Pier Protection

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• Why Install Pier Protection?

• Pier Protection Introduction

• Guidance for New Bridge Projects

• Guidance for Bridge Repair Projects

• Design of Crash Struts

• New Research
Why Install Pier Protection?

Figure 2.7. Truck Accident – SH 14 Bridge over IH-45, Corsicana, Texas.
Pier Protection Introduction

• MnDOT updated policy July 2016
• MnDOT LRFD Bridge Design Manual Article 11.2.3
• Design (BDM 11.2.3.2.1)
  • Crash Strut to resist 600 kip collision. See BDM 11.2.3.2.4
    OR
  • Individual column to resist 600 kip collision per AASHTO Article 3.6.5
    OR
  • Protect with TL-5 barrier
    OR
  • Validate bridge will not collapse with removal of any column
• Protect with TL-5 barrier

OR

• Validate bridge will not collapse with removal of any column
• Pier Considered Exempt from Protection Requirements (BDM 11.2.3.2.1)
  • Piers with ≥ 3 columns AND design speed of roadway below ≤ 40 MPH
  • *Non-Critical* bridges with piers with ≥ 3 columns and design speed or roadway below > 40 MPH if:
    • Annual Frequency of pier collision ≤ 0.001 (AASHTO Article C3.6.5.1)
    • Roadway underneath is undivided and HCADT < 800
    • Roadway underneath is divided, on a tangent under the bridge, and HCADT < 2400
    • Roadway underneath is divided, on a curve under the bridge, and HCADT < 1200
• What’s a non-critical bridge?

• Critical is defined as:
  • A bridge carrying mainline interstate
  • A bridge spanning over mainline interstate
  • A bridge carrying > 40,000 AADT
  • A bridge spanning over a roadway carrying > 40,000 AADT

• Critical bridges require annual frequency of collision ≤ 0.0001 for exemption (AADT ≤ 3,000 for divided tangent)
• Pile Bent Piers
  • Typically not used within 30 feet of roadway or 25 feet of railroad track
  • If necessary to use pile bent pier adjacent to roadway or railroad:
    • Protect using TL-5 barrier
    OR
    • Encase piles in pile wall
      • Design per “heavy construction” requirements of AREMA
      AND
      • Design pile wall to resist 600 kip collision load
Pier Protection Introduction

• Piers Adjacent to Railroads (BDM 11.2.3.2.2)
  • Piers within 25 feet of railroad must follow “heavy construction” requirements of AREMA 2.1.5.1
    • Area of Column $\geq 30 \text{ ft}^2$
    • Each column has minimum dimension of 2.5 ft
    • Larger dimension is parallel to track
Guidance for New Bridge Projects

• BDM 11.2.3.2.4 – Crash Struts for Pier Protection
  • Strut Geometry
  • Strut Design

• BDM 11.2.3.2.5 – Barrier Protection of Piers
  • TL-5 barrier requirements
Guidance for New Bridge Projects - Geometry

NOTES:

GUARDRAIL, END TREATMENT, OR OTHER TRAFFIC PROTECTION IS NOT SHOWN AND MUST BE COORDINATED WITH THE ROADWAY PLANS.

1. 3'-0" MIN. WHEN GUARDRAIL CONNECTION IS REQUIRED.
   1'-0" MIN. FOR ALL OTHER SITUATIONS.
   A VERTICAL TAPER MAY BE REQUIRED AT END OF STRUT.
   CONTACT THE MNDOT DESIGN STANDARDS UNIT AT 651-366-4 FOR END TAPER REQUIREMENTS.

2. 2" MIN. FOR NEW PIER CONSTRUCTION.
   5" MIN. FOR PIER RETROFIT CONSTRUCTION.

Figure 11.2.3.2.4.1
Crash Strut Details

5/17/2017
Bridge Office | mndot.gov/bridge
Guidance for New Bridge Projects - Geometry

- Vertical face typical, barrier shape is allowed – coordinate with roadway designer
- Strut may have to taper to tie into median barrier – coordinate with road designer.
Guidance for New Bridge Projects - Geometry

- Railroad Struts have different requirements
  - If between 12’ and 25’ to track, height must be 6’ above track
  - If closer than 12’ to track, height must be 12’ above track
  - Extend bottom of strut 4’-0” minimum below groundline
  - Thickness must be 2’-6” minimum
    - Locate vertical face 6” outside column on railroad side
  - Extend strut minimum 1’-0” beyond exterior columns
  - Minimum length is 12’-0”
• If geometry guidelines and minimum dimensions are met, standard figures and tables are provided

• Standard designs assume a 15° angle from load to strut – not explicit in BDM

• Figure 11.2.3.2.4.2
Figure 11.2.3.2.4.2

IN COLUMN FOOTING REGION

BETWEEN COLUMN FOOTINGS
Guidance for New Bridge Projects - Barrier

• Can use TL-5 barrier for pier protection

• AASHTO Article 3.6.5.1
   • 54” high barrier when located within 10 ft. of pier
   • 42” high barrier when located more than 10 ft. from pier

• Figure 11.2.3.2.5.1
Guidance for New Bridge Projects - Barrier

Figure 11.2.3.2.5.1
TL-5 Barrier Geometrics

NOTE:
1. GUARDRAIL END TREATMENT, OR OTHER TRAFFIC PROTECTION IS NOT SHOWN AND MUST BE COORDINATED WITH THE ROADWAY PLANS.
Guidance for Bridge Repair Projects

• BDM 11.2.3.2.3 – Pier Protection for Existing Bridges

• For trunk highway system, Regional Bridge Construction Engineer will coordinate with the District to determine if required per the *Bridge Preservation Improvement Guidelines*

• For local system, designer must coordinate with City or County Engineer
Guidance for Bridge Repair Projects - Geometry

- Follow same geometry requirements as new bridges
- Exception: locate vertical face 5” outside column
Guidance for Bridge Repair Projects - Design

• Custom design is required for all repair projects

• Must check existing foundation for ability to carry additional dead load

• Dowel reinforcement to be adhesive anchors
Design of Crash Struts

- 600 kip collision load applied up to 15° from roadway or railway
Design of Crash Struts

- Design for both custom new and all rehab projects
- Load applied 5 ft above ground line distributed over 5 ft
- Design strut to resist entire load independent of column
- Region between footings, design as simply supported beam spanning between footings (i.e. \( L = \) clear distance between footings)
Design of Crash Struts

• In footing region, design for two cases:
  • Case 1
    • Diagonal yield line at failure
    • Determine capacity similar to barrier capacity
      • AASHTO Article A13.3.1
    • In new bridges, design footing length $> L_c$
  • Case 2
    • Horizontal yield line at failure (at footing)
    • Flexural resistance of dowels only
    • Often controls for rehab projects
Design of Crash Struts

• Case 1
  • Yield Line Theory
  • T.J. Hirsch research paper
  • Hirsch, T.J. 1978. “Analytical Evaluation of Texas Bridge Rails to contain Buses and Trucks,” Research Report 230-2, August, Texas Transportation Institute, Texas A&M University, College State, TX.
Design of Crash Struts

• Yield Line Theory
  • Member yields along a diagonal line from footing
  • \( M_c \) – flexural resistance about horizontal axis (dowels)
  • \( M_w \) – flexural resistance about vertical axis (horizontals)
  • \( M_b \) – additional flexural resistance of beam additional to \( M_w \) if any
• **Interior Region**

  • \[ L_c = \frac{L_t}{2} + \sqrt{\left(\frac{L_t}{2}\right)^2 + \frac{8H(M_b+M_w)}{M_c}} \]

  • AASHTO Eqn. A13.3.1-2

  • \[ R_w = \left(\frac{2}{2L_c-L_t}\right)\left(8M_b + 8M_w + \frac{M_cL_c^2}{H}\right) \]

  • AASHTO Eqn. A13.3.1-1
Design of Crash Struts

• Exterior Region

  • \[ L_c = \frac{L_t}{2} + \sqrt{\left(\frac{L_t}{2}\right)^2 + \frac{H(M_b + M_w)}{M_c}} \]

    • AASHTO Eqn. A13.3.1-2

  • \[ R_w = \left(\frac{2}{2L_c - L_t}\right)(M_b + M_w + \frac{M_c L_c^2}{H}) \]

    • AASHTO Eqn. A13.3.1-3

Figure CA13.3.1-2—Yield Line Analysis of Concrete Parapet Walls for Impact near End of Wall Segment
• Region Between Footings
  • BDM suggests designing as simple supported beam between footings
  • Alternatively, modify AASHTO equations per Hirsch Figure 14

\[
L_c = \frac{L_t}{2} + \sqrt{\left(\frac{L_t}{2}\right)^2 + \frac{8H(M_b+M_w)}{M_c} - \frac{GL_t}{2}}
\]

• AASHTO Eqn. A13.3.1-2 mod

\[
R_w = \left(\frac{2}{2L_c-L_t}\right)\left(8M_b + 8M_w + \frac{M_cL_c(L_c-G)}{H}\right)
\]

• AASHTO Eqn. A13.3.1-1 mod

FIGURE 14. YIELD LINE ANALYSIS OF OPEN CONCRETE WALL OR PARAPET.
Design of Crash Struts

- $M_c$ using Adhesive Anchors
  - Resistance of dowels is limited to adhesive anchor capacity
    - Tension resistance of dowel
    - Combined tension and shear resistance of dowel
    - Concrete breakout resistance
    - Anchor bond resistance
  - See prior presentation about adhesive anchors
  - This limit can be $<<$ yield strength of dowels
  - As $M_c$ decreases, $L_c$ increases
Design of Crash Struts

• Case 2
  • I can’t get Case 2 to work!
  • Often occurs on rehab projects with limited footing sizes
  • Can incorporate column resistance
• Using column resistance
  • Requires approval from Bridge Office project manager
  • Determine moment resistance of column based on Extreme Event limit state
  • Check minimum dead load factors without live load
  • $\phi M_{n_{-total}} = \phi M_{n_{-strut}} + \phi M_{n_{-column}}$
• Why minimum factors?

\[ \phi M_n = 600 \text{ k-ft} \]
Design of Crash Struts

• What if my rehab project still won’t work?
  • Work with Bridge Office project manager for other options
  • Have had to implement “outside the box” solutions for challenging bridges
• **NCHRP 12-90**
  
  • Due out at end of 2017
  
  • Working to refine when pier protection is needed
    
    • Redundancy of substructure and superstructure
    
    • Size of columns
  
  • Will have recommendations for revisions to AASHTO Specifications
    
    • MnDOT will most likely update guidance based on recommendations
Questions?
Thank you!

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