 Geometric Constraints

When Iowa DOT provides design load information for shoring towers, it is important to provide any geometric constraints required for positioning the shoring towers. In particular, a plan view sketch or drawing should be provided showing the framing elements (that is, beams and diaphragms) of the bridge

superstructure in relation to the roadway below. Lane and shoulder lines for the roadway below should be indicated and any required clearances to those lane and shoulder lines should be designated.

3.4.3 Protection from Traffic

Generally, it is desirable to locate shoring towers as close as possible to the damaged portion of the affected beam members to minimize the span between shoring towers, thus minimizing the design load required for the shoring towers. To this end, shoring towers may need to be located close to active traffic. Placement of shoring towers will need to account for placement of temporary barriers between the active traffic lanes and the shoring towers to protect traffic from the lateral hazard created by the towers. OBS should consult with the Office of Traffic and Safety to determine an acceptable offset distance between the back of the TBR and the shoring towers to allow for displacement of the TBR and an adequate zone of intrusion to prevent damage or instability to the shoring tower in the event of a subsequent collision with the TBR.

3.5 LOCAL REPAIRS TO PREVENT STRESS RISERS

Often minor damage, such as minor paint scrapes, may not result in the District staff notifying OBS. Nevertheless, the damage should be documented in the next scheduled bridge inspection.

Gouges and scrapes to steel beams shall be removed by grinding if the actual net cross-sectional area which would remain after removal of the discontinuity is 98% or greater of the area of the material based on nominal dimensions. The purpose of this removal operation is to eliminate stress risers from the tensile zone that could become the source of later fatigue cracking in the steel. Such removal shall be faired to the material edge with a slope not steeper than one in ten and with machine or grinding marks parallel to the material surfaces in accordance with the AASHTO / AWS Bridge Welding Code, section 3.2.2. All grinding shall be performed longitudinally along the length of the beam in the direction of primary stresses such that the resulting finish shall have a polished bright metal appearance free of marks. The final surface shall be finished to a flush finish, or to a smooth transition, to a roughness not exceeding 3 µm (125µin). Repaired areas shall be magnetic particle tested after grinding to verify the corrected area is free from cracks or defects that could precipitate cracks in the future. Following surface grinding, the repaired area of the beam shall be coated with a prime coat and finish coat in accordance with Iowa DOT's Standard Specifications.

3.6 HEAT STRAIGHTENING

Heat straightening of steel I-beam and steel plate girder bridge members provides a viable repair method if impact distortion is not too severe (plastic strains less than 100 times the yield strain) and if primary members are not cracked or fractured. Refer to the FHWA "Guide for Heat-straightening of Damaged Steel Bridge Members" referenced in Appendix H of this manual for additional discussion of the plastic strain limits. Typical types of steel beam distortion that may be repaired by heat straightening techniques may include weak axis distortion; strong axis distortion; torsional distortion; or local distortions such as local flange buckling, web buckling, or plate member bends or crimps. Typically, impact damage may include a combination of any of the above distortions.

Heat straightening is a repair procedure in which controlled heat is applied in specific patterns to the plastically deformed regions of damaged steel in repetitive heating and cooling cycles to gradually straighten the material. The process relies on internal and external restraints that produce thickening (or upsetting) in the heating phase and in-plane contraction in the cooling phase. When heat straightening is done properly, the temperature of the steel should not exceed what is referred to as the phase transition temperature, at which material properties of the steel can change significantly. Heat straightening

generally requires multiple cycles of heat and restraint to incrementally return the member back to its original shape. Steel should be allowed to cool to 120 degrees Celsius (°C) (250 degrees Fahrenheit [°F]) before reheating steel.

Research on material properties of steel exposed to strain ratios of 100 or less has indicated minimal change in material properties for steel members heat straightened two or less times. Typically, two heat straightening repairs to the same section of beam will lead to a modest decrease in modulus of elasticity and ductility, but an increase in both yield stress and tensile strength. However, guidelines provided in the Federal Highway Administration's (FHWA's) *Guide for Heat-Straightening of Damaged Steel Bridge Members* recommend that the same areas of steel members should not be heat straightened more than twice due to concerns over an increased loss of ductility and a substantial decrease in fatigue life.

Prior to initiating heat straightening procedures, the damaged area of the beam should be thoroughly inspected to verify that it is free from cracks. Prior to heat straightening, the affected area of the beam should be blast cleaned to a bright metal finish and any gouges or nicks in the steel shall be removed by grinding to remove stress risers (see Section 3.5 of this manual). For Grade 36 or 50 carbon steels, the maximum temperature used for heat straightening shall be 649°C (1200°F); for Grade 70W steel, the maximum temperature used for heat straightening shall be 565°C (1050°F); for Grade 100 and 100W steels, the maximum temperature used for heat straightening shall be 593°C (1100°F). Temperatures shall be monitored using temperature indicating crayons, a contact pyrometer (thermocouple with digital readout), or a bimetal thermometer.

The use of heat straightening techniques typically includes the use of internal or external retraining forces. These forces shall be computed in advance and a constraint plan shall be established before applying heat, which defines the location of external jacks and the required bracing of undamaged members at jacking locations. Jacks, come-alongs, or other force application devices shall be gauged and calibrated so that the force applied can be controlled and measured. The load shall not be adjusted during heating or before the member has cooled to below 315°C (600°F).

Iowa DOT typically requires contractors who perform heat straightening services to have a minimum of 10 years of past experience consisting of a minimum of three successful heat straightening projects. Heating shall be with an oxygen–fuel gas mixture using a #8 or smaller torch tip typically sized based on the thickness of metal being heated. Heating patterns may be triangular (vee-shaped), strip, or rectangular heating patterns that should be spaced and marked out along the length of the damaged area before starting. Quenching the heated area with water, mist, or an air-water mix to accelerate cooling is not permitted. However, after the steel naturally cools to a temperature below 315°C (600°F), cooling with dry compressed air is permitted.

Inspection of heat straightening work should include verifying that the straightened steel members meet tolerance requirements listed in the contract documents. Following completion of heat straightening, non-destructive testing, such as magnetic particle testing, may be needed to confirm that no cracks formed as a result of the straightening procedures.

Appendix F includes a sample Iowa DOT special provisions for heat straightening bridge beams (Cedar County Design 214). In addition, FHWA's *Guide for Heat-Straightening of Damaged Steel Bridge Members*, which is referenced in Appendix H of this manual, also includes a sample special provision for heat straightening in its Appendix 1.

3.7 COLD JACKING

In the past, selective use of cold jacking has been utilized by Iowa DOT to return a distorted section of steel beam or plate girder to its original shape. Examples of this type of procedures are for Linn County Design 2570 and Linn County Design 673 (IA 13 over US-30) in the early 1970s.

Little research is available on the detrimental effects on steel from cold jacking of steel bridge members. If used, cold jacking is only recommended for use once and the plastic strains and number of cycles used to straighten the member should be limited. Cold bending steel can result in local work hardening of the material and the resulting material can result in reduced fracture toughness. A cold worked area is also susceptible to fracture or localized deformation during the jacking operation as well as longer term stress corrosion cracking in the area of the cold bending.

Limited cold jacking is allowed by Iowa DOT when other steel beam repairs are performed. For example, when partial removal and replacement of a steel beam bottom flange and web is performed as indicated in Section 3.2 of this manual, limited cold jacking of that portion of the existing beam web that remains after removal may be needed to straighten the web. The following plan note typically is included for these types of projects:

"Inspect remaining portion of beam web for straightness. Straighten any bent portion of the beam web by jacking against the adjacent beam as shown on these plans. If the beam requires straightening, it is to be straightened as closely as practical to its original alignment. The beam web shall be straightened by cold jacking or other mechanical operations. The steel shall not be heated for straightening, nor will any hammering of the steel be allowed."

3.8 STEEL BEAM REPAIR CONCEPT STATEMENT

Once a decision has been made to either repair or replace a damaged steel beam bridge, a Concept Statement would be prepared by OBS to describe the damage, define the work, provide recommendations, estimate the costs, and obtain buy-in from Iowa DOT management and the local District. The intent of the Concept Statement is to document the decision-making process and confirm that the recommendation made is the preferred solution. A sample Concept Statement for repairs to a rolled steel I-beam bridge (Pottawattamie County Design 713) is provided in Appendix A.

CHAPTER 4
PRESTRESSED CONCRETE BEAM BRIDGE REPAIR

4.1 TEMPORARY SHORING TOWERS

Section 3.4 of this manual includes a discussion on the use of temporary shoring towers for repairs of steel beam and plate girder bridges. The information provided in Section 3.4, including the discussion of loads for sizing shoring towers, geometric constraints to be considered, and protecting shoring towers from traffic is also applicable to repairs to prestressed concrete beam bridges. Therefore, refer to Section 3.4 for a detailed discussion of this topic.

4.2 CARBON FIBER AND FIBER REINFORCED POLYMER WRAP REPAIRS

Carbon fiber and FRP wraps are commonly used to help contain damage to prestressed concrete beams and to restore structural integrity to the damaged beam(s). An example of an in-place FRP-wrapped repair for a prestressed concrete beam is shown in Figure 4.2.

Figure 4.2. Fiber Reinforced Polymer Wrapped Repair

Typically, for prestressed concrete beams that have been damaged by an over height vehicle collision, repairs begin with removing any unsound concrete around the spalled area of the beam followed by preparing and cleaning the concrete surface at the repair area. Care should be taken to prevent additional damage to surrounding concrete, mild reinforcing steel, or prestressing strands. The limits of the repair area should be defined with a 0.75-inch-deep saw cut to prevent feathered edges of repair, and loose concrete around mild reinforcing steel and prestressing strands should be removed to provide 0.75-inch exposure all around. Next, the damaged area of the beam is repaired with Class “O” Structural Concrete.

Areas to receive the FRP laminate must be free from fins, sharp edges, or protrusions that will cause voids or depressions behind or within the installed FRP laminate or that might cause damage to the FRP fibers. Typically, the outside corners of the bottom flange are rounded to a 0.75-inch minimum radius, and inside corners where the bottom flange chamfers meet the beam web are also ground smooth to ensure proper adhesion between the FRP laminate and the concrete surface. In addition, any defects, spalls, chips, or hollow areas in the base concrete larger than 0.5 inch in diameter and 0.125 inch deep are filled with an FRP system-compatible epoxy or epoxy-based filler. Areas of concrete repair shall be allowed to cure for 7 days prior to applying the FRP wrap. In addition, it is important that no concrete sealers be applied to the repaired concrete where an FRP wrap is to be installed so the bond for the FRP laminate is not impaired.

Application of the FRP system must be performed under stringent temperature and humidity controls to ensure proper performance of the FRP wrap. Iowa DOT Developmental Specification DS-12023 for "Fiber Reinforced Polymer Repair for Concrete Containment of Collision Damaged Pretensioned Prestressed Concrete Beams" defines the material system to be used, the installation process, and the system manufacturer, supplier, and installer requirements for FRP repairs. If the FRP is to be painted after it is installed, Developmental Specification DS-12023 defines procedures for painting an FRP repair. A copy of Developmental Specification 12023 is included in Appendix F.

Typically with spalled areas of prestressed concrete beams, there may be cracking within the beam that may extend beyond the limits of the FRP repair. If these cracks are to be sealed by epoxy injection within the zone of the FRP wrap, the crack repair will need to be completed and all protrusions or fins ground smooth prior to installing the FRP wrap.

4.3 GROUTED STEEL SLEEVE REPAIRS

Another repair technique used for damaged prestressed concrete beams is to install a steel sleeve around the damaged bottom flange of a prestressed concrete beam and inject epoxy resin into the space between the sleeve and the face of the prestressed concrete beam. This type of repair is depicted in Figure 4.3.

Figure 4.3. Grouted Steel Sleeve Repair

For this type of repair, unsound concrete is removed from the spalled area, the area to be restored is cleaned, and the surface is prepared. Care should be taken to prevent additional damage to surrounding concrete, mild reinforcing steel, or prestressing strands. The limits of the repair area should be defined with a 0.75-inch-deep saw cut to prevent feathered edges of repair, and loose concrete around mild reinforcing steel and prestressing strands should be removed to provide 0.75-inch exposure all around.

Next, forms are constructed around the damaged area to match the original dimensions of the beam. The forms require holes to allow the concrete to be placed into the repair cavity. Class "O" Structural Concrete is placed within the forms and allowed to cure for 7 days before the forms are stripped. To prepare the new concrete to receive the steel sleeves and epoxy resin, the beam surfaces should be cleaned by sandblasting or another approved method.

The steel sleeves are two-piece components that are anchored into the web of the prestressed beam with concrete anchors (loosely tightened at first). Once in position, the sleeve components are then field-welded together, the concrete anchors are fully tightened, and the ends and tops of the sleeves are sealed with epoxy mortar. Finally, epoxy resin is pumped through ports in the sleeves and allowed to cure in order to bond the sleeves to the concrete beam.

4.4 PRESTRESSED STRAND SPLICING

If prestressing strands are severed or damaged as a result of an over height vehicle collision, specialized couplers and tensioning devices are available to splice the damaged strands and retension them. Alternatively, external post tensioning end blocks could be added to the girder to allow for anchoring Dwyidag bars to restore the lost compression force in the girder. However, splicing of damaged prestressing strands or the addition of external post tensioning should be considered a temporary repair as it is the expectation of Iowa DOT that a damaged beam shall be restored to its original condition, even if it requires partial deck removal and replacement of the damaged beam.

To splice a damaged prestressing strand, a length of the damaged strand is first cut out of the beam. Then a coupler is added to one free end and a new piece of strand installed to replace the damaged section of strand. At the other free end, a tensioning device is coupled onto the new strand on one side and the existing strand on the other side. Typically, the tensioning device may consist of a device similar to a turn buckle with a long tensioning nut and two threaded rods that connect into the couplers. As the nut is tightened onto the threaded rods, the wedges are set in the couplers and the strand is retensioned. A temporary stressing gauge is connected to the new section of prestressing strand to measure and confirm the force in the splice. In the case of multiple broken prestressing strands, the couplers and tensioning devices will need to be staggered due to limited available clearance between strands.

4.5 PRESTRESSED CONCRETE BEAM REPAIR CONCEPT STATEMENT

Once a decision has been made to either repair or replace a damaged prestressed concrete beam bridge, a Concept Statement would be prepared by OBS to describe the damage, define the work, provide recommendations, estimate the costs, and obtain buy-in from Iowa DOT management and the local District. The intent of the Concept Statement is to document the decision-making process and confirm that the recommendation made is the preferred solution. A sample Concept Statement for repairs to a prestressed concrete beam bridge (Linn County Design 512) is provided in Appendix A.

CHAPTER 5
RELATED TYPES OF BRIDGE DAMAGE AND OTHER BRIDGE TYPES

5.1 OTHER TYPES OF DAMAGE

Bridges can incur damage due to other events besides impact damage from over height vehicles. Bridges may incur damage from other man-made or natural events, from ongoing deterioration due to corrosion, or simply from wear and tear. Although this manual is not intended to address all types of bridge damage, similar response procedures may apply as a result of damage due to other man-made or natural events.

5.1.1 Fire Damage

A fire on or under a bridge can have an effect on both steel and concrete elements. However, most fires involving small vehicles or burning brush generally would not be expected to produce a fire intensity and duration severe enough as to cause serious damage to bridge structures. On the other hand, fires generated by tanker trucks carrying hydrocarbon fuels can produce intense fires that generally last until the fuel supply is depleted, thus causing major bridge damage.

Steel girders subject to the intense heat of a tanker fire could sustain damage or deform/deflect due to the heat. Structural steel typically will show only a gradual decrease in yield strength for temperatures up to approximately 500°C (932°F). However, at approximately 600°C (1,112°F), the yield strength of steel will be reduced to approximately 50 percent of its nominal yield strength. Steel also undergoes a phase transformation above approximately 725°C (1,337°F), where the grain structure may change through heating and cooling. Heat cambering and heat straightening operations typically limit the temperature of steel to below 650°C (1,202°F) so that the steel does not experience conditions worse than what it might see during a typical fabrication process. Steel heated to below the phase transformation stage and then cooled will return to its previous properties without detrimental long-term reduction in yield strength, toughness, or fatigue resistance. However, even though a steel member may return to its original properties after a fire, the member may undergo distortion, may sag, or may experience rapid thermal expansion during the fire due to the intense heat. During a fire, the temperature of a steel girder may be substantially below the maximum gas temperature of the actual fire. The bridge deck may be at an even lower temperature because of its added distance from the heat source and the lower thermal conductivity of concrete. A composite steel girder bridge exposed to intense heat from fire is susceptible to web buckling because the cooler composite deck would impose restraint to the top of the girder while the bottom of the girder is attempting to expand.

Figure 5.1.1. depicts the collapse of a steel girder bridge due to the temporary reduction in steel strength during an intense fire.

Figure 5.1.1. Collapse of I-880 Bridge in San Francisco from Fire Damage

Unlike steel members that can recover their properties up to a certain temperature threshold, the post-fire strength of concrete, once it cools down, does not recover like the post-fire strength of steel. Concrete strength starts decreasing rapidly after reaching about 400°C (750°F), and at about 500°C (932°F), concrete has only about 50 percent of its nominal compressive strength. Elevated temperatures from a fire also affect the steel components of a prestressed concrete beam. Although mild reinforcing steel has similar physical property recovery characteristics as structural grade steel, prestressing steel can experience notable loss of strength due to fire exposure, and relaxation of prestress force starts around 100°C (212°F). Loss of strength for prestressing steel starts around 400°C (750°F). But due to concrete's lower thermal conductivity, the internal temperature at 2-inch depth can be nearly half of the surface temperature of concrete. As a result, there may be some loss of prestress in the lower layer of strands but likely no loss in the upper layers of strands. Concrete also experiences cracking, spalling, and loss of stiffness as temperature increases. Moisture trapped in capillary and gel pores may form superheated steam that creates a damaging force when it cannot escape resulting in bursting pressure and spalling at the hot surface. This can be exacerbated during fire suppression when water is applied directly to fire-damaged concrete surfaces. If the bottom flange spalls, it could result in more layers of prestressing strands experiencing loss of prestress.

Steel girder or prestressed concrete beam bridges subjected to fire damage will require detailed inspection to determine the exposure temperature to which the structure was subjected and to determine the potential damage to structural members. Particularly for prestressed concrete beam bridges, physical testing may be required to determine strength values to use for load rating the bridge. Zinc melts at 419°C (787°F). Therefore an indication of the exposure heat to galvanized steel surfaces can be determined from a local absence of galvanizing. For steel bridges, deformation and or deflection caused by the heat rather than changes to the physical properties of the steel may control whether the bridge will require repair.

5.1.2 Impact to Bridge Pier Columns

Another type of incident that may warrant an emergency response for a bridge is when a truck or other vehicle crashes into a bridge pier or pier column. Although the current AASHTO LRFD Bridge Design Specifications require bridge piers adjacent to roadways to be designed for a 600 kip impact load, previous bridge design specifications did not require such a robust design, and a direct impact with a bridge column could jeopardize the stability of an existing bridge.

As is evident in Figure 5.1.2 below, this type of incident could trigger a similar type of emergency response as an over height collision, requiring lane closures for accident clean-up and emergency personnel, the need to inspect the bridge for damage, and potentially the need to stabilize or repair the bridge for carrying traffic loads.

Figure 5.1.2. Truck Collision with Bridge Pier

5.1.3 Flood Debris Damage

Damage to bridges due to floating flood debris is common, particularly for small bridges with low freeboard clearance over the water channel. Flood damage generally is more common on small county road bridges, particularly along the lower chords of steel truss bridges because these members are not sized for bending along their weak axes. However, steel beam bridges and prestressed concrete bridges with low freeboard can also sustain damage from flood debris. Heavily vegetated streams could dislodge large trees during a flood event, and the impact force of these floating or partially submerged trees may damage the exterior beam lines as the debris moves with the high velocity floodwaters. Damage may include spalling along the bottom flange of prestressed concrete beams and minor axis bending or bottom flange damage to steel beam members.

5.1.4 Flood Scour Damage

Damage to bridges from flood scour events likely would come with more warning than a sudden event like an over height collision because of the increased monitoring and required action plans for bridges deemed as scour critical. The use of underwater inspections and event-triggered monitoring generally provides bridge maintenance staff more time to respond to scour susceptible bridges and to implement corrective actions before a bridge closure is necessary.

However, a significant flood event could cause major scour to a bridge with little advance notice. A post-event inspection or signs of settlement could require emergency corrective action and thus require an emergency response for a critical route similar to an an over height collision event. Figure 5.1.4. shows an example of a bridge affected by flood scour.

Figure 5.1.4. Bridge Pier Scour Damage

5.1.5 Barge Impact

With major bridge structures located over navigable rivers such as the Mississippi and Missouri rivers, there is potential for damage to highway bridges in Iowa due to barge impact. Most, if not all, of the bridges carrying State and U.S. routes over these rivers are high-level structures with adequate vertical clearance to protect bridge superstructures from a barge impact. Nevertheless, the potential for damage to a bridge due to impact with a substructure component is very real, as shown in Figure 5.1.5 for the IA-9 Bridge over the Mississippi River near Lansing, Iowa.

The damage from a barge impact event has the potential to trigger an emergency response similar to one for an over height vehicle impact, and procedures developed from this manual could also apply to a barge impact event.

Figure 5.1.5. Barge Lodged Across the Mississippi River Channel Parallel to IA-9 Lansing Bridge

5.2 OTHER BRIDGE TYPES

Although the focus of this manual is on damage to steel beam bridges and prestressed concrete beam bridges, there are a number of other bridge types present on the State and U.S. highway system in Iowa that could incur impact damage from an over height vehicle. Predominantly, the other structure types used for overhead bridges would include truss bridges and cast-in-place T-beam or cast-in-place concrete slab bridges.

5.2.1 Truss Bridges

Truss bridges are particularly susceptible to damage from over height vehicle impacts because the bottom chord of a truss is typically a fracture critical tension member. The occurrence of truss bridges over State or U.S. highway routes in Iowa is becoming rare; therefore, the likelihood of a truss bridge being struck by an over height vehicle is less likely than in the past. However, impact damage by flood debris to a truss bridge spanning a river is still an event that could require a rapid response for repair.

5.2.2 Cast-in-Place Concrete Bridges

A number of cast-in-place concrete bridges remain on the State and U.S. highway system inventory in Iowa that could experience damage from an over height vehicle impact. These may include continuous concrete slab bridges, concrete frame or arch bridges, or concrete T-beam bridges. Figure 5.2.2 shows continuous concrete slab overpasses carrying I-35 over County Road D25, north of US 20 in Hamilton County.

Figure 5.2.2. Continuous Concrete Slab Overpass

Reinforced concrete bridges subjected to an over height vehicle strike typically would experience concrete spalling and cracking as a result of the collision. Of particular concern would be extensive damage to primary load carrying members such as a concrete arch rib for a concrete arch bridge or the web stems of a concrete T-beam bridge. Typical repairs may include patching concrete spalls, splicing damaged reinforcing steel to replace damaged or severed reinforcing steel, or epoxy injecting concrete cracks. Depending on the severity of the repairs, temporary shoring may be needed to support the damaged bridge and formwork for the repairs.

APPENDIX A
SAMPLE CONCEPT STATEMENTS FOR STEEL I-BEAM AND PRESTRESSED CONCRETE BEAM BRIDGE REPAIRS

Form 000021wd
4-96

IOWA DEPARTMENT OF TRANSPORTATION

To Office	District <#>	Date	<Month DD, YYYY>
Attention	<Assistant District Engineer>	Ref No.	<County> County <Project Number> PIN <PIN> Design No(s). <Design #> File No. <File #> FHWA No. <FHWA #>
From	<Bridge Design Engineer>		
Office	Bridges and Structures		

Subject <Final / Draft> Concept for Bridge Repair of <Bridge size and type>
Bridge Maintenance No. <0000.0X000>

The bridge on <Route> over <Route, River, RR, etc.> was struck on the <morning, afternoon, evening, or time if known> of <Date struck> by a <Vehicle or more descriptive if known> traveling <southbound on I-29>. The repair cost estimate is <cost estimate>. The project will be funded with <Emergency and Contingency Funds>. The proposed letting is <letting date>. I inspected the bridge on <Date> with <Bridge employees, other than yourself> of the Office of Bridges and Structures. Others in attendance included <Other personnel>, <Position> of <Office>.

<Note: The location description should match the SIIMS description. Both the cost estimate amount and programmed cost (if available) should be included.>

The bridge location map and asset information can be viewed in SIIMS using the following link:

<Link to structure map page in SIIMS>

EXISTING CONDITIONS

The bridge was constructed in <year>, design number <Design #>.

It is located <distance> miles from <nearest named crossing roadway, preferably a US or IA route>. The bridge is a <# spans> span <pretensioned prestressed concrete beam, steel girder, steel I-beam, etc.> structure. The cross section consists of <# beams> spaced at <beam spacing> supporting a <deck thickness including any PCC overlay present> thick concrete deck. The pier diaphragms are <concrete, steel>. The intermediate diaphragm(s) <is, are> <concrete, steel> located at <midspan; third points of span; X, X, X, and X feet from west pier of span>. The bridge rail is a <concrete retrofit, painted steel, galvanized steel, aluminum, concrete jersey, concrete F-shape> rail. <There is <empty, name utility> conduit in the south rail>.

<Description of Bridge damage including length and location. Be sure and identify any cracks in concrete beams that will require epoxy injection. Use same numbering scheme of beams and spans as shown in Bridge Maintenance file and describe location of first beam mentioned (i.e.: beam 1 (north exterior) and span (i.e.: span 2 from west abutment)>

RECOMMENDATIONS

It is recommended that the following repairs be made:

1. Remove and replace exterior beam(s) <X and X> along with a portion of the rail, curb, deck, pier diaphragms and intermediate diaphragm(s) in span <X>. <Carefully expose conduit and incorporate into new work.>

2. Remove and replace interior beam(s) <X, X, and X> along with a portion of the deck, pier diaphragms and intermediate diaphragm(s) in span <X>.

3. Repair beam(s) <X, X, and X>. Remove all unsound concrete, clean, and fill repair areas with class "O" concrete. <Install steel sleeve, Apply fiber reinforced polymer (FRP) sheets> to contain repair concrete. Cracks in beam(s) <X, X. and X> will be epoxy injected by D.O.T. personnel prior to contract repair.

Traffic control will involve <TBR, Shoulder strengthening, traffic signals, floodlighting, road closure, etc.> on <bridge route>. <route under bridge> will require a temporary lane closure and road closure for short periods to facilitate beam removal and replacement.

All recipients of this letter should review this concept of work to be accomplished and advise the Office of Bridges and Structures of any comments you have by <Date(approx. 3 weeks from date sent)>.

Estimated cost of repairs is as follows:

<Complete Concept Costs Estimate Template and paste area within yellow outline here, linking if desired.>

<Bridge Design Engineer's Initials(CAPITALS)>
Distributed to:
<Copy the appropriate list from Distribution Lists Master and paste here. Remove any non-applicable recipients and empty rows>

<Save a copy to the Projectwise directory under the Concept folder>

Form 000021wd
4-96

IOWA DEPARTMENT OF TRANSPORTATION

To Office	District 4	Date	December 5, 2012
Attention	Jim Bane	Ref No.	Pottawattamie County BRFN-059-39330-39-78
From	Dean Bierwagen		PIN 13-78-059-010 Design No. 713
Office	Bridges and Structures		FHWA No. 43340

Subject Final Concept for Bridge Repair of 150 ft x 28 ft Steel I-beam Bridge
Bridge Maintenance No. 7845.3S059

The bridge on US 59 over US 92 was struck in Span 2 on the afternoon of September 17, 2012 by a semi tractor trailer carrying a backhoe traveling west on US 92. Curtis Carter, Justin Sencer, and Dean Bierwagen from the Office of Bridges and Structures inspected the bridge on Friday, September 21, 2012. Estimated cost to repair the damage caused by the collision is $269,950.

EXISTING CONDITIONS

The bridge was constructed in 1957. It is located at the interchange of US 92 and US 59. The bridge is a three span rolled steel I-beam design with welded cover plates over the piers. The cross section consists of four beam lines spaced at 8'-11", supporting a 9" thick concrete deck (including overlay). Rolled steel diaphragms are used as cross bracing spaced at 14'-7½" in Span 2. The bridge rail is a concrete retrofit rail.

DAMAGE SUMMARY

The over height load struck the east exterior beam and both interior beams in Span 2. The impact was approximately 1'-4" south of the edge of the bolted splices. A summary of the damage to each beam is below.

Beam No. 4 (East Exterior)

The bottom flange was completely severed at the impact location and the web was cracked diagonally to within 7 inches of the top flange. See Photo No. 1 and No. 2. At the impact location the bottom flange was bent out of alignment approximately 7 ½ inches. One bolt was missing from the diaphragm connection. Clearance at the impact location was 15 ft 7 in.

Beam No. 3 (East Interior)

The east side of the bottom flange was cracked through to the web and bent out of alignment approximately 1'-2½" at the impact location. The web was cracked around the diaphragm and 9 of the 10 diaphragm bolts were broken. See photos No. 3 and No. 4. In addition, the diaphragm in Bay 2 was severely buckled. See photo No. 5.

Beam No. 2 (West Interior)

The bottom flange had two gouges at the impact location and the flange was bent approximately 6¼" out of alignment at the impact location. There were two bolts missing at the diaphragm connection. See Photos No. 6 and No. 7.

Beam No. 1 (West Exterior)

No signs of gouging or other direct impact damage were observed. The bottom flange was bent out of alignment approximately ½" at the splice location due to force transfer through the cross bracing diaphragms.

RECOMMENDATIONS

Because of the extensive damage to Beams 2, 3 and 4, it is recommended that the damaged portions of these beams be replaced. Replacement would be from the first cover plate location north of the impact location to the south bolted splice in span two. The work would include:

1. Removing the barrier rail on the east side of the bridge in span two
2. Removing the deck over the damaged beams.
3. Provide temporary support during removal for the continuous beams.
4. Remove and replace the damaged rolled beams and diaphragms.
5. Recast bridge deck and barrier rail.
6. Paint new steel sections.

A summary of the cost estimate is shown below. Estimated cost for the work is $265,750.

Estimated cost of repairs is as follows:

	QUANTITY	UNIT	RATE	AMOUNT
Removals	1	LS	$50,000	$50,000
Structural Concrete	30	CY	$150	$45,000
Reinforcing Steel Epoxy Coated	6500	LB	$2	$13,000
Structural Steel (Beam Replacement)	14150	LB	$5	$70,750
Barrier Rail Replacement	45	LF	$100	$4,200
Temporary Supports	1	LS	$20,000	$20,000
Containment	1	LS	$2,000	$2,000
Painting of Structural Steel	1	LS	$20,000	$20,000
Traffic Control	1	LS	$10,000	$10,000
Mobilization and Contingencies (15%)	1	LS	$35,000	$35,000
			TOTAL	$269,950

This is the final concept for this repair. The Office of Bridges and Structures will work with Contracts to set up a project for letting in April 2013 and begin preparing plans for the repair work noted above. Thank you.

DGB

cc: Troy Jerman, District 4
Don Stevens, District 4
Delmar Gettler, District 4
M. Kennerly, Design
J. Ranney, Program Management
M. Swenson, Project Scheduling
J. Smith, Contracts
V. Richards, Claims Management
J. Adam, Highway Division
M. Dillavou, Engineering Bureau
J. Rost, Location and Environment
S. Marler, Location and Environment
C. Cromwell, FHWA
N. McDonald
G. Novey
S. Neubauer
J. McClain
B. Worrel
J. Sencer
C. Carter
File

Photo No. 1 (East Exterior Beam Looking South)

Photo No. 2 (East Exterior Beam Looking West)

Photo No. 3 (East Interior Beam Looking West)

Photo No. 4 (East Interior Beam Looking Up From Below)

Photo No. 5 (Diaphragm 3, Bay 2, Looking South)

Photo No. 6 (West Interior Beam, Looking West)

Photo No. 7 (West Interior Beam, Impact Location Looking East)

Form 000021wd
4-96

IOWA DEPARTMENT OF TRANSPORTATION

To Office	District 6	Date	December 20, 2011
Attention	Jim Schnoebelen	Ref No.	Linn County IMN-360-6(281)-21-OE-57
From	Haiping Chen/Dean Bierwagen		PIN 12-57-380-010 Design No(s). 512
Office	Bridges and Structures		File No. 30715 FHWA No. 603860

Subject Concept for Repair of 264'-6 X 30'-0 Pretensioned Prestressed Concrete Beam Bridge Carrying 8th Street Over I-380; Bridge Maintenance No. 5720.8O380

ACCIDENT SUMMARY

The bridge was struck on December 1, 2011 by an over height excavator traveling southbound on I-380 in the center lane. On December 7, 2011, Dean Bierwagen and Haiping Chen from the Office of Bridge and Structures inspected the collision damage to the bridge.

BRIDGE DESCRIPTION

The bridge was built in 1972 and is a four span prestressed pretensioned concrete beam bridge which carries two traffic lanes, one way (westbound) on 8th street. The bridge roadway is 30 feet wide and has five beams in the cross-section at 7'-3 spacing. The vertical clearance at the damage areas are 16'-8 under the north exterior beam and 16'-7 under the south exterior beam.

DAMAGE DESCRIPTION

The over height excavator struck the north and south exterior beams in span three over I-380 (Photos 1 and 6). The collision location for the north beam is approximately 38 feet west of pier no. 2 and the collision location for the south exterior beam is approximately 39 feet west of pier no. 2 directly below the light pole support.

North Exterior Beam (see attached photo 1-5):

There are spalled and delaminated concrete areas for a distance of approximately five feet on the beam bottom flange. (Photo 2, 3, and 4). The bottom flange has one broken stirrup, two broken strands, and three exposed strands on the north side of the beam; two exposed stirrups and two exposed strands on the south side of the beam; and three exposed strands on the bottom of the beam (Photo 5). On the south side of the beam, there is a crack, approximately 4'-11 long, between the junction of the web and bottom flange fillet.

South Exterior Beam (see attached photo 6-15):

There are spalled and broken areas of the flange concrete throughout the impact location. The damage to the bottom flange extends for a distance of approximately three feet on the north side of the beam and eleven feet on the south side of the beam (Photo 7, 8, 9, 11, and 12). The bottom flange has six broken stirrups, three broken strands, and three vertical rows exposed strands. There are two spalled areas on the beam web, south side, approximately three feet wide by two feet high (Photo 10). There is also a hollow area on the south web face of the beam above the collision area. The area is approximately four and a half feet wide and extends to the top flange fillet.

The east intermediate concrete diaphragm between the south exterior beam and first interior beam is cracked (Photo 13, 14, and 15). The south exterior beam is also cracked along the junction of the web and top flange fillet from the pier no.2 diaphragm to the west undamaged intermediate concrete diaphragm.

RECOMMENDATIONS

Due to the extensive loss of concrete material, stirrups, and strands in the bottom flanges of both exterior beams in span three, we are recommending that both exterior beams be replaced. Estimated cost for the repair is $221,200.

Temporary barrier rails (TBR) should be utilized to restrict 8th street (westbound) traffic to one lane in the middle of the bridge. The TBR should remain in place until after both exterior beams in the span three are replaced.

Estimated cost of replacement of the two exterior beams:

Item Description	Quantity	Unit	Unit Price	Cost
Removal, as per plan	1	LS	$23,000	$23,000
Structural Concrete (Misc.)	44	CY	$2,000	$88,000
Reinforcing Steel, Epoxy Coated	10,000	LB	$1.00	$10,000
Beam, PPC, D95	2	Each	$15,000	$30,000
Temporary Barrier Rail	520	LF	$10.00	$5,200
Traffic Control	1	LS	$10,000	$10,000
Mobilization	1	LS	$35,000	$35,000
Contingency	1	LS	$20,000	$20,000
Total				**$221,200**

It is proposed to use emergency contingency funds for the contract to perform the repair work. This project has tentatively been scheduled for May 15, 2012 letting.

All recipients of this letter should review this concept of work to be accomplished and advise the Office of Bridges and Structures of any comments you have by December 27th, 2011. After this time period the concept will be considered approved or will be revised according to concerns.

HC/DGB:jaw

cc: K. Yanna, District 6 Assistant District Engineer
B. Kuehl, District 6 Construction Engineer
J. Tjaden, District Operations Manager, Cedar Rapids
M. Carter, Bridge Crew Leader, District 6
J. Adam, Highway Division
M. Dillavou, Engineering Bureau
M. Kennerly, Design
D. Ohman, Design
P. Flattery, Design
J. Ranney, Program Management
M. Swenson, Project Scheduling
J. Smith, Contracts
V. Richards, Claims Management
D. Newell, Location and Environment
N. McDonald, Bridges and Structures

G. Novey, Bridges and Structures
J McClain, Bridges and Structures
W. Sunday, Construction
L. Funnell, Location and Environment
J. Rost, Location and Environment

Photo Attachments

Photo 1: North Exterior Beam, North Side, Looking South.

Photo 2: North Exterior Beam, North Side.

Photo 3: North Exterior Beam, South Side.

Photo 4: North Exterior Beam, South Side.

Photo 5: North Exterior Beam, Bottom Flange.

Photo 6: South Exterior Beam, South Side, Looking North.

Photo 7: South Exterior Beam, Bottom Flange.

Photo 8: South Exterior Beam, South Side.

Photo 9: South Exterior Beam, South Side.

Photo 10: South Exterior Beam, South Side.

Photo 11: South Exterior Beam, North Side.

Photo 12: South Exterior Beam, North Side.

Photo 13: South Exterior Beam, North Side, Looking East.

Photo 14: South Exterior Beam, North Side.

Photo 15: South Exterior Beam, North Side, Looking West.

APPENDIX B
CRITICAL FINDINGS REPORT

IOWA DOT Form 532043 (12-09) Critical Finding

Part I ***(To be completed by inspector or owner)***

Bridge ID	FHWA No.	Facility Carried	Feature Intersected
2339.8S136	21171	IA 136	DRAINAGE DITCH

Critical Finding Date	Report Date	Inspector's Name	Bridge Owner
			01

Reason for Report: ☐ Collapse ☐ Structural Damage ☐ Structural Failure ☐ Approach Failure ☐ Delaminated Concrete over Traffic ☐ Bridge Hit

Location of Finding: ☐ Deck ☐ Superstructure ☐ Substructure ☐ Approaches ☐ Piles ☐ Railing ☐ Other

Immediate Action Taken: ☐ Close Bridge ☐ Close Lane ☐ Other

Description of Critical Finding: (attach Photos)

Part II ***(To be completed by owner)***

Reviewed by	Title	Date Part II Completed

Resolution: ☐ Close Bridge ☐ Close Lane ☐ Load Posting ☐ Repair ☐ Other

Owner's Anticipated Plan for the Bridge: (Repair, Replace, Remove, Permanently Close, Load Post, etc.)

Note: Before a bridge may be reopened to traffic, a licensed engineer must approve any structural repairs, the bridge must be load rated and the bridge must be inspected.

APPENDIX C
DAMAGE INSPECTION NOTES - TEMPLATE

Damage Inspection Notes

Inspection date: _____ Date damage occurred: _____
Structure number: _____
Structure description: _____
_____
Structure location: _____
_____

Inspectors/personnel present:
Bridges and Structures: _____
District: _____
Other: _____

Nature of damage:
Deterioration/age __ Vehicle/vessel impact __ Other _____
Accident report available __ Responsible party identified __ Clearance _____
Location of damage on structure: _____
_____
_____
_____

Description of damage: _____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Immediate actions taken: _____
_____
_____
_____
_____
_____
_____
_____

Immediate traffic impacts: _____

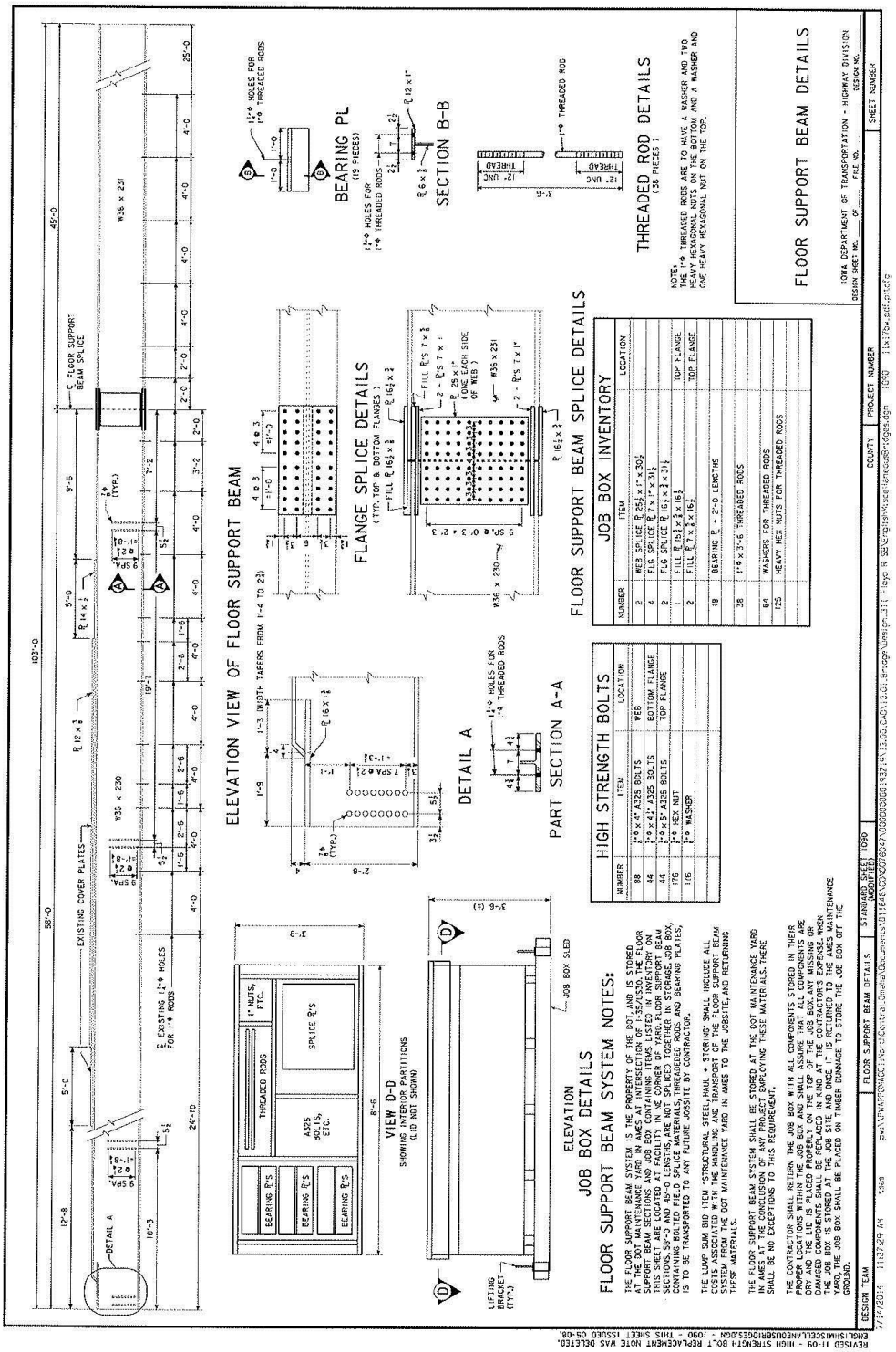
Long term actions needed: _____

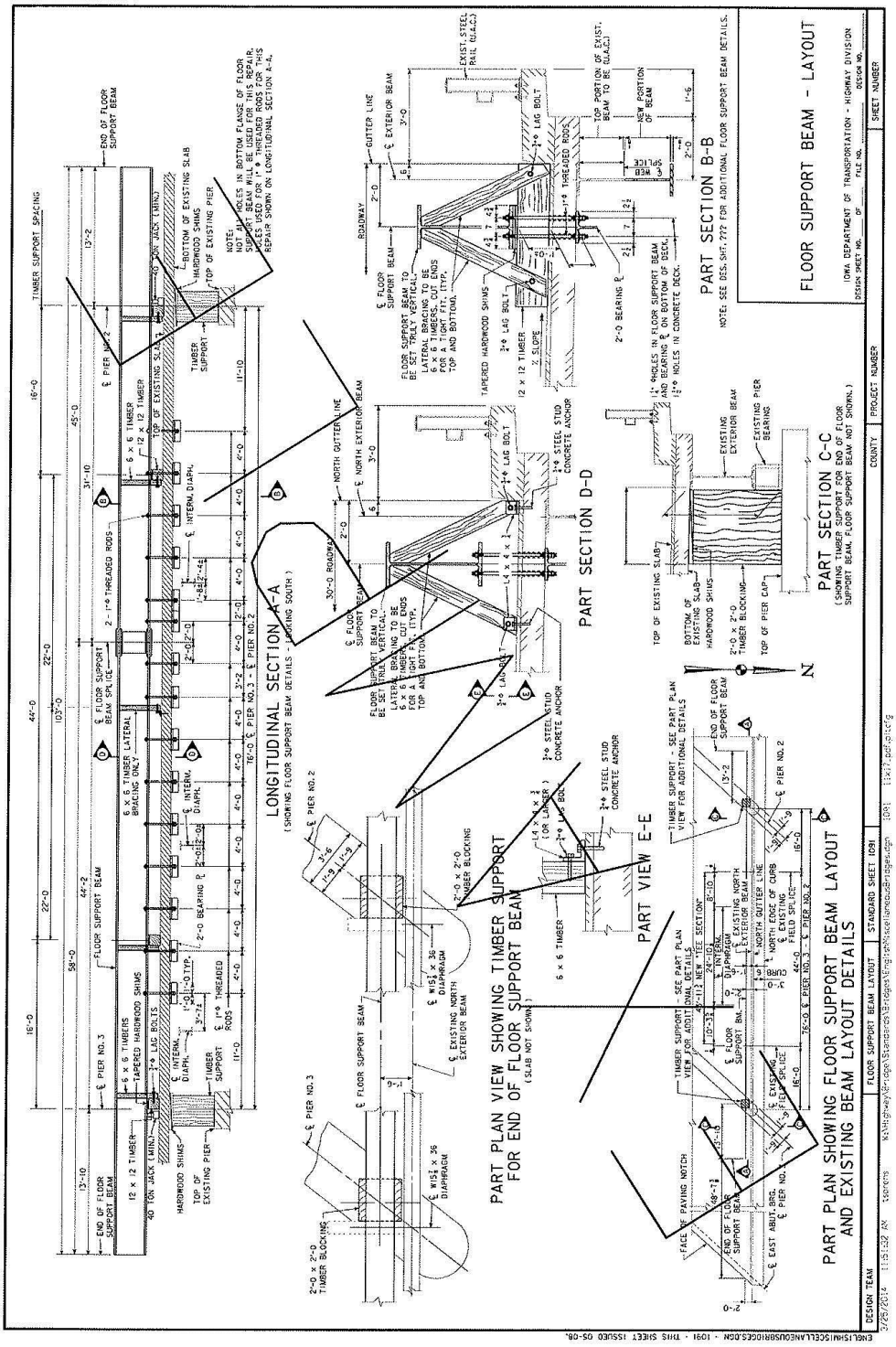
Long term traffic impacts:_____

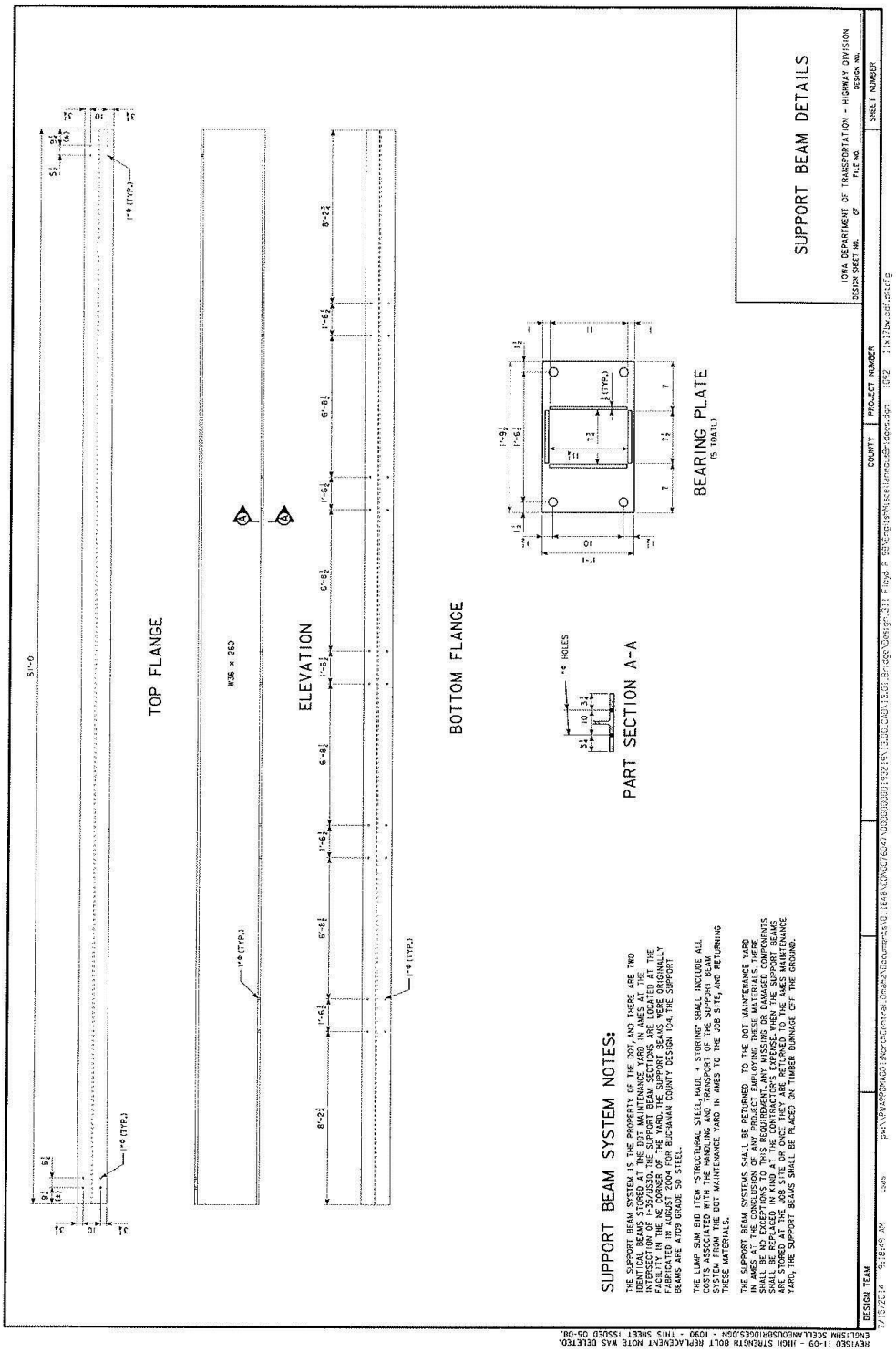
Attachments:
Additional information __ Photos __ Sketches __

Completed by: _____ Date: _____

APPENDIX D
STRONG BACK AND SUPPORT BEAM DETAILS FOR DAMAGED BRIDGES


FLOOR SUPPORT BEAM DETAILS
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. ___ OF ___ FILE NO. ___ DESIGN NO. ___
SHEET NUMBER
PROJECT NUMBER
COUNTY
DESIGN TEAM
FLOOR SUPPORT BEAM DETAILS
STANDARD SHEET 1090 (MODIFIED)
ELEVATION VIEW OF FLOOR SUPPORT BEAM
FLANGE SPLICE DETAILS
(TYP. TOP & BOTTOM FLANGES)
BEARING PL
(19 PIECES)
SECTION B-B
THREADED ROD DETAILS
(38 PIECES)
NOTE:
THE 1"Φ THREADED RODS ARE TO HAVE A WASHER AND TWO HEAVY HEXAGONAL NUTS ON THE BOTTOM AND A WASHER AND ONE HEAVY HEXAGONAL NUT ON THE TOP.
FLOOR SUPPORT BEAM SPLICE DETAILS
JOB BOX INVENTORY
NUMBER | ITEM | LOCATION
2 | WEB SPLICE PL 25½ x 1 x 30½
4 | FLG SPLICE PL 7 x 1 x 31½
4 | FLG SPLICE PL 16½ x 3 x 31½
2 | FILL PL 23½ x 3 x 16½ | TOP FLANGE
1 | FILL PL 7 x 3 x 16½ | TOP FLANGE
19 | BEARING PL - 2'-0 LENGTHS
38 | 1"Φ x 3'-6 THREADED RODS
64 | WASHERS FOR THREADED RODS
125 | HEAVY HEX NUTS FOR THREADED RODS
DETAIL A
PART SECTION A-A
HIGH STRENGTH BOLTS
NUMBER | ITEM | LOCATION
88 | ¾"Φ x 4" A325 BOLTS | WEB
44 | ¾"Φ x 4½" A325 BOLTS | BOTTOM FLANGE
44 | ¾"Φ x 5" A325 BOLTS | TOP FLANGE
176 | ¾"Φ HEX NUT
176 | ¾"Φ WASHER
VIEW D-D
SHOWING INTERIOR PARTITIONS
(LID NOT SHOWN)
ELEVATION
JOB BOX DETAILS
FLOOR SUPPORT BEAM SYSTEM NOTES:
THE FLOOR SUPPORT BEAM SYSTEM IS THE PROPERTY OF THE DOT, AND IS STORED AT THE DOT MAINTENANCE YARD IN AMES. THE SYSTEM CONSISTS OF FLOOR SUPPORT BEAM SECTIONS AND JOB BOX CONTAINING ITEMS LISTED IN INVENTORY. ON THIS SHEET ARE LOCATED AT FACILITY IN NE CORNER OF YARD. FLOOR SUPPORT BEAM SECTIONS, 58'-0 AND 45'-0 LENGTHS, ARE NOT SPLICED TOGETHER IN STORAGE. JOB BOX, IS TO BE TRANSPORTED TO ANY FUTURE JOBSITE BY CONTRACTOR.
THE LUMP SUM BID ITEM "STRUCTURAL STEEL, HAUL + STORING" SHALL INCLUDE ALL COSTS ASSOCIATED WITH HAULING AND TRANSPORTING THE FLOOR SUPPORT BEAM SYSTEM FROM THE DOT MAINTENANCE YARD IN AMES TO THE JOBSITE, AND RETURNING THESE MATERIALS.
THE FLOOR SUPPORT BEAM SYSTEM SHALL BE STORED AT THE DOT MAINTENANCE YARD IN AMES AT THE CONCLUSION OF ANY PROJECT EMPLOYING THESE MATERIALS. THERE SHALL BE NO EXCEPTIONS TO THIS REQUIREMENT.
THE CONTRACTOR SHALL RETURN THE JOB BOX WITH ALL COMPONENTS STORED IN THEIR PROPER LOCATIONS WITHIN THE JOB BOX AND SHALL ASSURE THAT ALL COMPONENTS ARE DRY AND THE LID IS PLACED PROPERLY ON THE TOP OF THE JOB BOX. ANY MISSING OR DAMAGED COMPONENTS SHALL BE REPLACED IN KIND AT THE CONTRACTOR'S EXPENSE. WHEN THE JOB BOX IS STORED AT THE DOT MAINTENANCE YARD, THE JOB BOX SHALL BE PLACED ON TIMBER DUNNAGE TO STORE THE JOB BOX OFF THE GROUND.
REVISED 11-09 - HIGH STRENGTH BOLT REPLACEMENT NOTE WAS DELETED.
EMC\SIMSCELLANEOUS\BRIDGES.DGN - 1090 - THIS SHEET ISSUED 05-08.


LONGITUDINAL SECTION A-A
(SHOWING FLOOR SUPPORT BEAM DETAILS - LOOKING SOUTH)
PART SECTION D-D
PART SECTION B-B
PART SECTION C-C
(SHOWING TIMBER SUPPORT FOR END OF FLOOR SUPPORT BEAM. FLOOR SUPPORT BEAM NOT SHOWN.)
PART VIEW E-E
PART PLAN VIEW SHOWING TIMBER SUPPORT FOR END OF FLOOR SUPPORT BEAM
(SLAB NOT SHOWN)
PART PLAN SHOWING FLOOR SUPPORT BEAM LAYOUT AND EXISTING BEAM LAYOUT DETAILS
FLOOR SUPPORT BEAM - LAYOUT
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. ___ OF ___ FILE NO. ___ DESIGN NO. ___
DESIGN TEAM
FLOOR SUPPORT BEAM LAYOUT
STANDARD SHEET 1031
COUNTY
PROJECT NUMBER
SHEET NUMBER


TOP FLANGE
ELEVATION
BOTTOM FLANGE
PART SECTION A-A
BEARING PLATE
SUPPORT BEAM DETAILS
SUPPORT BEAM SYSTEM NOTES:
THE SUPPORT BEAM SYSTEM IS THE PROPERTY OF THE DOT AND THERE ARE TWO IDENTICAL BEAMS STORED AT THE DOT MAINTENANCE YARD IN AMES AT THE INTERSECTION OF I-35/US30. THE SUPPORT BEAM SECTIONS ARE LOCATED AT THE FACILITY IN THE NE CORNER OF THE YARD. THE SUPPORT BEAMS WERE ORIGINALLY FABRICATED BY BLAGOEVICH FOR BUCHANAN COUNTY DESIGN 104. THE SUPPORT BEAMS ARE A709 GRADE 50 STEEL.
THE LUMP SUM BID ITEM "STRUCTURAL STEEL, HAUL - STORING" SHALL INCLUDE COSTS SPECIFIED IN THE HAUL AND STORAGE OF THE SUPPORT BEAM SYSTEM FROM THE DOT MAINTENANCE YARD IN AMES TO THE JOB SITE, AND RETURNING THESE MATERIALS.
THE SUPPORT BEAM SYSTEMS SHALL BE RETURNED TO THE DOT MAINTENANCE YARD IN AMES AT THE CONCLUSION OF ANY PROJECT EMPLOYING THESE MATERIALS. THERE SHALL BE NO EXCEPTIONS TO THIS REQUIREMENT. ANY MISSING OR DAMAGED COMPONENTS SHALL BE REPLACED IN KIND AT THE CONTRACTOR'S EXPENSE. WHEN THE SUPPORT BEAMS ARE RETURNED TO THE AMES SITE, THEY WILL BE STORED IN THE MAIN MAINTENANCE YARD. THE SUPPORT BEAMS SHALL BE PLACED ON TIMBER DUNNAGE OFF THE GROUND.
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION
DESIGN SHEET NO. ___ OF ___ FILE NO. ___ DESIGN NO. ___
SHEET NUMBER
DESIGN TEAM
COUNTY
PROJECT NUMBER
REVISED 11-09 - HIGH STRENGTH BOLT REPLACEMENT NOTE WAS DELETED.
ENGLISHMISCELLANEOUSGRIDCS.DGN - 1090 - THIS SHEET ISSUED 05-08.

APPENDIX E
CALCULATIONS FOR STRONG BACK BEAM, SUPPORT BEAM, AND STEEL BEAM WEB SPLICE

Emergency Response Manual
For Over Height Collisions to Bridges
Strong Back Beam Analysis

Table of Contents

Contents **Page**

1.0 Capacity of Strong Back Beam E-4
1.1 Compression Flange Local Buckling E-4
1.2 Moment Capacity E-5
1.3 Shear Capacity E-6
1.4 Net Section Fracture at Splice E-6

Strong Back Check

Check the strong back beam for collision repair adequacy.

SPECIFICATION: LRFD 6th Edition, 2012 (U.S. Units).

ASSUMPTIONS: Using Rolled Shapes (W36x230)
Webs meet proportion limits of 6.10.2.1.1 and 6.11.2.1.2

INPUT SECTION

Compression Flange Thickness:	$t_{fc} := 1.26in$
Compression Flange Width:	$b_{fc} := 16.475in$
ϕ :	$\phi := 1.0$
Web Depth:	$D := 33.36\ in$
Web Thickness:	$t_w := 0.765\ in$
Yield Strength:	$F_y := 36ksi$
Ultimate Strength:	$F_u := 58ksi$
Compression Flange Yield Strength:	$F_{yc} := 36\ ksi$
Tension Flange Yield Strength:	$F_{yt} := 36\ ksi$
Web Yield Strength:	$F_{yw} := 36\ ksi$
Steel Modulus of Elasticity:	$E := 29000\ ksi$
Hybrid Factor:	$R_h := 1.0$
Unbraced Length:	$L_b := 25\ ft$
Section Modulus:	$S_x := 835.5in^3$

CALCULATION SECTION

1.0 Flexural Capacity

1.1 Compression Flange Local Buckling

LRFD 6.10.8.2.2

$\lambda_f := \frac{b_{fc}}{2\,t_{fc}}$ $\lambda_f = 6.5$

$\lambda_{pf} := 0.38\sqrt{\frac{E}{F_{yc}}}$ $\lambda_{pf} = 10.8$

$F_{yr} := \max\left(\min\left(.7\,F_{yc}, F_{yw}\right), .5\,F_{yc}\right)$ $F_{yr} = 25200.0\,\text{psi}$

$\lambda_{rf} := 0.56\sqrt{\frac{E}{F_{yr}}}$ $\lambda_{rf} = 19.0$

$Rb := 1$ web proportion limits of 6.10.2.1.1 and 6.11.2.1.2 are met

$Rh := 1$ for rolled shapes

$\lambda_f < \lambda_{pf}$ yields $F_{nc} = R_b{*}R_h{*}F_{yc}$

$\lambda_{rw} := 5.7\sqrt{\frac{E}{F_{yc}}}$ $\lambda_{rw} = 161.8$

$D_c := \frac{D}{2}$ $D_c = 1.4\,\text{ft}$

$2\,\frac{D_c}{t_w} = 43.6$ $< \lambda_{rw}$ Therefore, $R_b = 1.0$, web compact

$F_{nc} := Rb\,Rh\,F_{yc}$ $F_{nc} = 36000.0\,\text{psi}$

1.2 Moment Capacity

Lateral Torsional Buckling

LRFD 6.10.8.2.3

$$r_t := \frac{b_{fc}}{\sqrt{12\left[1 + D_c \frac{t_w}{\left(3\, b_{fc}\, t_{fc}\right)}\right]}}$$ $r_t = 0.4\ \text{ft}$

$$L_p := 1.0\, r_t \sqrt{\frac{E}{F_{yc}}}$$ $L_p = 10.2\ \text{ft}$

$$L_r := \pi\, r_t \sqrt{\frac{E}{F_{yr}}}$$ $L_r = 38.5\ \text{ft}$

$$F_{nc} := 1\left[1 - \left(1 - \frac{F_{yr}}{Rh\, F_{yc}}\right)\left[\frac{\left(L_b - L_p\right)}{\left(L_r - L_p\right)}\right]\right] Rb\, Rh\, F_{yc}$$ $F_{nc} = 30356.5\ \text{psi}$

Tension Flange - LRFD 6.10.8.3

$$F_{nt} := Rh\, F_{yt}$$ $F_{nt} = 36000.0\ \text{psi}$

Web Bending Buckling - LRFD 6.10.1.9

$$k := \left[\frac{9}{\left(\frac{D_c}{D}\right)^2}\right]$$ $k = 36.0$

$$F_{crw} := \min\left[.9\, E \frac{k}{\left(\frac{D}{t_w}\right)^2}, \min\left(Rh\, F_{yc}, \frac{F_{yw}}{.7}\right)\right]$$ $F_{crw} = 36000.0\ \text{psi}$

Net Section Fracture - LRFD 6.10.1.8

$$A_g := 16.475\ 1.26$$ $A_g = 20.8$

$$A_n := \min\left[20.76 - 2\ 1.25\ 1.26, 20.76 - 4\left(\frac{15}{16}\right) 1.26\right]$$ $A_n = 16.0$

$$f_t := \min\left[0.84\left(\frac{A_n}{A_g}\right) F_u, F_{yt}\right]$$ $f_t = 36000.0\ \text{psi}$

Moment Resistance

$F_n := \min(\min(F_{nc}, F_{crw}), \min(F_{nt}, f_t))$ $F_n = 30356.5\ psi$

$M_n := F_n\ S_x$ $M_n = 2113.6\ kip\ ft$

$M_r := \phi\ M_n$ $\boxed{M_r = 2113.6\ kip\ ft}$

1.3 Shear Capacity - LRFD 6.10.9

$V_p := 0.58\ F_{yw}\ D\ t_w$ $V_p = 532.9\ kip$

$\frac{D}{t_w} = 43.6$

$1.12\sqrt{E\frac{5}{F_{yw}}} = 71.1$ >43.6, therefore $C := 1.0$

$V_n := C\ V_p$ $V_n = 532.9\ kip$

$V_r := \phi\ V_n$ $\boxed{V_r = 532.9\ kip}$

1.4 Check net section fracture at splice

*4- 15/16" holes through section with no stagger
*controlling stress = 32.64 ksi at midthickness of flange (from splice analysis)

$\phi_u := .8$ $\phi_y := .95$ $A_n = 16.0$ $A_g = 20.8$

$F_{cf} := 32.64ksi$

$A_e := \min\left[\left[\phi_u\ F_u\ \frac{A_n}{(\phi_y\ F_y)}\right], (A_g)\right]$ $A_e = 20.8$ in^2

$0.8\ A_n\ F_u \geq F_{cf}\ \frac{A_e}{2}$

$A_{nreq} := F_{cf}\ \frac{A_e}{(2\ .8\ F_u)}$ $A_{nreq} = 7.3$

Outside Plate:

$A_g := 16.5in \cdot .75in$ $\qquad A_g = 12.4\ in\ in$

$A_n := 12.375 - 4\left(\frac{15}{16}\right) \cdot .75$ $\qquad A_n = 9.6$

$$EQ_1 := \begin{cases} \text{"OUTSIDE PLATE OK"} & \text{if } A_n \geq A_{nreq} \\ \text{"OUTSIDE PLATE NG"} & \text{otherwise} \end{cases}$$

$EQ_1 = \text{"OUTSIDE PLATE OK"}$

Inside Plate:

$A_g := 2in\ 7in$ $\qquad A_g = 14.0\ in\ in$

$A_n := 14 - 4\left(\frac{15}{16}\right) 1$ $\qquad A_n = 10.3$

$$EQ_1 := \begin{cases} \text{"INSIDE PLATE OK"} & \text{if } A_n \geq A_{nreq} \\ \text{"INSIDE PLATE NG"} & \text{otherwise} \end{cases}$$

$EQ_1 = \text{"INSIDE PLATE OK"}$

NET SECTION FRACTURE "OK" FOR NON-STAGGERED PATTERN

Table of Contents

Contents	Page
1.0 Flexural Capacity	E-10
2.0 Shear Capacity	E-12

Support Beam

Flexural and shear checks for a W36x260 support beam.

SPECIFICATION: LRFD 6th Edition, 2012 (U.S. Units).

ASSUMPTIONS:

INPUT SECTION

ϕ shear:	$\phi := 1.0$
Compression Flange Width:	$b_{fc} := 16.555in$
Compression Flange Thickness:	$t_{fc} := 1.44in$
Web Depth:	$D := 33.36 \cdot in$
Web Thickness:	$t_w := 0.845 \cdot in$
Yield Strength:	$F_y := 50ksi$
Ultimate Strength:	$F_u := 70ksi$
Flange Yield:	$F_{yc} := 50ksi$
Web Yield Strength:	$F_{yw} := 50 \cdot ksi$
Steel Modulus of Elasticity:	$E := 29000 \cdot ksi$
Unbraced Length:	$L_b := 51ft$

CALCULATION SECTION

1.0 Flexural Capacity

Compression Flange - LRFD 6.10.8.2

Local Buckling

$\lambda_f := \frac{b_{fc}}{(2 \cdot t_{fc})}$ $\lambda_f = 5.7$

$\lambda_{pf} := .38 \sqrt{\frac{E}{F_{yc}}}$ $\lambda_{pf} = 9.2$

$Rb := 1$ web proportion limits of 6.10.2.1.1 and 6.11.2.1.2 are met

$Rh := 1$ for rolled shapes

$\lambda_f < \lambda_{pf}$ yields $F_{nc} = R_b * R_h * F_{yc}$

$\lambda_{rw} := 5.7 \sqrt{\frac{E}{F_{yc}}}$ $\lambda_{rw} = 137.3$

$D_c := \frac{D}{2}$ $D_c = 1.4\,ft$

$2 \cdot \frac{D_c}{t_w} = 39.5$ $< \lambda_{rw}$ Therefore, $R_b = 1.0$, web compact

$F_{nc} := Rb \cdot Rh \cdot F_{yc}$ $F_{nc} = 50000.0\,psi$

Lateral Torsional Buckling

LRFD 6.10.8.2.3

$$r_t := \frac{b_{fc}}{\sqrt{12\cdot\left[1 + D_c\cdot\frac{t_w}{\left(3\cdot b_{fc}\cdot t_{fc}\right)}\right]}}$$ $r_t = 4.4\cdot in$

$$L_p := 1.0\cdot r_t\cdot\sqrt{\frac{E}{F_{yc}}}$$ $L_p = 105.2\cdot in$

$$F_{yr} := \max\left(\min\left(.7\cdot F_{yc}, F_{yw}\right), .5\cdot F_{yc}\right)$$ $F_{yr} = 35000.0\,psi$

$$L_r := \pi\cdot r_t\cdot\sqrt{\frac{E}{F_{yr}}}$$ $L_r = 395.0\cdot in$

$L_b > L_r$

$C_b := 1.0$

$R_b := 1$

$$F_{cr} := C_b\cdot R_b\cdot\pi^2\cdot\frac{E}{\left(\frac{L_b}{r_t}\right)^2}$$ $F_{cr} = 14579.7\,psi$

*Tension, net section fracture and web bend buckling will not control by inspection.
Flexural Capacity:

$\phi_f := 1.0$ $S_x := 951.1\,in^3$

$M_r := \phi_f\cdot F_{cr}\cdot S_x$ $\boxed{M_r = 1155.6\cdot kip\cdot ft}$

2.0 Shear Capacity

LRFD 6.10.9

Unstiffened Resistance - No Intermediate Stiffeners

$V_n = V_{cr} = C^*V_p$

$V_p := .58 \cdot F_{yw} \cdot D \cdot t_w$ $\qquad V_p = 817.5 \cdot kip$

$\frac{D}{t_w} = 39.5$

$k := 5 \qquad C := 1$

$1.12 \cdot \sqrt{E \cdot \frac{k}{F_{yw}}} = 60.3$ > 39.5, therefore C=1.0

$V_n := C \cdot V_p$ $\qquad V_n = 817.5 \cdot kip$

$\phi_v := 1.0$

$V_r := \phi_v \cdot V_n$ $\qquad \boxed{V_r = 817.5 \cdot kip}$

Emergency Response Manual
For Over Height Collisions to Bridges
Web Splice Repair Analysis

Table of Contents

Contents	Page
1.0 Web Repair Splice - 160'	E-15
2.0 Web Repair Splice - 240'	E-19

Web Splice Repair

Size the web splice for collision repair adequacy. Using IaDOT standards for 3 span rolled steel beam bridges (40' Roadway). The minimum bridge length provided was 160' and the maximum bridge length which can utilize the 103' strong back beam was 240' (96' center span). These two designs were considered to create an envelope for bolt spacing.
Only the center span between field splices was examined, as this is the most likely location where an exterior girder may be damaged from traffic below.
Loads at the 2.2/2.8 points (F.S.) and 2.5 point (Midspan) were used to determine if bolt spacing could vary along the splice.
The repair splice was treated like a true web splice.

SPECIFICATION: LRFD 6th Edition, 2012 (U.S. Units).

ASSUMPTIONS: Using Rolled Shapes (W30x99) (W36x170)
Webs meet proportion limits of 6.10.2.1.1 and 6.11.2.1.2

INPUT SECTION - W30x99

ϕ shear:	$\phi := 1.0$
Web Depth:	$D := 28.36 \cdot in$
Web Thickness:	$t_w := 0.52 \cdot in$
Yield Strength:	$F_y := 50ksi$
Ultimate Strength:	$F_u := 70ksi$
Web Yield Strength:	$F_{yw} := 50 \cdot ksi$
Steel Modulus of Elasticity:	$E := 29000 \cdot ksi$

CALCULATION SECTION

1.0 Web Repair Splice - 160'

Shear Capacity of W30x99 - LRFD 6.10.9

Unstiffened Resistance (No Intermediate Stiffeners)

$\frac{D}{t_w} = 54.5$ $\quad k := 5$

$1.12\sqrt{E \cdot \frac{k}{F_{yw}}} = 60.3$

54.5 < 60.3, therefore $C := 1$

$V_p := 0.58 \cdot F_{yw} \cdot D \cdot t_w$ $\quad V_p = 427668.8\,lbf$

$V_n := C \cdot V_p$ $\quad V_n = 427668.8\,lbf$

Determined Factored Loading

at 2.2/2.8 point:

$V_u := 1.25 \cdot 15kip + 1.5 \cdot 3kip + 1.75 \cdot 54kip$ $\quad V_u = 117.8 \cdot kip$

at 2.5 point:

$V_u := 1.75 \cdot 26kip$ $\quad V_u = 45.5 \cdot kip$ $\quad < 0.5 * V_r$

Therefore, $V_{uw} := 1.5 \cdot V_u$ LRFD 6.13.6.1.4b

Determine Horizontal Shear at N.A.

Non-Composite

$y_{bot_non} := 14.85in$ $\quad I_{non} := 3990in^4$

$Q_{non} := 154.392in^3$

@ 2.2/2.8 point: $V_{dl} := 15kip$

$\tau_{non} := 1.5 \cdot 1.25 \cdot V_{dl} \cdot \frac{Q_{non}}{I_{non}}$ $\quad \tau_{non} = 1.1 \cdot kpi$

@ 2.5 point: $V_{dl} := 0kip$ therefore, $\tau_{non} = 0$

Composite (n=8.5)

$y_{bot_comp} := 28.7593in$ $I_{comp} := 12040.9in^4$

$$Q_{comp} := 8\left[\frac{81.41\cdot\left(29.7 + .5 + 8 - 28.7593 - \frac{8}{2}\right)}{8.5}\right] + 10.5\cdot.67\cdot\left(29.7 - 28.7593 - \frac{.67}{2}\right) + .52\cdot\frac{(29.7 - 28.7593 - .67)^2}{2}$$

$Q_{comp} := 421.1in^3$

@ 2.2/2.8 point: $V_{LL_IM} := 54kip$ $V_{DW} := 3kip$

$$\tau_{comp} := \frac{1.5\cdot\left[\left(1.5\cdot V_{DW} + 1.75\cdot V_{LL_IM}\right)\cdot Q_{comp}\right]}{I_{comp}} \qquad \tau_{comp} = 5.2\cdot kpi$$

@ 2.5 point: $V_{LL_IM} := 26kip$ $V_{DW} := 0kip$

$$\tau_{comp} := 1.5\cdot1.75\cdot V_{LL_IM}\cdot\frac{Q_{comp}}{I_{comp}} \qquad \tau_{comp} = 2.4\cdot kpi$$

Total:

@ 2.2/2.8 point: $\tau_{2.2} := 1.09kpi + 5.19kpi$ $\tau_{2.2} = 6.3\cdot kpi$

@ 2.5 point: $\tau_{2.5} := 2.39kpi$ $\tau_{2.5} = 2.4\cdot kpi$

Determine Max Bolt Spacing

Capacity of Bolt in Double Shear - LRFD 6.13.2.7

$A_b := \left(\frac{\pi}{4}\right)\cdot(.875in)^2$ $A_b = 0.6\cdot in^2$

$F_{ub} := 120ksi$

$N_s := 2$

$R_n := 0.38\cdot A_b\cdot F_{ub}\cdot N_s\cdot.8$ $R_n = 43.9\cdot kip$

$\phi := .8$

$R_r := \phi \cdot R_n$ $\qquad R_r = 35.1 \cdot kip$

Max Spacing for Sealing - LRFD 6.13.2.6.2

$t := .375in$

$s_{max} := \min(4in + 4 \cdot t, 7in)$ $\qquad s_{max} = 5.5 \cdot in$

Required Spacing @ 2.2/2.8:

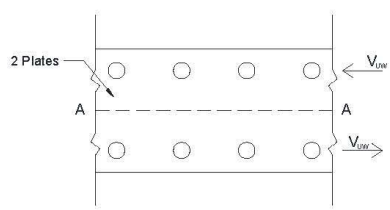
$s_{2.2} := \frac{R_r}{\tau_{2.2}}$ $\qquad s_{2.2} = 5.6 \cdot in$

Required Spacing @ 2.5:

$s_{2.5} := \frac{R_r}{\tau_{2.5}}$ $\qquad s_{2.5} = 14.7 \cdot in$

Use 5.5" spacing

Determine Size of Connection Plates



shear on section A-A

$V_{uw} := \max(\tau_{2.2}, \tau_{2.5})$ $\qquad V_{uw} = 6.3 \cdot kpi$

$R_r = \min(.58 \cdot F_y \cdot A_{vg}, .58 \cdot F_y \cdot .8 \cdot .9 \cdot F_u \cdot A_{vn})$

net area controls: 133.4*t

$t := \frac{(6.25 \cdot 5.5)}{(133.4 \cdot 2)}$ $\qquad t = 0.4 \cdot in$

USE 3/8" PLATES

INPUT SECTION - W36x170

ϕ (shear) :	$\phi := 1.0$
Web Depth:	$D := 34 \cdot in$
Web Thickness:	$t_w := 0.68 \cdot in$
Yield Strength:	$F_y := 50ksi$
Ultimate Strength:	$F_u := 70ksi$
Web Yield Strength:	$F_{yw} := 50 \cdot ksi$
Steel Modulus of Elasticity:	$E := 29000 \cdot ksi$

2.0 Web Repair Splice - 240'

Shear Capacity of W36x170 - LRFD 6.10.9

Unstiffened Resistance (No Intermediate Stiffeners)

$\frac{D}{t_w} = 50.0$ $\quad k := 5$

$1.12\sqrt{E \cdot \frac{k}{F_{yw}}} = 60.3$

50 < 60.3, therefore $\quad C := 1$

$V_p := 0.58 \cdot F_{yw} \cdot D \cdot t_w$ $\quad V_p = 670480.0\,lbf$

$V_n := C \cdot V_p$ $\quad V_n = 670480.0\,lbf$

Determined Factored Loading

at 2.2/2.8 point:

$V_u := 1.25 \cdot 25kip + 1.5 \cdot 4kip + 1.75 \cdot 62kip$ $\quad V_u = 145.8 \cdot kip$ $\quad < 0.5 * V_r$

at 2.5 point:

$V_u := 1.75 \cdot 31kip$ $\quad V_u = 54.3 \cdot kip$

Therefore, $V_{uw} := 1.5 \cdot V_u$ LRFD 6.13.6.1.4b

Determine Horizontal Shear at N.A.

Non-Composite

$y_{bot_non} := 18.1\,in$ $\quad I_{non} := 10500in^4$

$Q_{non} := 329.9in^3$

@ 2.2/2.8 point: $\quad V_{dl} := 25kip$

$\tau_{non} := 1.5 \cdot 1.25 \cdot V_{dl} \cdot \frac{Q_{non}}{I_{non}}$ $\quad \tau_{non} = 1.5 \cdot kpi$

@ 2.5 point: $V_{dl} := 0kip$ therefore, $\tau_{non} = 0$

Composite (n=8.5)

$y_{bot_comp} := 31.7918in$ $I_{comp} := 26183.2in^4$

$$Q_{comp} := 8\left[\frac{81.41\cdot\left(36.2 + .5 + 8 - 31.7918 - \frac{8}{2}\right)}{8.5}\right] + 12\cdot1.1\cdot\left(36.2 - 31.7918 - \frac{1.1}{2}\right) + .68\cdot\frac{(36.2 - 31.7918 - 1.1)^2}{2}$$

$Q_{comp} = 737.2\cdot in^3$

@ 2.2/2.8 point: $V_{LL_IM} := 62kip$ $V_{DW} := 4kip$

$$\tau_{comp} := \frac{1.5\cdot\left[\left(1.5\cdot V_{DW} + 1.75\cdot V_{LL_IM}\right)\cdot Q_{comp}\right]}{I_{comp}}$$ $\tau_{comp} = 4.8\cdot kpi$

@ 2.5 point: $V_{LL_IM} := 31kip$ $V_{DW} := 0kip$

$$\tau_{comp} := 1.5\cdot1.75\cdot V_{LL_IM}\cdot\frac{Q_{comp}}{I_{comp}}$$ $\tau_{comp} = 2.3\cdot kpi$

Total:

@ 2.2/2.8 point: $\tau_{2.2} := 1.5kpi + 4.8kpi$ $\tau_{2.2} = 6.3\cdot kpi$

@ 2.5 point: $\tau_{2.5} := 2.3kpi$ $\tau_{2.5} = 2.3\cdot kpi$

Determine Max Bolt Spacing

Capacity of Bolt in Double Shear - LRFD 6.13.2.7

$A_b := \left(\frac{\pi}{4}\right)\cdot(.875in)^2$ $A_b = 0.6\cdot in^2$

$F_{ub} := 120ksi$

$N_s := 2$

$R_n := 0.38\cdot A_b\cdot F_{ub}\cdot N_s\cdot.8$ $R_n = 43.9\cdot kip$

$\phi := .8$

$R_r := \phi \cdot R_n$ $\qquad R_r = 35.1 \cdot kip$

Max Spacing for Sealing - LRFD 6.13.2.6.2

$t := .375in$

$s_{max} := \min(4in + 4 \cdot t, 7in)$ $\qquad s_{max} = 5.5 \cdot in$

Required Spacing @ 2.2/2.8:

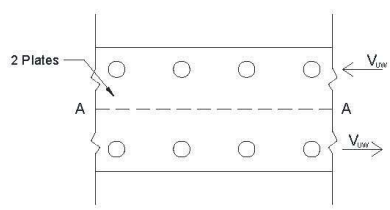
$s_{2.2} := \frac{R_r}{\tau_{2.2}}$ $\qquad s_{2.2} = 5.6 \cdot in$

Required Spacing @ 2.5:

$s_{2.5} := \frac{R_r}{\tau_{2.5}}$ $\qquad s_{2.5} = 15.3 \cdot in$

Use 5.5" spacing

Determine Size of Connection Plates



shear on section A-A

$V_{uw} := \max(\tau_{2.2}, \tau_{2.5})$ $\qquad V_{uw} = 6.3 \cdot kpi$

$R_r = \min(.58 \cdot F_y \cdot A_{vg}, .58 \cdot F_y \cdot .8 \cdot .9 \cdot F_u \cdot A_{vn})$

net area controls: 133.4*t

$t := \frac{(6.31 \cdot 5.5)}{(133.4 \cdot 2)}$ $\qquad t = 0.4 \cdot in$

USE 3/8" PLATES

APPENDIX F
SAMPLE DEVELOPMENTAL AND SPECIAL PROVISIONS

DS-12023
(New)

Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATIONS
FOR
FIBER REINFORCED POLYMER REPAIR FOR CONCRETE CONTAINMENT OF COLLISION DAMAGED PRETENSIONED PRESTRESSED CONCRETE BEAMS

Effective Date
October 16, 2012

THE STANDARD SPECIFICATIONS, SERIES OF 2012, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

12023.01 DESCRIPTION.
These specifications describe a Fiber Reinforced Polymer (FRP) repair system which comprises the:

- Materials system specified, including the fiber material, physical form of the fiber material, resin, primer, and adhesive as applicable,
- Installation process,
- System manufacturer,
- Supplier, and
- Installer.

12023.02 MATERIALS.

A. Comply with the following requirements:

Table DS-12023.02-1: Tests and Requirements for FRP Laminate Systems

PROPERTIES AT 72 ± 2°F(22 ± 1°C)	MINIMUM VALUES	ASTM TEST METHOD
Ultimate Tensile Strength in Primary Fiber Direction	500 pounds per inch of width (87.6 kN per meter of width)	D 3039
Ultimate Tensile Strength at 90° to Primary Fibers	500 pounds per inch of width (87.6 kN per meter of width)	D 3039
Tensile Modulus of Elasticity	2000 ksi (13,790 mPa)	D 3039

B. FRP Laminate Systems shall be in accordance with Materials I.M. 491.25, Appendix A.

C. Store and handle materials according to the manufacturer's recommendations, except as modified by this specification. Protect materials from dirt, moisture, chemicals, extreme temperatures, and physical damage. Do not use components exceeding their shelf life. In case of

conflict between manufacturer's recommendations and the requirements listed in this specification, the Engineer will determine which governs.

12023.03 CONSTRUCTION.

A. Surface Preparation.

1. Ensure that, where shown on the plans, corners are rounded and smoothed to a surface finish in compliance with these specifications prior to the application of fibers. Surface finish consists of finishing the surfaces of the structure to produce smooth even surfaces of uniform texture and appearance that are free of unsightly bulges, depressions, and other imperfections. Use power sanders or other approved abrasive means to achieve a smooth even surface of uniform texture and appearance. Repair defects in the base concrete, such as spalls, chips, and hollow areas as shown in the contract documents.

2. Ensure surfaces to receive FRP laminate are free from fins, sharp edges, and protrusions that will cause voids or depressions behind or within the installed FRP laminate, or that in the opinion of the Engineer will damage the fibers. Voids or depressions are defined as volumes greater than 0.5 inch (12.5 mm) in diameter by 0.125 inches (3 mm) deep. Fill existing uneven surfaces to receive FRP laminate, including voids or depressions, with an FRP system compatible epoxy or epoxy-based filler.

B. Application Conditions.

1. Ensure the contact surfaces at any stage of installation are completely dry and free of dust and other contaminants at the time of application of the FRP laminate. Mix and apply the epoxy resin components only when their temperatures and the ambient temperature are between 45ºF (7ºC) and 95ºF (35ºC). Apply the FRP laminate when the relative humidity is less than 90% at the site and the surface temperature is more than 5ºF (3ºC) above dew point.

2. Replace or repair FRP laminate damage caused by the elements at no additional cost to the Contracting Authority.

3. With the Engineer's written approval, the Contractor may provide suitable enclosures to permit application and curing of the FRP laminate during inclement weather. Control atmospheric conditions artificially inside the enclosures within limits specified for application and curing of the FRP laminate.

4. During application of the FRP system, maintain a Daily Installation Log. Make this log available to the Engineer for review. Provide the Engineer a copy at the completion of each day's work. In the log provide materials certification data and application records for each installation. Include, at a minimum, the following information:

a. Installation identification with beam number, construction and installation requirements, including plans and drawings, or references thereto.

b. Materials information including product description, date of manufacture, and lot or batch numbers.

c. Fabrication, inspection, and verification data for the manufacturing and construction operations including:

- A list of materials and quantities used during each work shift.
- Number of layer counts.
- FRP laminate thickness measurements.
- Installation time per beam.
- Ambient temperature and humidity readings at beginning, middle, and end of each work shift.

- Curing processes including full documentation of time and temperature relationship for curing and at final curing temperature.
- Thickness measurements of any protective coating applied to the completed FRP laminate following installation.

C. Application of System.

1. Use automated equipment to proportion and thoroughly mix the components of epoxy resin to within 5% of the specified mix ratio. Check the accuracy of proportions and mixing.

2. Apply the resin within one hour after a batch has been mixed, or as recommended by the FRP manufacturer. Measure and uniformly apply both epoxy resin and fiber sheet at the rates shown on the approved working drawings.

3. Apply the fiber sheet to the surface using methods that produce a uniform tensile force distributed across the entire width of fiber sheet.

4. Place successive layers of FRP laminate materials before complete cure of the previous layer of epoxy to achieve complete bond between layers. After seven calendar days, or complete cure, a light surface sand blasting, cleaning with fresh water, and drying is required prior to placing additional layers.

5. Maintain an epoxy application rate for each layer of FRP laminate such that the fiber sheet is completely saturated.

6. Undulations in the surfaces are not to exceed 0.25 inches per foot (20 mm per meter) in any direction. The cured FRP laminate is to have a uniform thickness, density, and bond between layers and to lack porosity.

7. Except as specified otherwise, roll or squeegee out entrapped air beneath each layer before the epoxy sets. Firmly bed and adhere each individual layer and ending of the FRP laminate to the preceding layer.

8. An overlap length of 4 inches (100 mm) or that recommended by the FRP manufacturer is required for splices in the fiber direction of individual layers. No horizontal overlap is required when placing parallel sheets.

9. Ensure the cured FRP laminate system has uniform thickness, density, and bond between layers. Protect the system from exposure to rainfall or submersion for a period of at least 48 hours. Inspect the cured FRP systems for defects consisting of external abrasions or blemishes, delaminations, voids, external cracks, chips, cuts, loose fibers, foreign inclusions, depressible raised areas, or fabric wrinkles. Apply the following criteria:

- Each layer is to have full contact with the concrete surface or subsequent layers subject to the following tolerances. Repair or replace all defects or voids with a dimension greater than 1.5 inches (40 mm), defect areas greater than 1 square inch (650 mm^2), or defect areas with any dimension greater than 1 inch (25 mm) within 1 foot (300 mm) from another defect area of similar size, as determined by the Engineer.
- Surfaces of butted joints are to be flush with adjacent surfaces.
- Prior to preparing surfaces for painting, obtain the Engineer's approval for all repairs completed and cured.

D. Painting FRP Laminates.

1. Clean and paint exposed surfaces of FRP laminates according to this specification and the FRP manufacturer's recommendations.

DS-12023, Page 4 of 4

2. Lightly roughen surfaces to be cleaned and painted by uniform abrasive blasting using an abrasive no larger than 80 mesh. Do not allow the air pressure at the nozzle used for abrasive blasting to exceed 80 psi (550 kPa). Use abrasive of appropriate hardness to roughen the surface without damaging the fiber portion of the FRP laminate. Do not expose the fiber portion of the FRP laminate by the abrasive blasting operation. Abrasive blasting will not be required if the first coat of paint is applied within 48 hours after mixing the components for the final resin coating.

3. Remove dust and blast residue from all surfaces by flushing with clean water before painting.

4. Ensure all surfaces of the FRP laminate are completely dry before applying a minimum of two finish coats of an exterior grade paint that is formulated to be system-compatible with the FRP in compliance with the requirements in ASTM D 3359, Method A, with a minimum rating of 4A.

5. Apply the first finish coat in a minimum of two applications. Verify the total dry film thickness of all applications of the first finish coat is no less than 2 mils (50 µm).

6. Successive applications of paint are to be of such a shade as to contrast with the paint being covered.

7. Unless the Engineer approves otherwise, allow a minimum drying time of 12 hours between finish coats.

8. The second finish coat color is to match Federal Standard 595B No. 26408. The total dry film thickness of all applications of the second finish coat is to be no less than 2 mils (50 µm).

9. Apply the two finish coats in three or more applications to a total dry film thickness of no less than 4 mils (100 µm) or more than 8 mils (200 µm).

12023.04 METHOD OF MEASUREMENT.
None.

12023.05 BASIS OF PAYMENT.

A. Payment for Beam Repair, as per plan, will be the lump sum contract price.

B. Payment is full compensation for furnishing all material, labor, and equipment required to complete the work according to the contract documents.

SP-120081
(New)

Iowa Department of Transportation

SPECIAL PROVISIONS
FOR
HEAT STRAIGHTENING OF BRIDGE BEAMS

Cedar County
BRFN-038-2(35)--39-16

Effective Date
September 17, 2013

THE STANDARD SPECIFICATIONS, SERIES 2012, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

120081.01 DESCRIPTION.
This work is to permanently repair a damaged steel beam on the 261'-6 x 28' continuous steel I-beam bridge carrying Iowa 38 over I-80 at the north junction of Iowa 38 and I-80. This bridge was struck by an over height load on eastbound I-80. The damaged beam shall be repaired by heat straightening to restore it to its original shape and alignment. In addition to heat straightening of the beam, the Contractor shall blast clean the damaged structural member to be straightened and contain waste material generated by blast cleaning.

120081.02 EXPERIENCE REQUIREMENTS.
Prior to beginning work, the Contractor shall submit to the Engineer documentation of 10 or more years of experience in the field of heat straightening major structural elements on highway or railroad bridges and a documented list of at least three bridge structures that have been successfully heat straightened.

120081.03 NOTIFICATION AND PRELIMINARY WORK.
The Contractor shall notify the Engineer 2 weeks prior to the starting date of heat straightening operations.

Prior to blast cleaning of structural steel, the Contractor and the Engineer shall inspect the damaged section for gouges, sharp dents, cracks or other impact caused defects and document any damage observed. If cracks are found, the Iowa DOT's Office of Bridges and Structures will be informed by the Engineer prior to the Contractor proceeding with the repair.

The Contractor shall blast clean the portions of the beam, in accordance with the plans, that have been damaged and require heat straightening.

120081.04 REPAIR BEAM, HEAT STRAIGHTENING.
Jacks or "Come-Alongs" may be used to mechanically augment the heat straightening process. Jacking forces shall be limited to 4 tons. Loading shall be judiciously applied to the beam during the straightening process. The jacking force shall not be adjusted during heating or before the temperature in the beam has

SP-120081, Page 2 of 2

cooled to 600ºF or less. The Contractor shall adequately brace the adjacent beams at the jacking locations in order to prevent overloading due to applied lateral loads.

Heating shall be done using No. 8 or smaller torch tips on an oxygen-acetylene gas mixture. Vee line or spot heating patterns shall be conducted to bring the steel within the planned pattern to a temperature between 600ºF and 1200ºF to produce deformations of the steel member conforming to the tolerances outlined on the plans and these special provisions. After the beam has been heat straightened, the heating pattern used shall be furnished to the Engineer for informational purposes. In no case shall the temperature exceed 1200ºF (a dull red) as determined with use of temperature indicating crayons, liquids or a bimetal thermometer.

The Contractor shall provide the Engineer with temperature indicating crayons manufactured for 600ºF, 1000ºF, and 1350ºF.

The temperature of the heated metal may be determined by the color of the steel adjacent to the tip of the torch by using temperature crayons to correlate the temperature of the heated metal to the color of the steel. In normal daylight conditions, 1200ºF will be indicated by a satiny, silver color near the torch tip. After cooling, the area should be gray in color.

Only quenching with clean dry air will be permitted. Cooling with compressed air may be done only after the steel has cooled naturally to at least 600ºF. Cooling shall be uniform throughout the heated area.

After the heat straightening has been completed, the Engineer will visually inspect the repaired beam. At the Engineer's discretion, nondestructive testing of the structural steel and weld may be performed if cracks are suspected. The Contracting Authority will do all testing.

120081.05 TOLERANCES.
The alignment of the repaired beam shall be within the following tolerances:

> Tolerances for sweep shall be 1/4 inch per 20 feet of length. Vertical deflections or waves in the flange shall not be more than 1/4 inch. The web shall be straightened to within 1/4 inch of plumb. Camber shall be within 1/4 inch of comparable readings of an undamaged adjacent interior beam. Camber readings shall be taken at 2 foot intervals within the span and submitted to the Engineer. In the event that the camber is not within tolerances, the Contractor shall adjust camber using the heating process.

120081.06 PERFORMANCE.
If the alignment of the beam is not straightened to within the tolerances specified or if the beam is cracked as a result of the heat straightening process performed by the Contractor, the Contractor shall replace or repair the portions of the beam as determined by the Office of Bridges and Structures of the Iowa DOT. The cost of repair or replacement with a new section of beam, associated materials, and labor shall be borne by the Contractor at no cost to the Contracting Authority.

120081.07 METHOD OF MEASUREMENT AND BASIS OF PAYMENT PAYMENT.
The Contractor will be paid the lump sum contract price bid for "Repair Beam, Heat Straightening, As Per Plan." This lump sum shall include furnishing all labor, materials and equipment required to heat straighten all damaged portions of the beam to its original alignment as noted herein. This includes furnishing all jacks and temporary bracing needed in the heat straightening process.

APPENDIX G
PARTIAL REFERENCE LIST OF PAST IOWA DOT OVER HEIGHT VEHICLE COLLISION REPAIRS

	County	Location	FHWA Bridge No.	Bridge Maint. No.	Design Number	Letting Date	Repair Features
PPCB Bridges	Scott	Local Road over I-80	047700	8204.8O080	412	7/17/12	Replace one exterior beam and FRP wrap the other exterior beam
	Cass	Co. Rd. N28 over I-80	018110	1564.6R080	8370?	March 1985	Beam Replacement
	Hardin	S.R. JJ Ave. over US 20 (Design 1489 , May 1989)	606225	4266.8O02	214	8/20/13	Replace exterior beam and FRP wrap first interior beam
	Linn	8th Street over I-380	603860	5720.8O380	512	5/15/2012	Beam replacement (both exterior beams)
	Warren	Co. Rd. G6R over I-35	051380	9158.5O035	503?	7/15/2003?	FRP wrap
	Warren	Co. Rd. R35 over I-35	051460	9166.6O035	406 or 210?	8/15/06 or 2/16/2010	Debris diaper
	Johnson	I-80 WB over Black Hawk Ave	031940	5230.5L080	115	7/15/14	Debris diaper
	Poweshiek	I-80 over IA 21	046210	7901.8R080	198 or 105 or 114	10/13/1998 or 5/17/2005 or 8/20/13	Beam patching and beam replacement (1998); Spall patching with FRP Wrap (2006 and 2013); Steel sleeve with epoxy injection (2006)
	Warren	Co. Rd. G-14 over I-35	051450	9165.1O035	603	2003	Beam replacement
	Warren	Co. Rd. G-14 over I-35	051450	9165.1O0365	108	2009	FRP wrap
	Warren	Co. Rd. G-14 over I-35	051450	9165.1O0375	510	4/2/2010	Spall patching with grouted steel sleeve

	County	Location	FHWA Bridge No.	Bridge Maint. No.	Design Number	Letting Date	Repair Features
Steel Beam or CWPG Bridges	Cedar	IA-38 over I-80	018330	1616.8S038	214	9/17/2013	Grind nicks and gouges; heat straighten
	Franklin	Local Road over I-35	602420	3566.8O035	692	January 1992	Grind nicks and gouges; heat straighten; diaphragm replacement
	Harrison	Local road over I-29 1.3 miles south of Co. Rd. F-50	028170	4380.5O029	204	6/27/2004	Grind nicks and gouges; heat straighten; add strengthening plates
	Johnson	SB Dubuque Street over I-80 EB	032110 (SB)	5244.3O080 (SB)	409	5/18/2010	Grind nicks and gouges; heat straighten
	Linn	IA-13 0ver US-30	033610	5730.1R151	2570	10/7/1970	Cold jacking
	Linn	IA-13 0ver US-30	033610	5730.1R151	673	12/7/1972	Cold jacking
	Marshall	IA-330 over US 30	- - -	6420.5S330	393	August 1993	Strong back beam used to remove/replace lower portions of beam and to straighten diaphragm
	Polk	Hubble Ave over I-80	042020	7742.1R080	1707	6/27/2007	Strong back beam used to remove/replace lower portions of beams and diaphragm replacement
	Polk	I-80 WB over US 65	042030	77421L080	1807	9/5/2007	Strong back beam used to remove/replace lower portions of beam
	Polk	Original Design No. 7456 Douglas Ave over I-35	041330	7726.1O080	No Design No.	Unknown	Strengthening angles added at mid-depth of web

	County	Location	FHWA Bridge No.	Bridge Maint. No.	Design Number	Letting Date	Repair Features
	Pottawattamie	US 59 0ver US 92	043340	7845.3S059	713	April 2013	Shoring towers; replace lower portions of three damaged beams
	Pottawattamie	Original Design 6764 -- I-29 over I-480 Ramp	044800	7853.8L029	1410	5/4/2010	Shoring towers; replace positive moment section of damaged exterior beam; replaced damaged diaphragms
	Scott	I-74 Mississippi River Approach over US 67	604080	8204.3R074	306	5/16/2006	Grind nicks and gouges; heat straighten
	Woodbury	Co. Rd. D-51 over I-29	053660	9735.8O029	913	6/18/2013	Strong back beam used to remove/replace lower portions of beams and diaphragm replacement

APPENDIX H
REFERENCES

CHAPTER 1 OVERVIEW AND DEFINITIONS

CHAPTER 2 RESPONSE PROCEDURES

2.4.1 State of Iowa Emergency Response Plan

Iowa Homeland Security and Emergency Management Division. 2010. "Iowa Emergency Response Plan." http://homelandsecurity.iowa.gov/documents/misc/HSEMD_IAEmergencyResponsePlan_OCT2010.pdf.

2.4.2 Iowa DOT Systems Operation Bureau, Traffic Operations Center

Iowa Department of Transportation (DOT). 2003. "Instructional Memorandum 1.255. – Highway Incident Management." Iowa Department of Transportation, Highway Division, Office of Maintenance. http://www.iowadot.gov/traffic/manuals/pdf/1001-255im.pdf.

2.7 REPORTING HAZARDOUS MATERIALS SPILLS

U.S. National Archives and Records Administration. 2013. Code of Federal Regulations. Title 49 "Hazardous Materials Regulations Part 171." http://www.gpo.gov/fdsys/pkg/CFR-2009-title49-vol2/pdf/CFR-2009-title49-vol2-part171.pdf.

2.10 ACCESSING DAMAGE AND DETERMINING FOLLOW-UP and 2.11 ACCESSING BRIDGE REPAIR VS. BRIDGE REPLACEMENT

Iowa DOT. 2014. "Bridge Design Manual." Iowa Department of Transportation, Highway Division, Office of Bridges and Structures. http://www.iowadot.gov/bridge/manuallrfd.htm

2.12.3 Emergency Lettings

State of Iowa. Iowa Code Section 313.10. https://www.legis.iowa.gov/docs/ico/code/313.10.pdf.

State of Iowa. Iowa Code Section 313.11. https://www.legis.iowa.gov/docs/ico/code/313.11.pdf.

CHAPTER 3 STEEL BEAM OR GIRDER REPAIR

3.5 LOCAL REPAIRS TO PREVENT STRESS RISERS

American Association of State Highway Transportation Officials (AASHTO) / American Welding Society (AWS). 2010. "Bridge Welding Code D.15M/D1.5." Section 3.2.2.

3.6 HEAT STRAIGHTENING

Federal Highway Administration (FHWA). 2008. "Guide for Heat-straightening of Damaged Steel Bridge Members." Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. http://www.fhwa.dot.gov/bridge/steel/heat_guide.pdf.

CTC and Associates LLC. 2009. "Effect of Heat Straightening on Girders Subjected to Multiple Repairs." Wisconsin Department of Transportation. http://wisdotresearch.wi.gov/wp-content/uploads/tsrheatstraightenedgirders.pdf

Connor, Robert, Michael Urban, Eric Kaufmann. 2008. "Heat-Straightening Repair of Damaged Steel Bridge Girders: Fatigue and Fracture Performance." *NCHRP Report 604.* Transportation Research Board of the National Academies. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_604.pdf

CHAPTER 4 PRESTRESSED CONCRETE BEAM REPAIR

Klaiber, F. Wayne, Terry Wipf, Ryan Paradis, and Robert Mateega. 1999. "Field/Laboratory Testing of Damaged Prestressed Concrete Girder Bridges." Iowa Department of Transportation, Iowa State University. http://publications.iowa.gov/17339/1/IADOT_hr397_Field_Lab_Test_Dmgd_Prestrssd_Conc_Grdr_Brdgs_1999.pdf.

Belarbi, Abdeldjelil, Sang-Wook Bae, Ashraf Ayoub, Daniel Kuchma, Amir Mirmiran, Ayman Okeil. 2011. "Design of FRP Systems for Strengthening Concrete Girders in Shear." *NCHRP Report 678.* Transportation Research Board of the National Academies. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_678.pdf

CHAPTER 5 RELATED TYPES OF BRIDGE DAMAGE AND OTHER BRIDGE TYPES

5.1.1 Fire Damage

Brandt, Thomas, Amit Varma, Brent Rankin, Sorin Marcu, Robert Connor, and Kent Harries. 2011. "Effects of Fire Damage on the Properties of Steel Bridge Elements." *Report No. FHWA-PA-2011-009-PIT011*, Commonwealth of Pennsylvania Department of Transportation, University of Pittsburgh. http://www.transportation.alberta.ca/Content/docType30/Production/RpMConcBrEl2.pdf.

Wright, William, Brian Lattimer, Michael Woodworth, Mohammad Nahid, and Elisa Sotelino. 2013. "Highway Bridge Hazard Assessment Draft Specifications for Fire Damage Evaluations in Steel Bridges." *NCHRP Project No. 12-85*. Transportation Research Board of the National Academies, Virginia Polytechnic Institute and State University. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP12-85_Guide.pdf.

Dunker, Kenneth. 2008. "Fire and Thermal Damage." Iowa Department of Transportation, Highway Division, Office of Bridges and Structures.

Waheed, Abdul, Ed Kowal, and Tom Loo. 2005. "Repair Manual for Concrete Bridge Elements." Alberta Ministry of Transportation. http://www.transportation.alberta.ca/Content/docType30/Production/RpMConcBrEl2.pdf.