Piers

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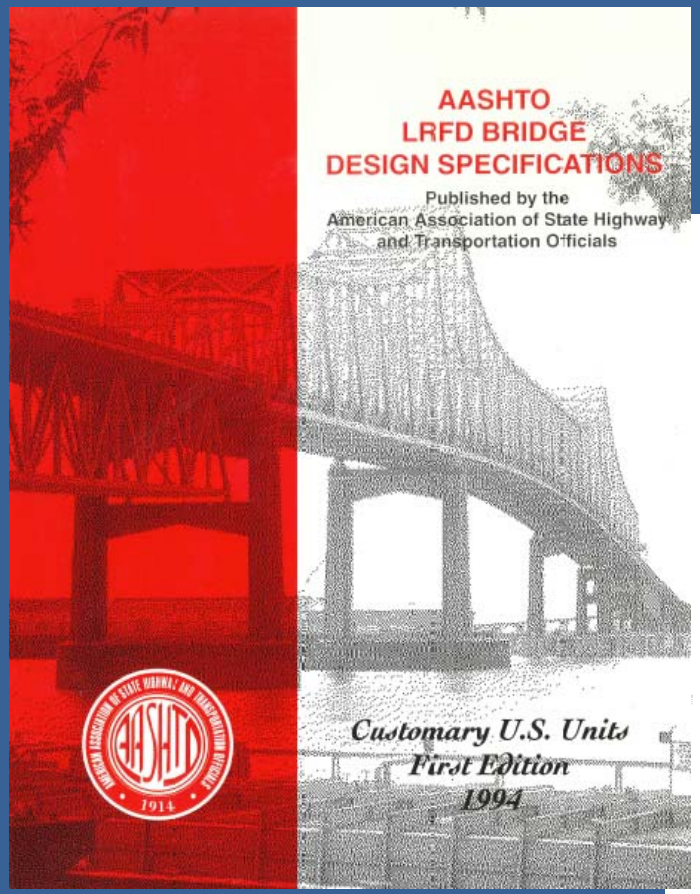
Presentation Overview

- Pier Protection
  - Introduction
  - Original AASHTO LRFD Specification requirements
  - MnDOT Substructure Protection Policy
  - Changes to AASHTO LRFD Specifications
  - Changes to MnDOT policy
- Design & Detailing Issues

Pier Protection - Introduction



AASHTO LRFD Article 3.6.5

expected to brake out of phase.

3.6.5 Vehicular Collision Force: CT

3.6.5.1 PROTECTION OF STRUCTURES

C3.6.5.1

The provisions of Article 3.6.5.2 need not be considered for structures which are protected by:

- an embankment,
- a structurally independent, crashworthy ground-mounted 54.0-IN high barrier, located within 10.0 FT from the component being protected, or
- a 42.0-IN high barrier located at more than 10.0 FT from the component being protected.

In order to qualify for this exemption, such barrier shall be structurally and geometrically capable of surviving the crash test for Performance Level 3, as specified in Section 13.

For the purpose of this article, a barrier may be considered structurally independent if it does not transmit loads to the bridge.

Full scale crash tests have shown that some vehicles have a greater tendency to lean over, or partially cross over, a 42.0-IN high barrier than a 54.0-IN high barrier. This behavior would allow more significant collision of the vehicle with the component being protected if located within a few FT of the barrier. If the component is more than about 10.0 FT behind the barrier, the difference between the two barrier heights is no longer important.

3.6.5.2 VEHICLE AND RAILWAY COLLISION WITH STRUCTURES

C3.6.5.2

Unless otherwise permitted in Article 3.6.5.1, abutments and piers located within a distance of 30.0 FT to the edge of roadway, or within a distance of 50.0 FT to the centerline of a railway track, shall be designed for an equivalent static force of 400 KIP, assumed to act in any direction in a horizontal plane, at a distance of 4.0 FT above ground.

The equivalent static force of 400 KIP is based on the information resulting from full-scale crash tests of barriers for redirecting 80.0-KIP tractor trailers and from analysis of other truck collisions. The 400-KIP train collision load is based on recent, physically unverified, analytical work, Hirsch (1989). For individual column shafts, the 400-KIP load should be considered a point load. For wall piers, the load may be considered to be a point load or may be distributed over an area deemed suitable for the size of the structure and the anticipated impacting vehicle, but not greater than 5.0 FT wide by 2.0 FT high. These dimensions were determined by considering the size of a truck frame.

Pier Protection - Introduction

Figure 2.12. Truck Accident – Mile Post 519 Bridge over IH-20, Canton, Texas.

Pier Protection - Introduction

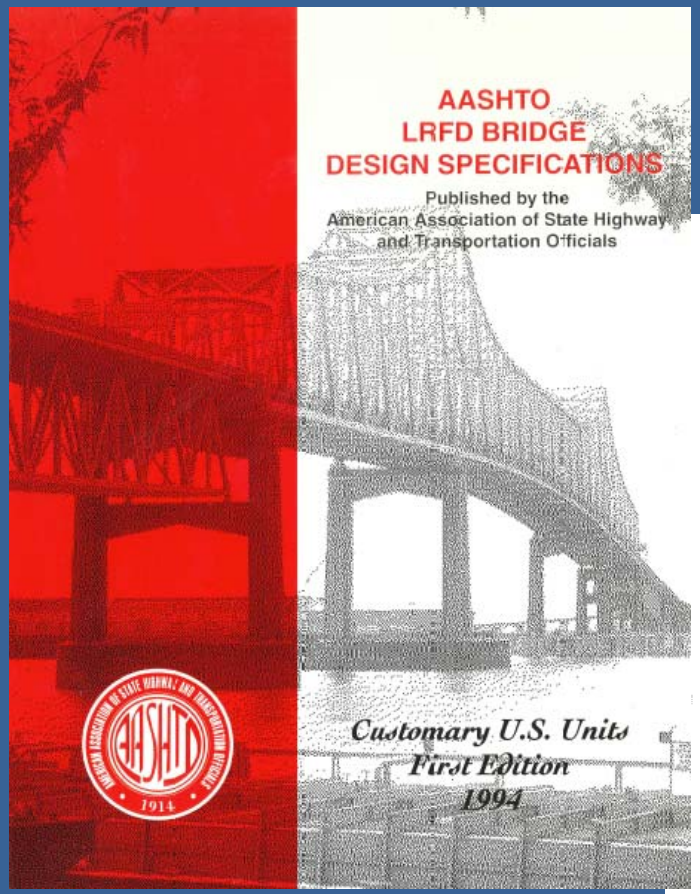
Pier Protection - Introduction

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

Pier Protection - Introduction

I-90 near
Worthington, MN

AASHTO Spec Requirements



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AASHTO Spec Requirements

- Three options for protection given in Article 3.6.5
  1) Locate pier outside of clear zone (30 ft for roadway & 50 ft for railway)
  2) Protect pier by placing a TL-5 barrier in front, with barrier height dependent on clear distance
  3) Design pier to resist a collision load
     - 400 kip load for truck or train
     - Load applied at any angle
     - Load applied at 4 ft above ground

AASHTO Spec Requirements

- Applied to all substructures, with no variation in requirements
- No consideration of the probability of a vehicle collision
- No reduction in collision load or required protection for low speeds and low truck traffic

MnDOT Substructure Protection Policy

Designer Memo 2007-01

http://www.dot.state.mn.us/bridge/manuals/LRFD/index.html

Mn/DOT Bridge Office Substructure Protection Policy

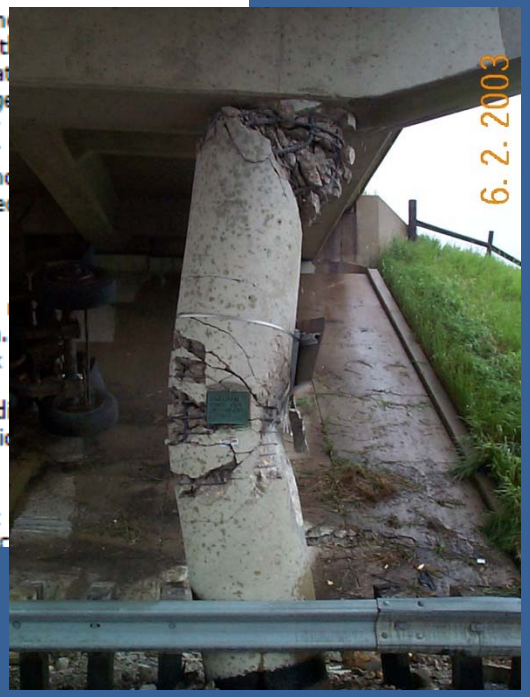
The purpose of this document is to define the Mn/DOT policy for design of bridge substructures as it relates to Article 3.6.5 of the AASHTO LRFD Bridge Design Specifications.

Article 3.6.5 of the LRFD Specifications includes requirements for th
structures against vehicle and railway train collision. The intent of t
protect bridges from vehicle and train hits on a substructure that
progressive collapse of the bridge. The article states that all bridge
located within 30 feet of a roadway or within 50 feet of a railway
protected by a structurally independent Test Level 5 (TL-5) barrier or
resist an equivalent static load of 400 kips. The barrier must be 54 in
placed within 10 feet of the substructure and 42 inches high when place
feet from the substructure. The 400 kip load is to be applied at 4
ground, in any direction in a horizontal plane.

Mn/DOT considers Article 3.6.5 to be overly restrictive because it does
variation in requirements due to the probability of vehicle collision.
allowance for reduction in the load or protection due to amount of truck
of traffic adjacent to the substructure. Mn/DOT has raised this issue
Loads Committee along with suggested revisions to Article 3.6.5. Pend
the LRFD Specifications, the following guidelines for substructure protecti

Abutments

Due to the existence of soil behind abutment walls, abutments are not
collision load and are considered exempt from meeting the substruc



MnDOT Substructure Protection Policy

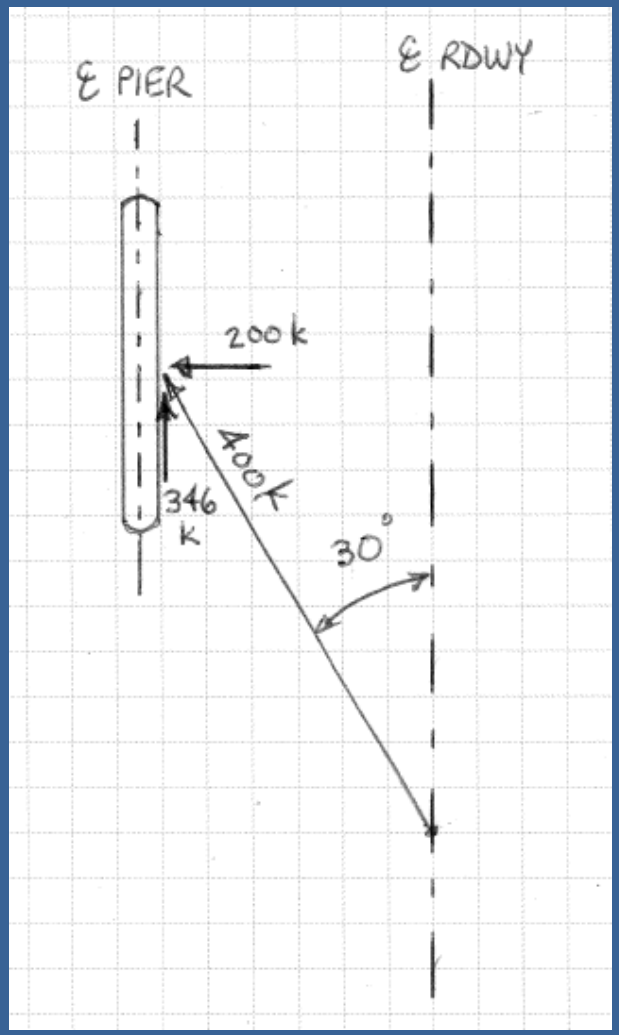
- Exemptions for substructure protection given to the following:
  - All abutments, due to soil behind them
  - Piers with redundancy (3 or more columns) adjacent to roadways with design speeds ≤ 40 mph
  - Piers with redundancy (3 or more columns) adjacent to roadways with design speeds > 40 mph that are not on the National Highway System and have an ADTT < 250

MnDOT Substructure Protection Policy

- All other new piers must meet the AASHTO LRFD Article 3.6.5 requirements modified as follows:
  - Spread footing, pile, and drilled shaft foundations are considered adequate to survive a collision and need not be analyzed
  - For piers designed to resist collision loading, apply the 400 kip load at a maximum angle of 30 degrees from the direction of the roadway or railway tangent

MnDOT Substructure Protection Policy

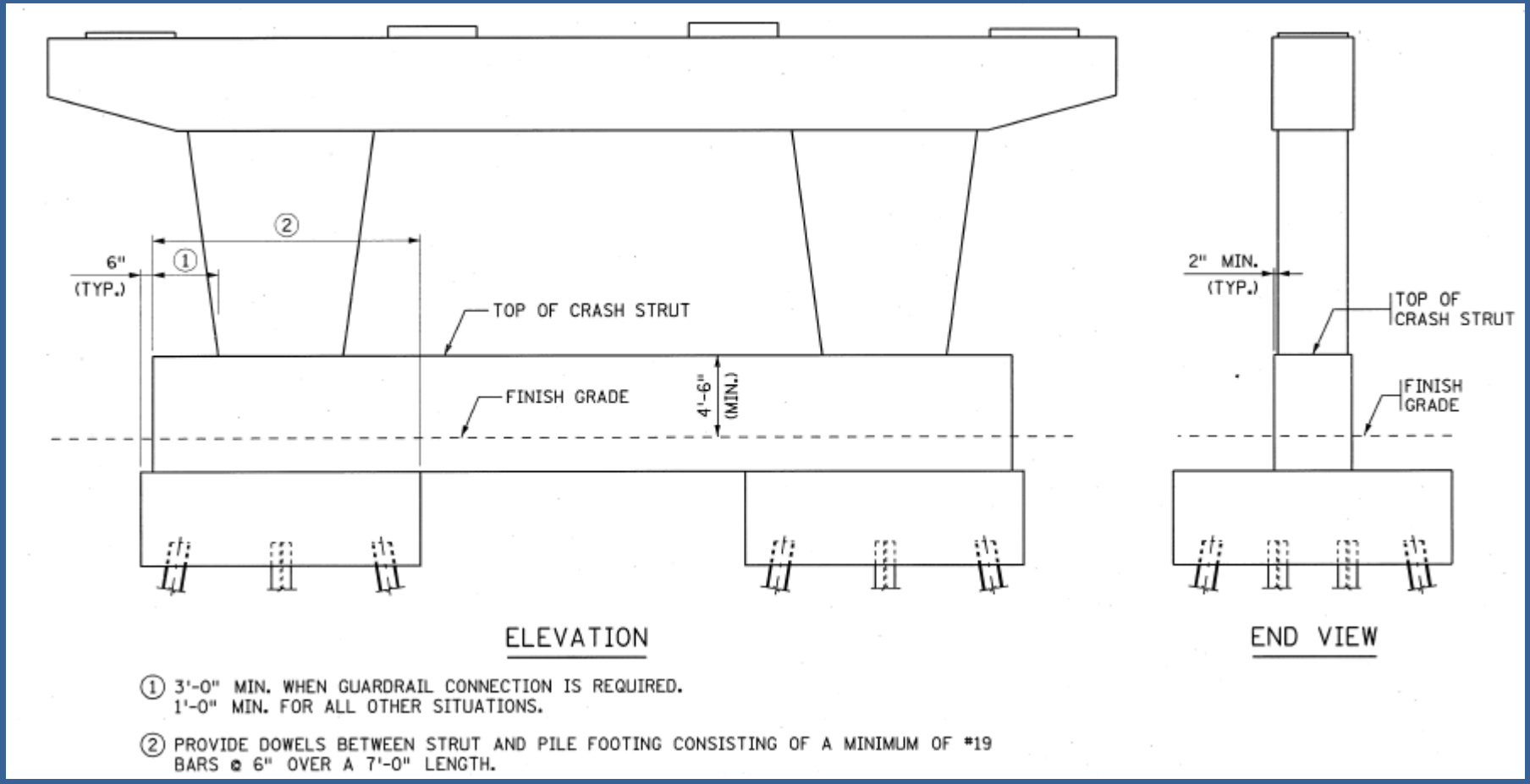
- Results in max transverse collision load component = 200 kips



MnDOT Substructure Protection Policy

- For new piers designed to resist collision loading:
  - Design columns to resist the collision load
  - Provide a crash strut designed to resist the collision load and having a height of 54 inches above the ground

MnDOT Substructure Protection Policy



MnDOT Substructure Protection Policy

- Existing piers on bridge repair projects that include substructure widening must meet the AASHTO LRFD Article 3.6.5 requirements (as modified by MnDOT)
- Existing piers on other bridge repair projects will typically be considered exempt

AASHTO Pier Protection Changed

- Other states wrestled with this issue
- Was discussed in AASHTO T-5 Loads Committee
- Pooled fund study formed
- In 2010 AASHTO LRFD 5th Edition, revision made that allowed owner discretion:

  "Unless the Owner determines that site conditions indicate otherwise…"

AASHTO Pier Protection Changed

- TPF-5(106) Guidelines for Designing Bridge Piers & Abutments for Vehicle Collisions

  Texas Transportation Institute

AASHTO Pier Protection Changed

- TPF-5(106) objectives:
  - Determine what risks warrant application of pier protection requirements
  - Determine whether magnitude of 400 kip load is appropriate

AASHTO Pier Protection Changed

- Collision loads found to be significantly higher

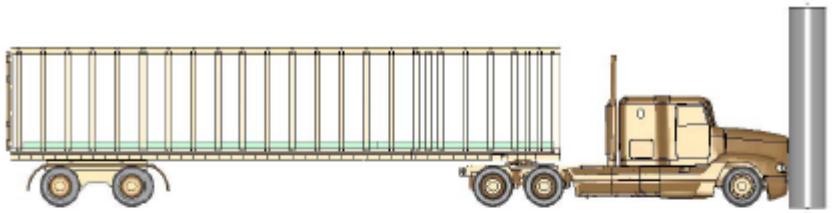
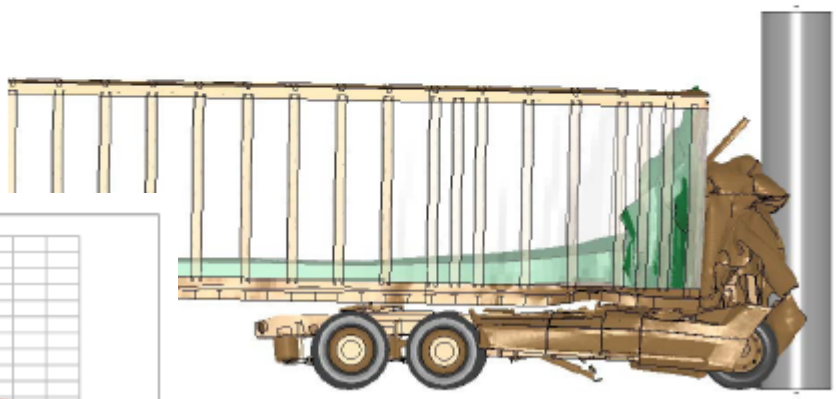


Figure 4.58. Trailer with Deformable Cargo Pre-Impact (Right View).



ure 4.59. Sloshing of Tractor-Trailer Cargo (Right View).

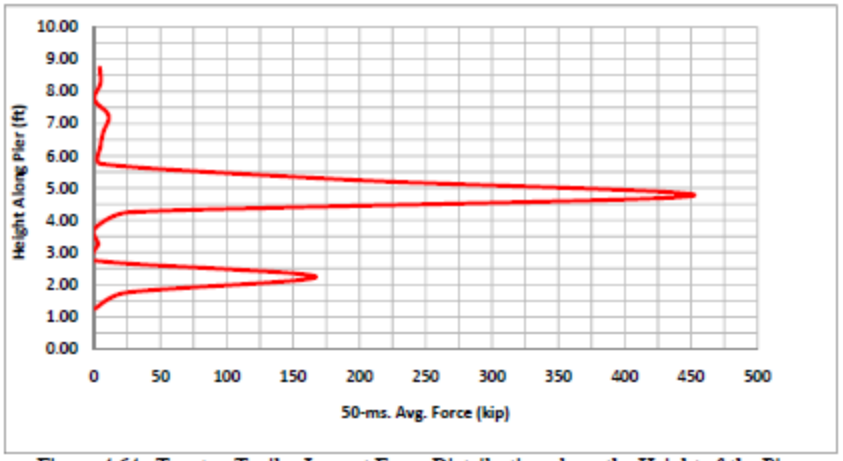


Figure 4.64. Tractor-Trailer Impact Force Distribution along the Height of the Pier at 0.2 sec.

What are the AASHTO Changes?

- 5th Edition
  - 400 k load
  - Load applied at any angle
  - Load applied at 4 ft above ground

- 6th Edition
  - 600 k load
  - Load applied at up to 15 degrees from roadway tangent
  - Load applied at 5 ft above ground

What are the AASHTO Changes?

- 5th Edition
  - Requirements applied for roadways within 30 ft and railways within 50 ft

- 6th Edition
  - Train collision provisions removed
  - Commentary suggests following:

    American Railway Engineering and Maintenance-of-way Association (AREMA) Manual for Railway Engineering

What are the AASHTO Changes?

- 6th Edition
  - Commentary now includes discussion on what site conditions warrant exemption from pier protection requirements
  - Exemption based on AF_{HBP} = annual frequency of bridge pier hits by a heavy vehicle
  - Commentary would not require pier protection when:
    - $AF_{HBP} < 0.0001$ for critical or essential bridges
    - $AF_{HBP} < 0.001$ for typical bridges

What are the AASHTO Changes?

- 6th Edition

Table C3.6.5.1-1—Typical Values of AF_{HBP}

ADT (Both Directions)	ADTT* (One Way)	Undivided	Divided Curved	Divided Tangent
		P_{HBP}=3.457E-09	P_{HBP}=2.184E-09	P_{HBP}=1.09E-09
		$AF_{HPB} = 2 \times ADTT \times 365 \times P_{HBP}$		
1000	50	0.0001	0.0001	0.0000
2000	100	0.0003	0.0002	0.0001
3000	150	0.0004	0.0002	0.0001
4000	200	0.0005	0.0003	0.0002
6000	300	0.0008	0.0005	0.0002
8000	400	0.0010	0.0006	0.0003
12000	600	0.0015	0.0010	0.0005
14000	700	0.0018	0.0011	0.0006
16000	800	0.0020	0.0013	0.0006
18000	900	0.0023	0.0014	0.0007
20000	1000	0.0025	0.0016	0.0008
22000	1100	0.0028	0.0018	0.0009
24000	1200	0.0030	0.0019	0.0010
26000	1300	0.0033	0.0021	0.0010
28000	1400	0.0035	0.0022	0.0011

*Assumes ten percent of ADT is truck traffic.

CRITICAL

TYPICAL

What are the AASHTO Changes?

- 6th Edition
  - Design speed is not a consideration in the latest revisions
  - Redundancy is also not a consideration

What is MnDOT's Policy now?

Mn/DOT Bridge Office Substructure Protection Policy

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Abutments
Due to the existence of soil be
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Figure 2.10. Truck Accident – IH-90 Bridge, #53812, Minnesota.

Policy Considerations

- New bridges
  - ADTT of roadway under
  - Design speed of roadway under
  - Redundancy
  - Critical roadway under or over
  - Pier distance to roadway
  - Side pier or median pier
  - Roadway alignment

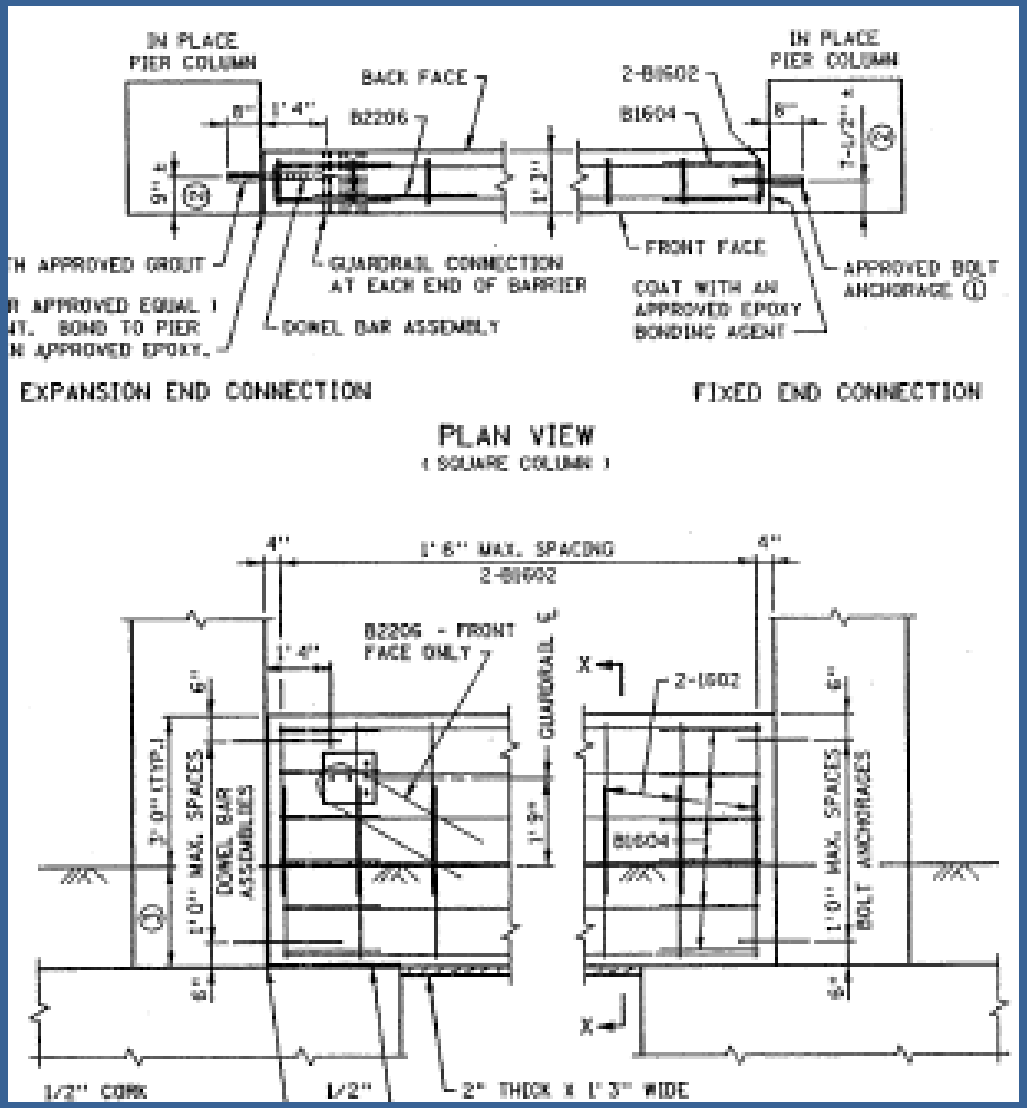
Policy Considerations

- Existing bridges
  - Everything mentioned for new bridges

    plus
  - Scope of the construction project
  - Existing median barrier
  - Existing in-fill wall

Policy Considerations

- In-fill wall based on archived standard plan 5-297.610
- Height is 36” and does not meet current AASHTO



Revised Policy for New Bridges

- Bridges over roadways
  - Will adopt 600 kip load with load application at up to 15 degrees maximum from tangent to roadway
  - Will continue exemption for all abutments, due to soil behind them
  - Will continue exemption for redundant piers (3 or more columns) adjacent to roadways with design speeds ≤ 40 mph

Revised Policy for New Bridges

- Bridges over roadways
  - Other criteria still being studied
    - Design speed > 40 mph
    - Exemption based on AF_{HBP}
    - Definition of critical bridge
    - Increase in height of collision load impact

Revised Policy for New Bridges

- Bridges over railroads
  - Will follow requirements found in

    AREMA Manual for Railway Engineering

    Chapter 8, Article 2.1.5
    - Pier protection required when distance from centerline of railway to face of pier < 25 ft
    - When pier protection is required, can provide crash wall (minimum of 2.5 ft x 12 ft) with height of 6 ft or 12 ft above top of rail depending on clearance to rail

      or

      pier shall be “of heavy construction”

      (minimum cross-sectional area of 30 sq ft)

Revised Policy for New Bridges

- Bridges over railroads

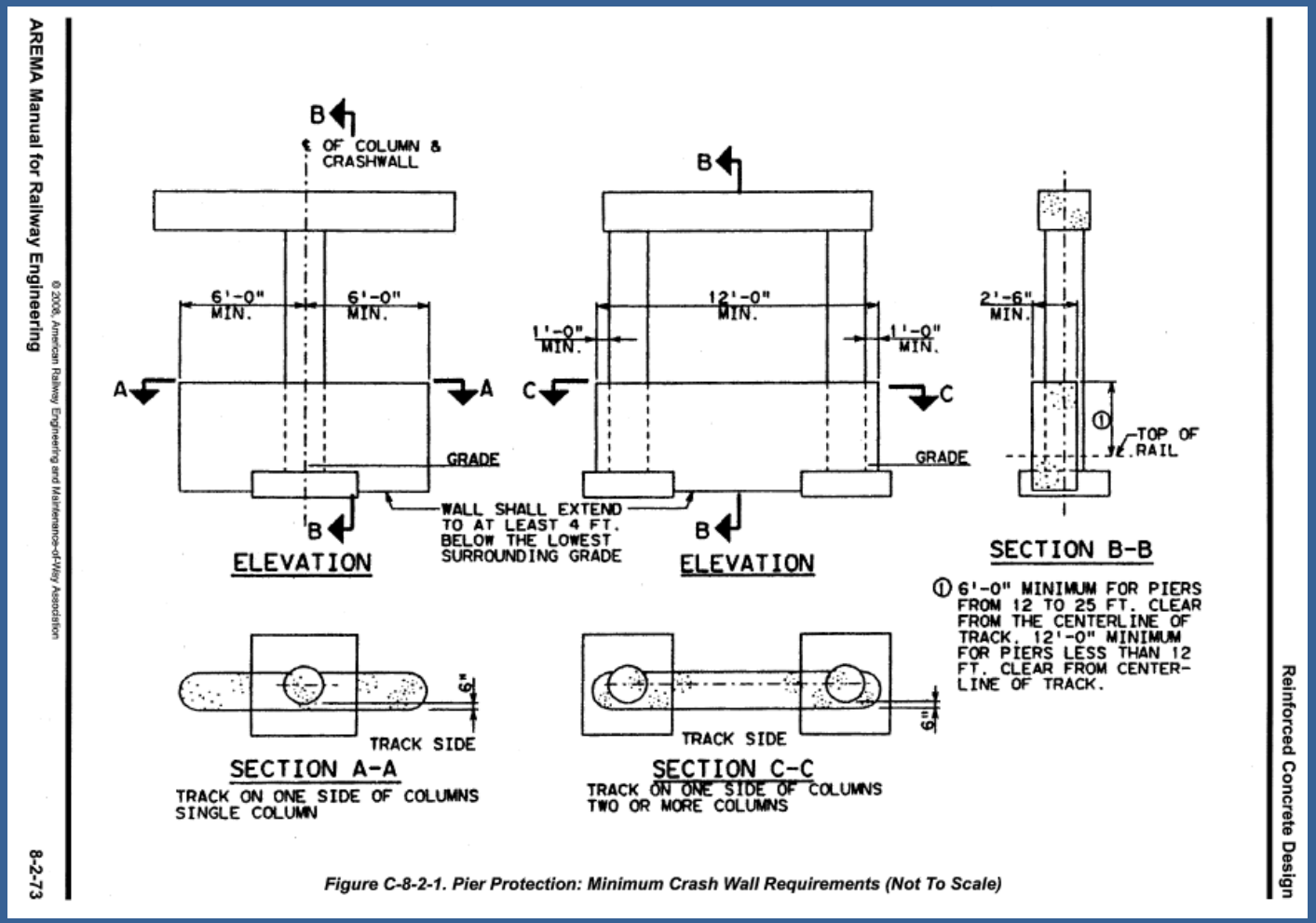


Figure C-8-2-1. Pier Protection: Minimum Crash Wall Requirements (Not To Scale)

Revised Policy for Existing Bridges

- Retrofitting of piers to meet current pier protection policy will be required for:
  - Bridge repair projects that include substructure widening
  - Roadway projects beneath bridges that move the edge of travel lane within 30 feet of the pier

Revised Policy for Existing Bridges

- Retrofitting of piers to meet current pier protection policy will be considered for bridge repair projects in the following situations:
  - High speed limit
  - High ADTT
  - Curved alignment
  - Piers with less than 3 columns & non-continuous superstructure

Revised Policy for Existing Bridges

- Retrofitting of piers to meet current pier protection policy will be considered for roadway projects in the following situations:
  - Profile grade raise resulting in significant reduction of current in-fill wall height
  - Guardrail replacement where new connections to piers are required

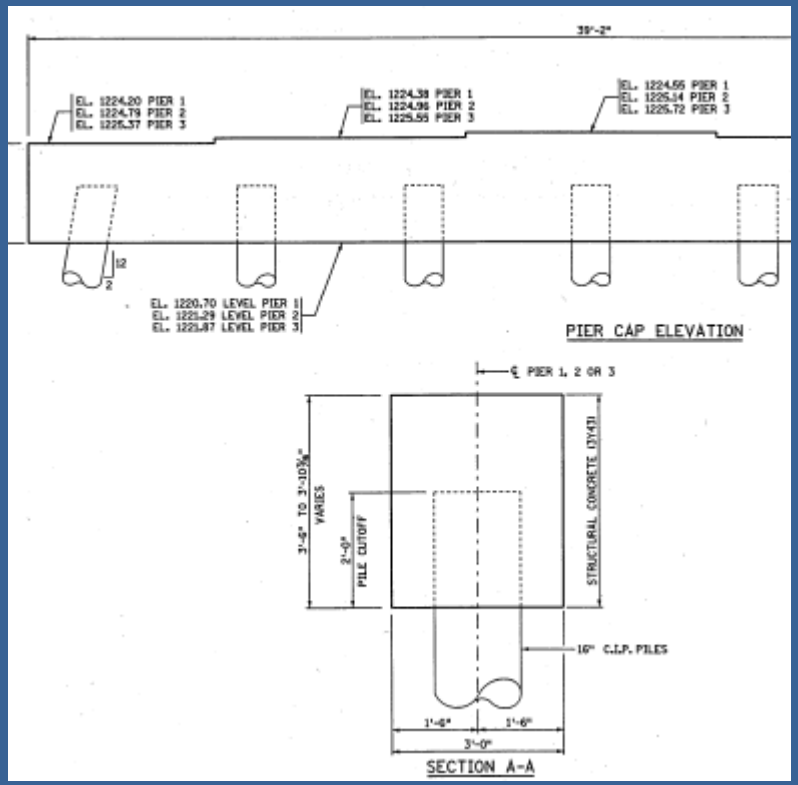
Future Changes?

- NCHRP 12-90 Guidelines for Shielding Bridge Piers
  - Develop risk-based guidelines that quantify when pier protection investigation is needed considering site conditions, traffic, etc.
  - Develop guidelines for barrier selection, length, and placement to shield bridge piers

- 3 year project

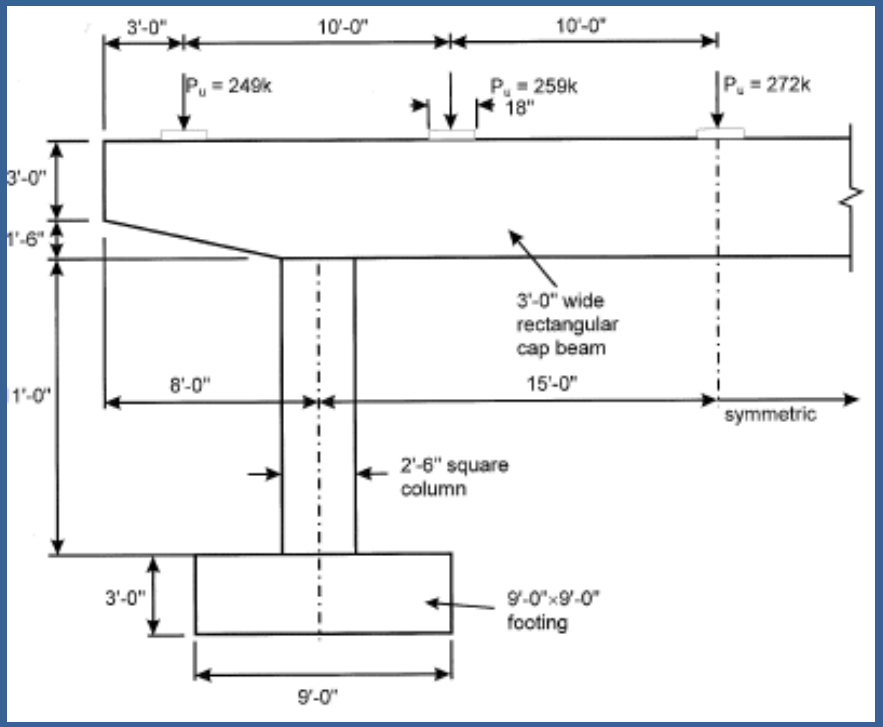
Design & Detailing Issues

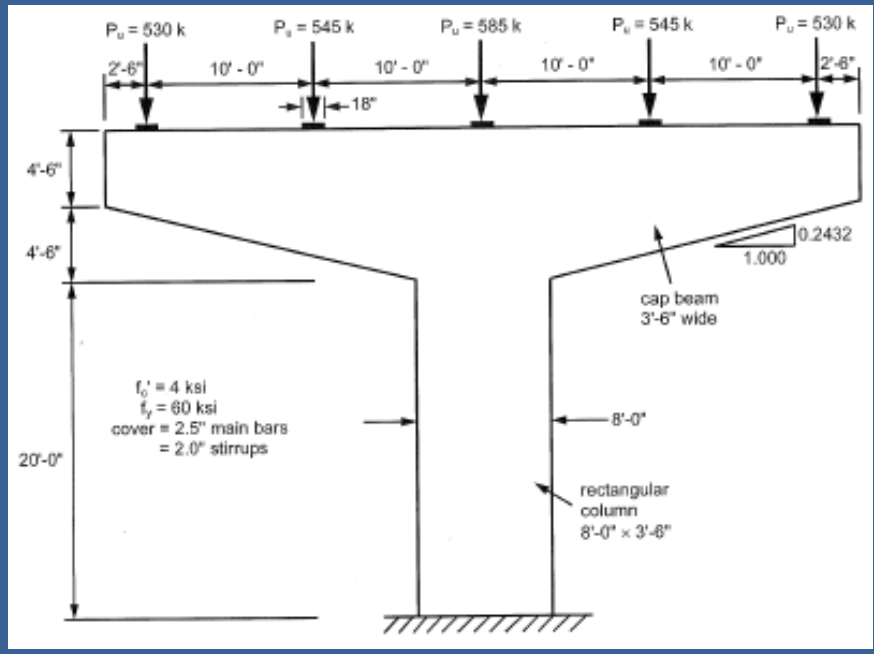
- Pile bent piers
  - Check stability
    - Consider scour
    - Do not use MnDOT Bridge Design Manual (BDM) Article 10.6



Design & Detailing Issues

- Pier caps
  - Strut and tie





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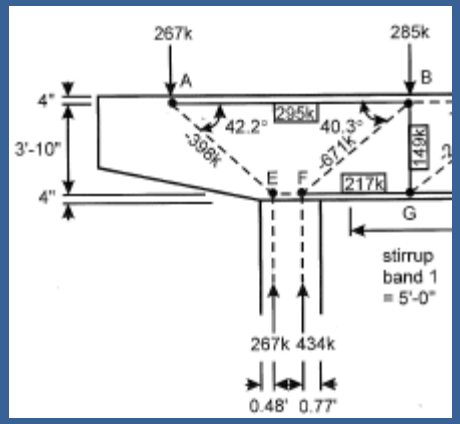
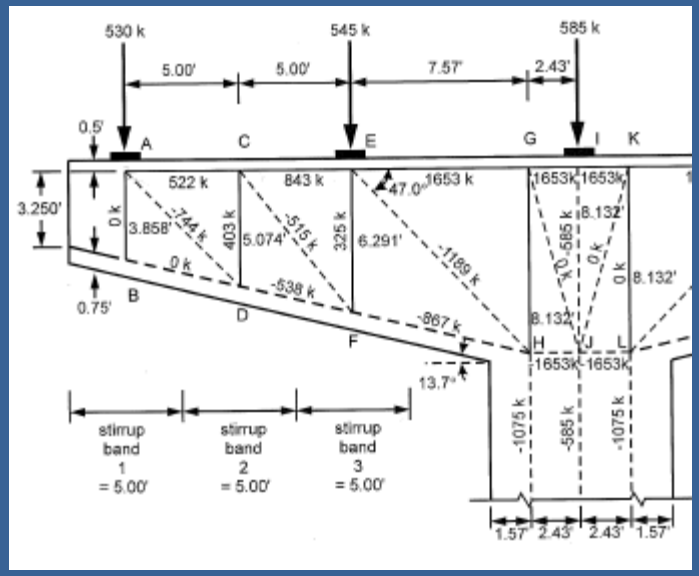
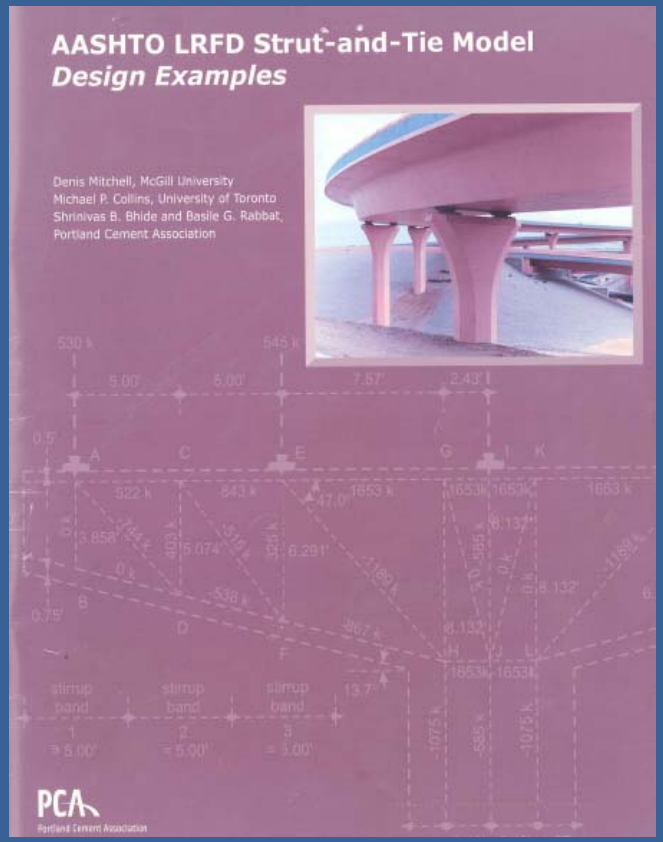
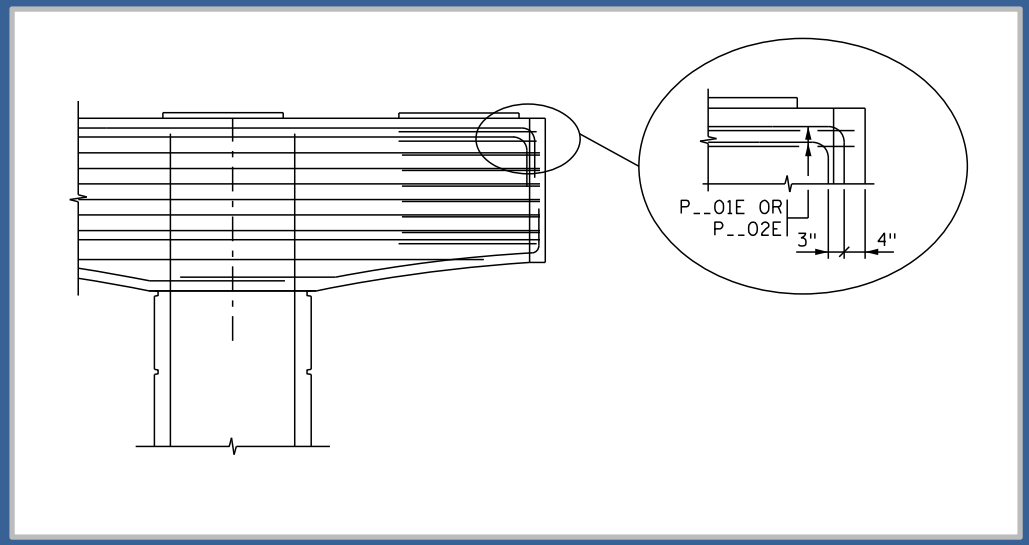






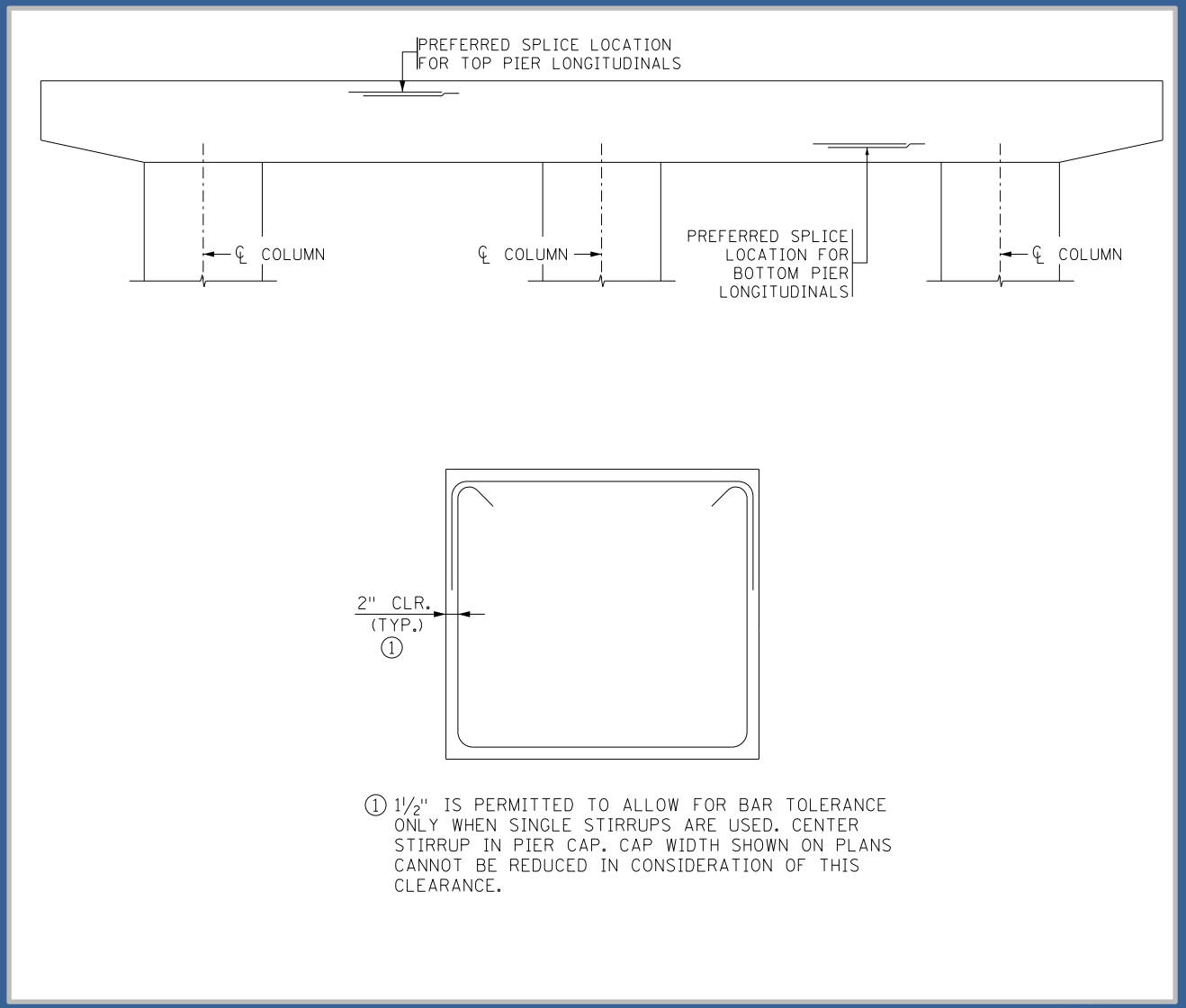
Design & Detailing Issues

- Pier caps
  - Provide standard hooks at ends of longitudinal bars & detail bars to avoid conflicts



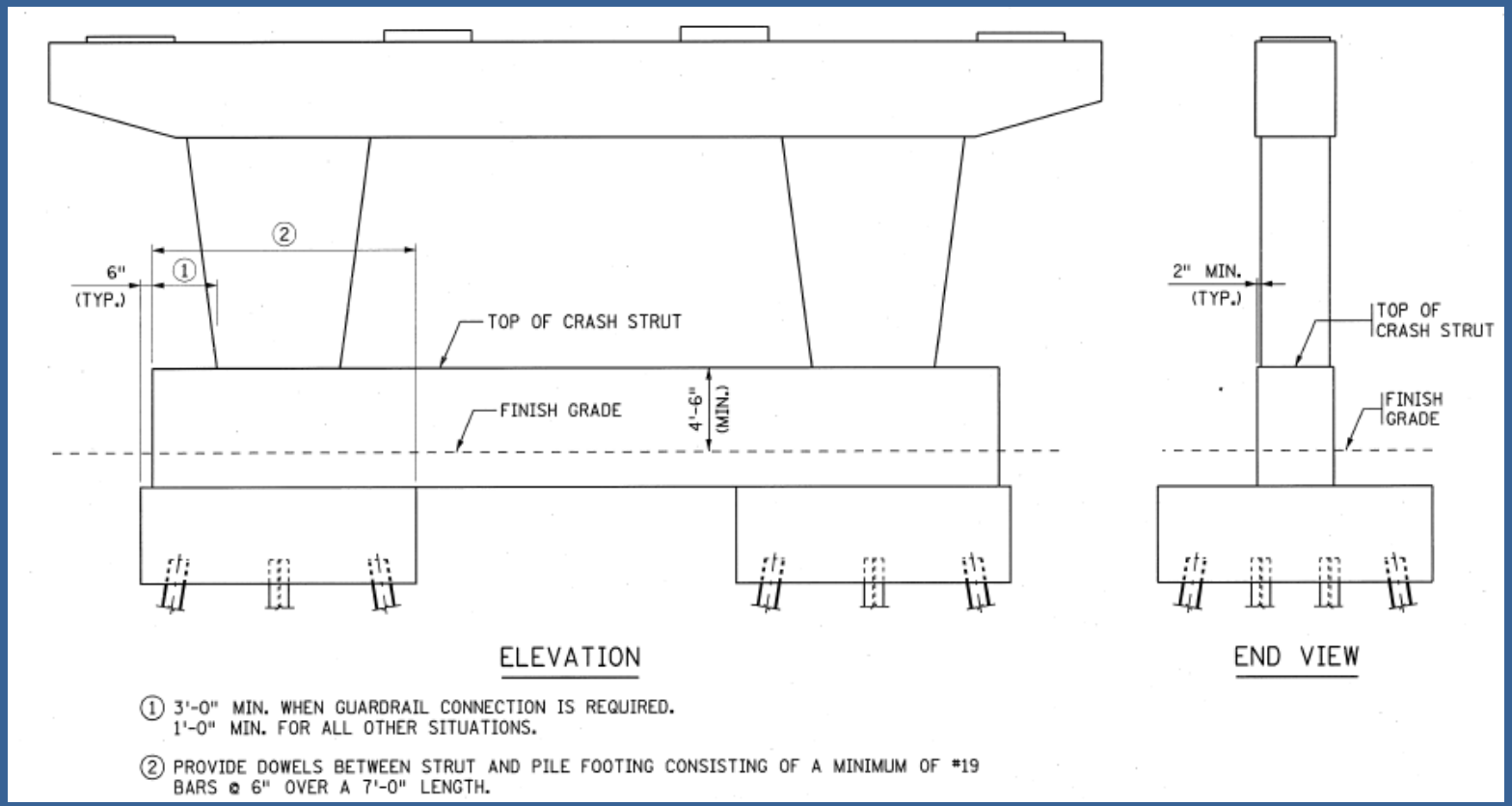
Design & Detailing Issues

- Pier caps
  - Provide spliced longitudinal bars
  - For single stirrups, provide note



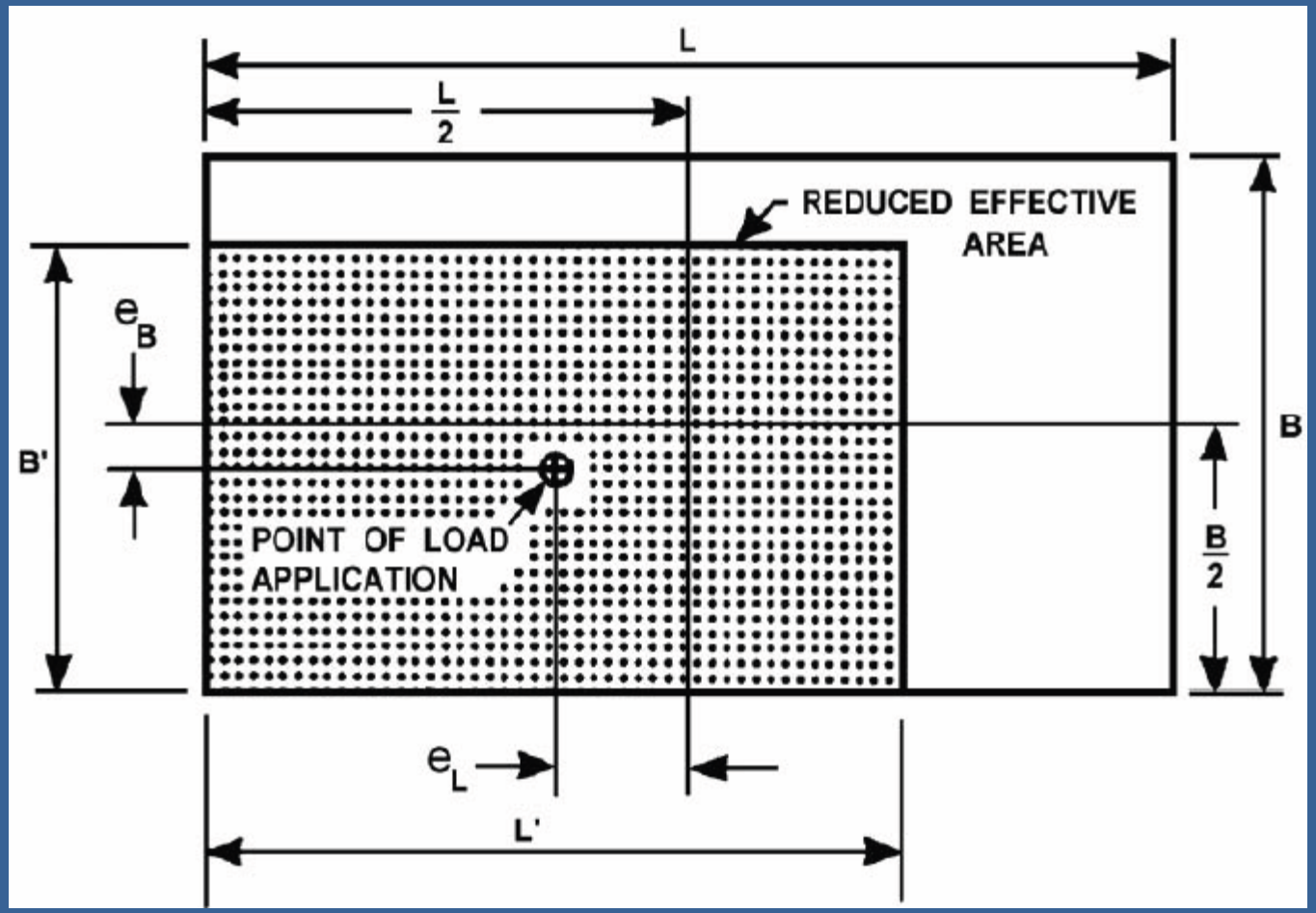
Design & Detailing Issues

- Pier columns
  - Thermal loads



Design & Detailing Issues

- Piers on spread footings



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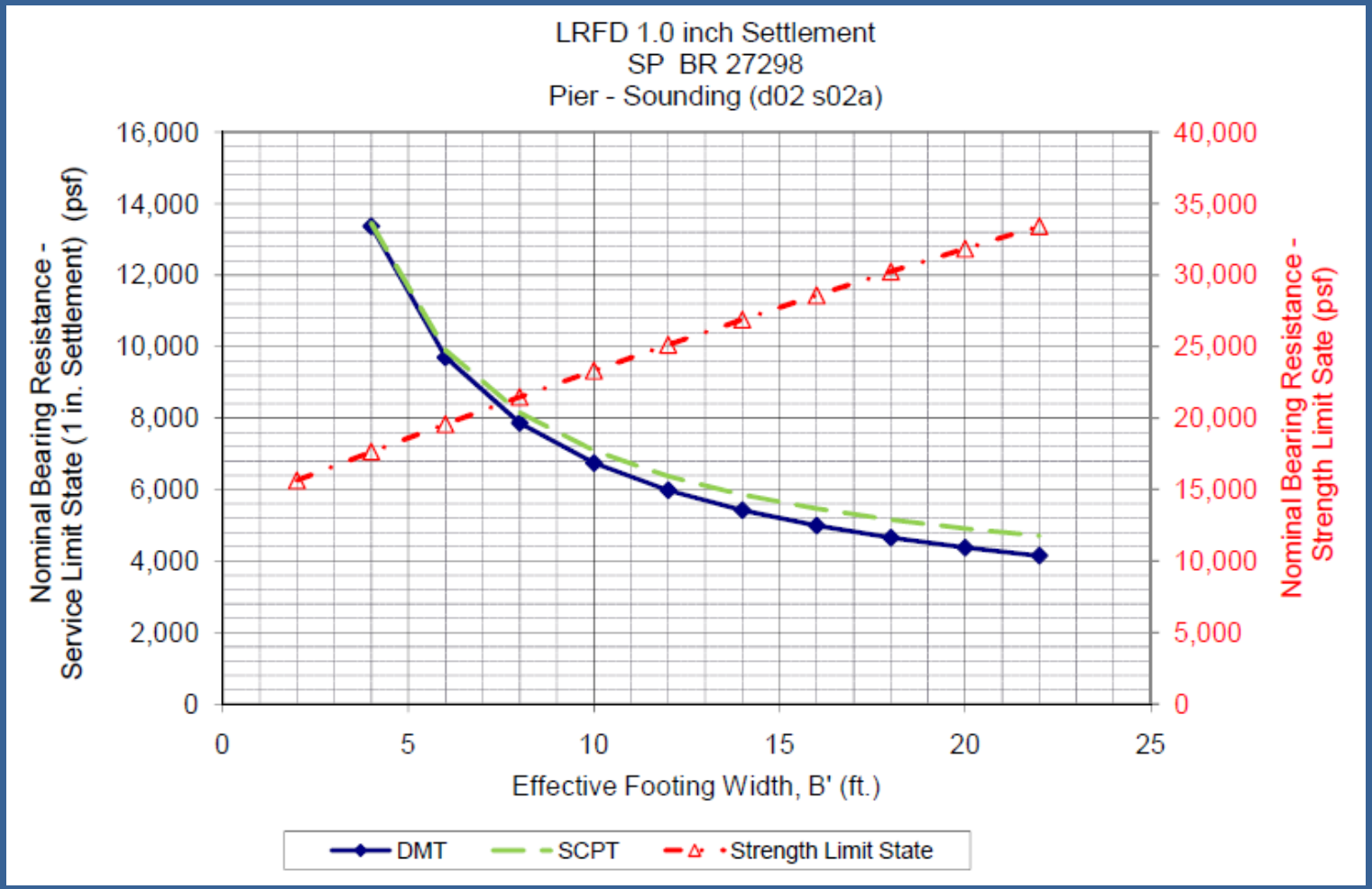

Questions?