INTRODUCING:
THE NEW PCI BRIDGE DESIGN MANUAL
and
PCI Precast “Folded Slabs”
for
Superelevation Transitions

PCI Precast/Prestressed Concrete Institute

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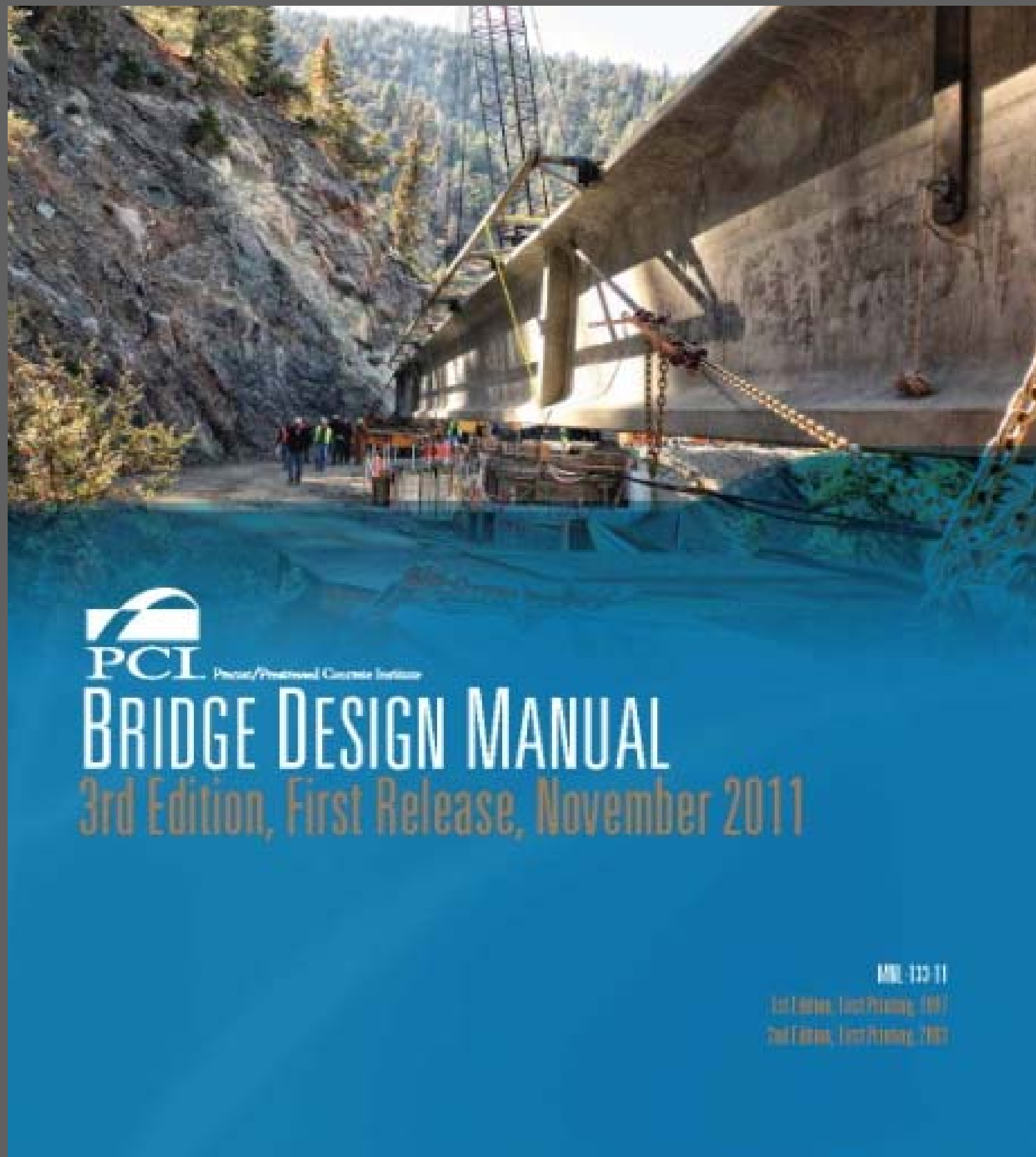

BDM HISTORY

- The original BDM dates to Oct. 1997.
  - At that time, many States still used the old AASHTO Standard Specifications.
- 2nd Edition 2003
- Between 1997 and 2009, chapters were added and existing chapter updated.
- Last Revision: June 2009 – added Chapters 5 (aesthetics) , 10 (bearings) and 20 (piles).
- Last update of Chapter 9, Design Examples was July 2003.
- Third Edition released 2011; through *LRFD Specifications, 5th Ed.*

WHY THE EXTENSIVE REWRITE?

- Standard Specification references and examples are no longer needed.
- The BDM needed to add changes in knowledge, technology and materials since the original version was written. This could not be done with a simple update.
- The BDM needed to be updated to current LRFD Specifications
- Ch 18 updated to include LRFR.

OUR GOAL

PCI Precast/Prestressed Concrete Institute

The Bridge Design Manual should be educational as well as an excellent reference on bridge design.

EDUCATION

PCI Precast/Prestressed Concrete Institute

- Expanded design examples show various options for bridge design methods
- Improved chapters cover complex or less common design methods.
- Information on new technologies

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GENERAL CHANGES TO ALL CHAPTERS

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- Unnecessary material on Standard Specifications has been removed.
- All references to AASHTO or ASTM Specifications have been updated through 2011.
- Notation has been standardized and made consistent with all applicable AASHTO Specifications.

CHAPTER 1 - SUSTAINABILITY

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A NEW CHAPTER!

ADDRESSES THE ISSUES/QUESTIONS ABOUT SUSTAINABILITY

CHAPTER 1 - SUSTAINABILITY

1.1 Scope

1.2 Life Cycle

- Addresses life cycle cost, service life and environmental assessment

1.3 Sustainability Concepts

- Triple bottom line, cost of green, “reduce, reuse, recycle”.

CHAPTER 1 - SUSTAINABILITY

1.4 Sustainability and Precast Concrete Bridges

– Durability, resistance to disasters and environmental benefits.

1.5 Sustainable Features of Precast Concrete

– Use of recycled/waste materials, use of local materials and reduction of waste in the factory.

CHAPTER 1 - SUSTAINABILITY

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1.6 Simplified Tools and Rating Systems

1.7 State of the Art and Best Practices

- -Green plants are a reality at PCI
- -Second Generation of Plant Certification WILL have requirements for green plants (more to come!)

CHAPTER 2 – MATERIALS

Update to recent HPC developments and ASTMs

CHAPTER 3- Production

References have been added to:

- **FHWA Report on Lightweight Concrete**
- **FHWA Report on UHPC Connections**
- **PCI Full Depth Deck Panel Report**
- **PCI State of the Art of Report on Box Girders**

CHAPTER 4 – Economy

Minor update to reflect recent proper and safe practices

Added references on:

FHWA "Everyday Counts"

FHWA Accelerated Bridge Construction

NCHRP Reports 472 and 698 (seismic)

CHAPTER 5- Aesthetics

No Changes

CHAPTER 4 - ECONOMY

Chapter 4 now discusses proper width of bearing pads, and refers the reader to Chapter 10.

CHAPTER 6 – PRELIMINARY DESIGN

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Table 6.9-1
Design Charts

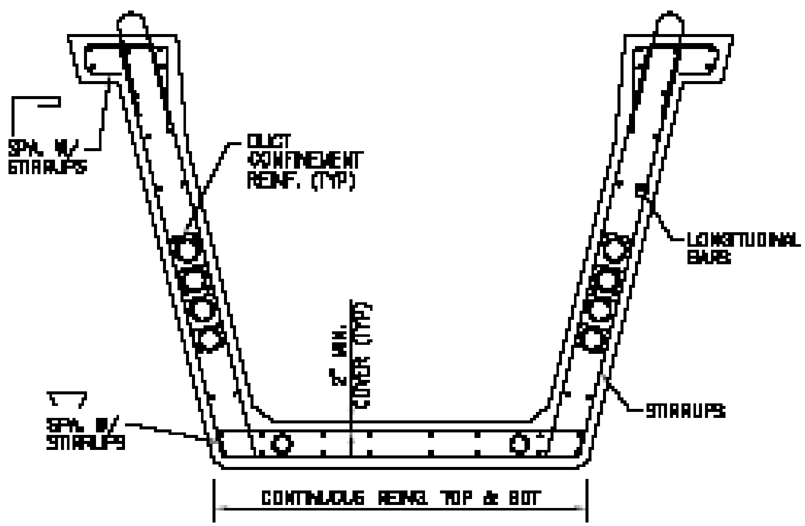
Chart No.	Beam Type	Chart Type
BB-1	AASHTO Box Beams 48 in. Wide	Maximum span versus beam spacing
BB-2	AASHTO Adjacent Box Beams 48 in. Wide	No. of strands versus span length
BB-3	AASHTO Spread Box Beams BII-48	No. of strands versus span length
BB-4	AASHTO Spread Box Beams BIII-48	No. of strands versus span length
BB-5	AASHTO Spread Box Beams BIV-48	No. of strands versus span length
BB-6	AASHTO Box Beams 36 in. Wide	Maximum span versus beam spacing
BB-7	AASHTO Adjacent Box Beams 36 in. Wide	No. of strands versus span length
BB-8	AASHTO Spread Box Beams BII-36	No. of strands versus span length
BB-9	AASHTO Spread Box Beams BIII-36	No. of strands versus span length
BB-10	AASHTO Spread Box Beams BIV-36	No. of strands versus span length

Table 6.9-1
Design Charts

Chart No.	Beam Type	Chart Type
NEXT-1	NEXT Type D Beams	Maximum span versus section depth
NEXT-2	NEXT Type D x 96 Beams	No. of strands versus span length
NEXT-3	NEXT Type D x 120 Beams	No. of strands versus span length
NEXT-4	NEXT Type F Beams	Maximum span versus section depth
NEXT-5	Next Type F x 96 Beams	No. of strands versus span length
NEXT-6	Next Type F x 144 Beams	No. of strands versus span length
U-1	U-Beams	Maximum span versus beam spacing
U-2	Texas U-40 Beams	No. of strands versus span length
U-3	Texas U-54 Beams	No. of strands versus span length
U-4	Washington U66G5Beams	No. of strands versus span length
U-5	Washington U78G5 Beams	No. of strands versus span length

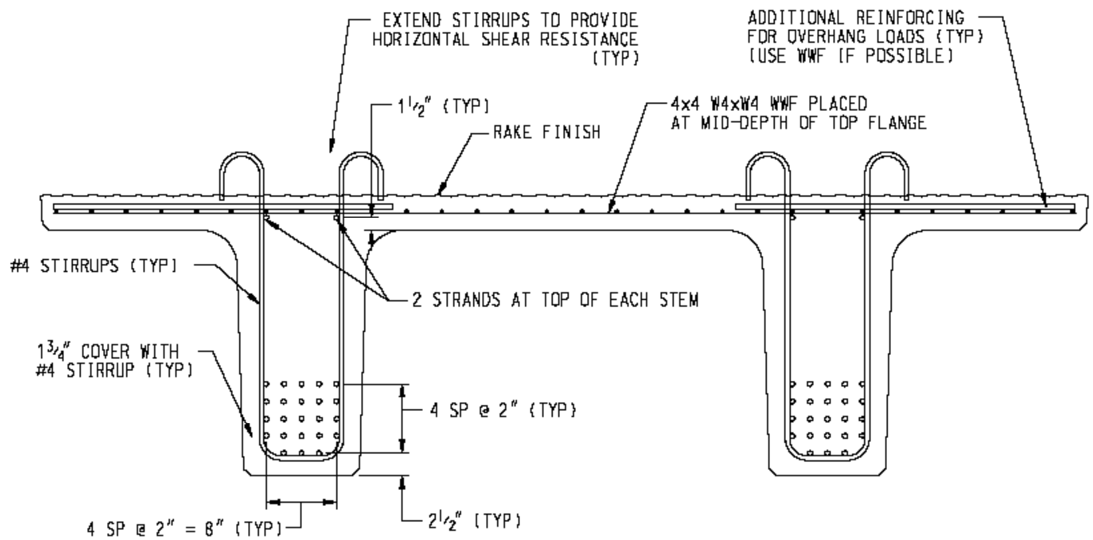
CHAPTER 6 – PRELIMINARY DESIGN

U Beam



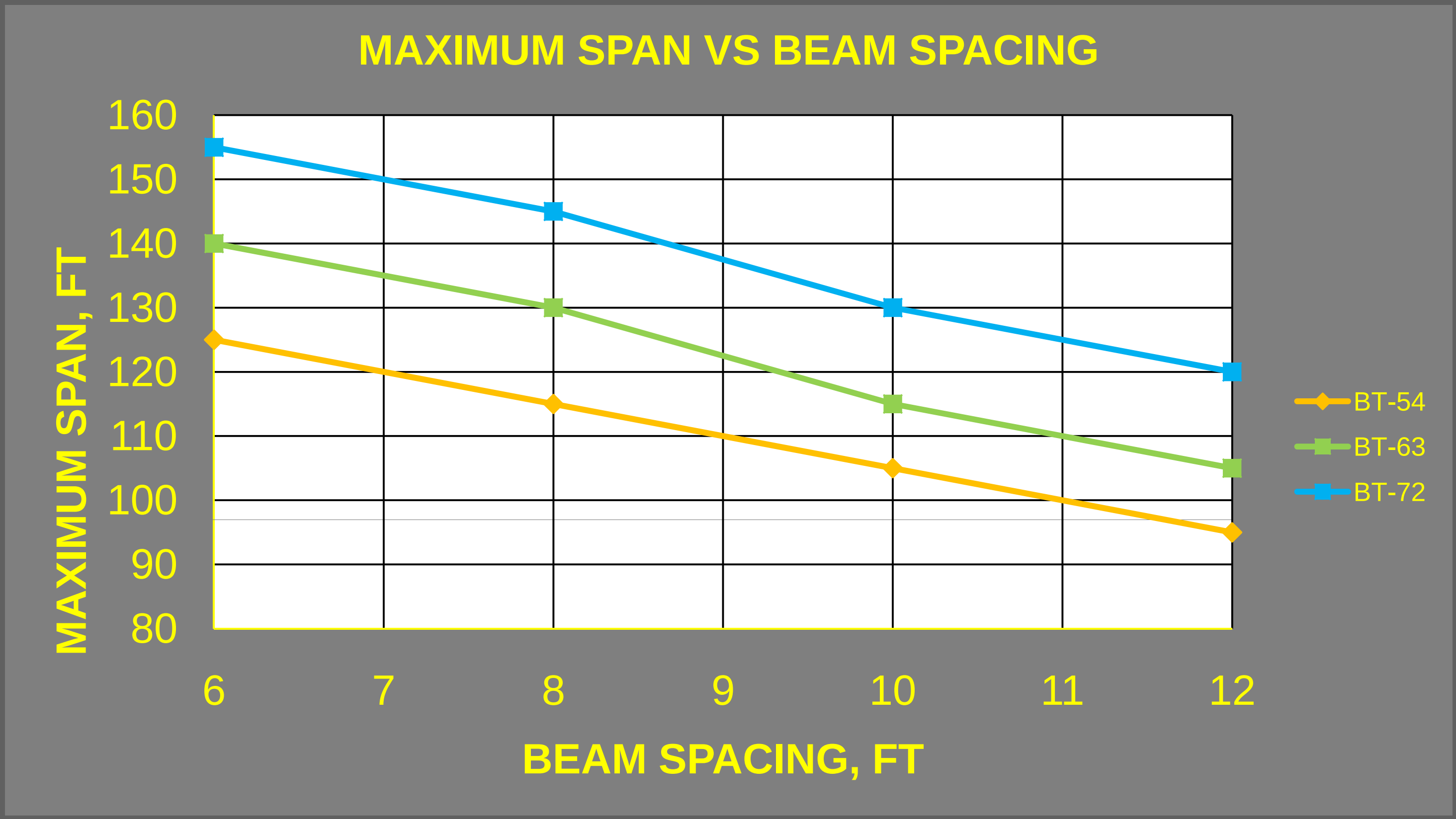
TYPICAL GIRDER REINFORCING

NEXT Beam



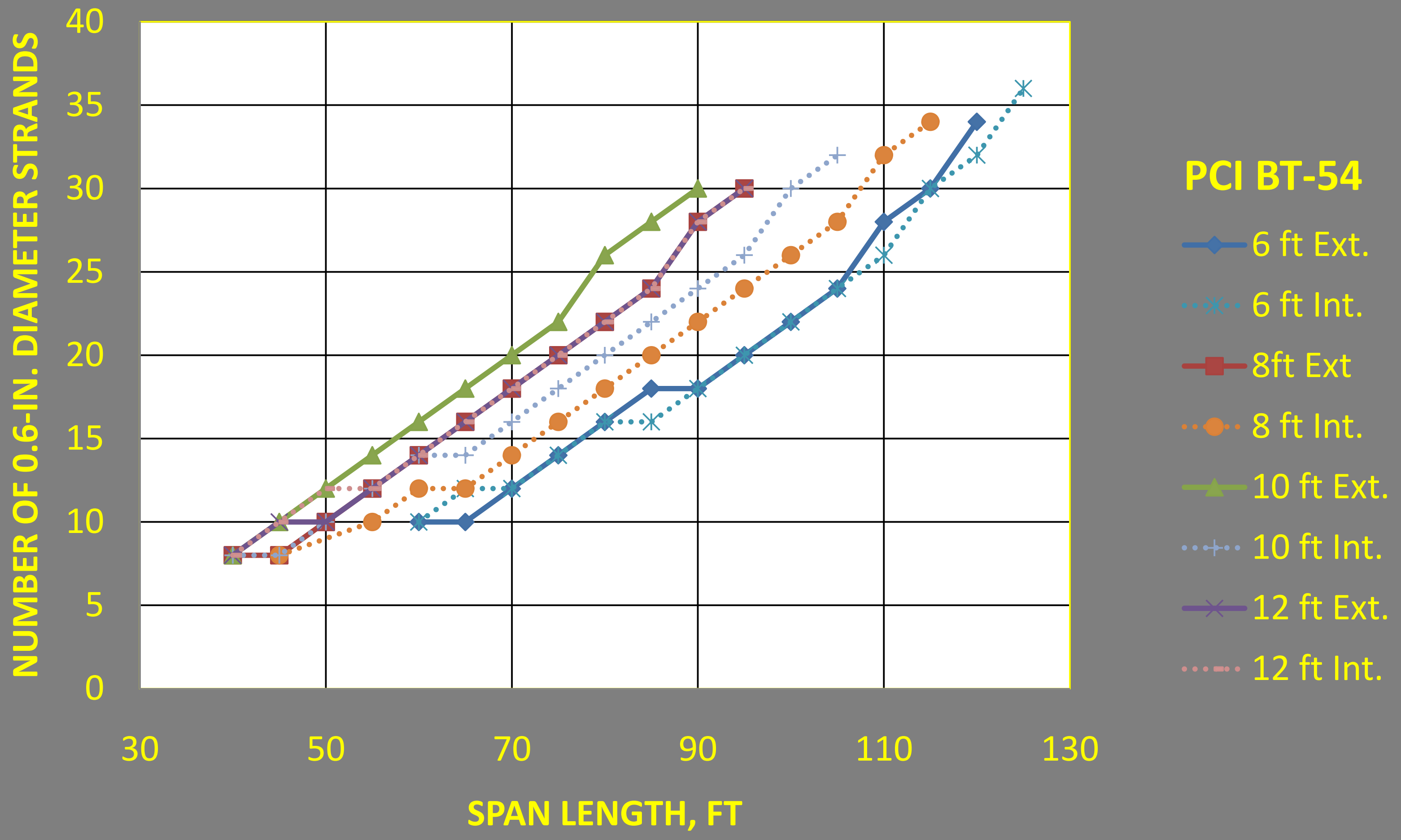
TYPICAL BEAM REINFORCING

CHAPTER 6 – PRELIMINARY DESIGN



Maximum Spans for Bulb Tee Girders

CHAPTER 6 – PRELIMINARY DESIGN



Number of Strands vs. Span Length for Bulb Tee Girders

Table BB-2
AASHTO Adjacent Box Beams 48 in. Wide

Spacing ft	Span ft	Slab Thickness in.	f'_{ci} ksi	No. of Strands	Camber in.	f_b @ $L/2$ ksi	f_t @ $L/2$ ksi	M_u @ $L/2$ ft-kips	M_r @ $L/2$ ft-kips	Control
AASHTO BII Adjacent 48-in.-Wide Exterior Box Beam										
BII	40	6	1.358	6	0.08	0.059	0.454	817	1,077	Strength
BII	45	6	1.344	6	-0.02	-0.121	0.610	992	1,077	Strength
BII	50	6	1.813	8	0.03	-0.053	0.720	1,186	1,414	Strength
BII	55	6	1.800	8	-0.18	-0.269	0.910	1,393	1,414	Strength
BII	60	6	2.266	10	-0.18	-0.238	1.051	1,612	1,741	Strength
BII	65	6	2.727	12	-0.21	-0.229	1.208	1,843	2,058	Strength
BII	70	6	3.185	14	-0.27	-0.240	1.382	2,088	2,365	Strength
BII	75	6	3.178	14	-0.87	-0.517	1.631	2,345	2,365	Stress
BII	80	6	4.091	18	-0.58	-0.326	1.779	2,615	2,951	Stress
BII	85	6	4.540	20	-0.87	-0.399	2.001	2,898	3,231	Stress
BII	90	6	4.986	22	-1.26	-0.493	2.240	3,194	3,502	Stress
BII	95	6	5.612	25	-1.54	-0.517	2.490	3,503	3,873	Stress
BII	100	6	6.409	29	-1.65	-0.479	2.754	3,825	4,327	Stress

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Major Changes

- More detailed information on fatigue.
- Information on loads in the *LRFD Specifications* has been updated.
- *Standard Specifications* information has been removed.

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- Sectional and Simplified methods for shear resistance calculation are presented
  - Sectional Model (modified compression field theory) using equations for β and θ.
  - Simplified Method (V_{ci} and V_{cw})
- Updated Horizontal Shear provisions

CHAPTER 9 – DESIGN EXAMPLES

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MAJOR REVISIONS!!

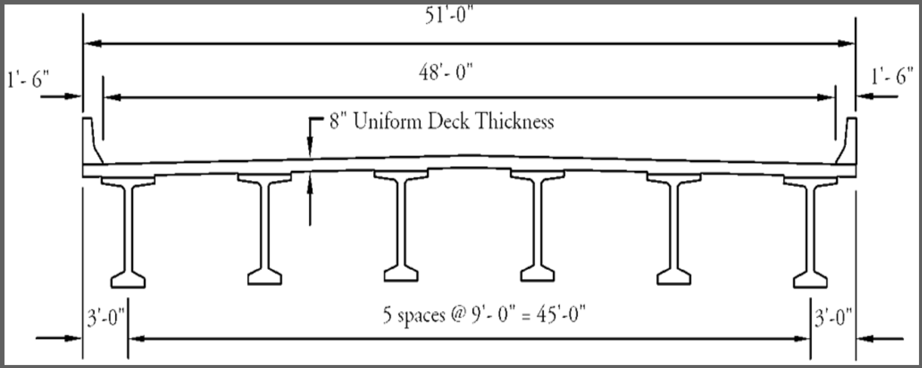
- 11 all new design examples (+ 1 to come later)
- All Examples based on *LRFD Specification, 4th Ed. w/ 2011 interim.*
- Examples illustrate
  - Use of gross and transformed sections
  - Use of approximate and refined losses
  - Use of Sectional Model (Modified Compression Field) and Simplified Shear.

NEW CHAPTER 9 EXAMPLES

No.	Type	Beam	Span (ft)	Cross Section	Losses	Shear
9.1a	Bulb T w/ deck Simple	BT-72	120	Transf.	Refined	Sectional
9.1b	Bulb T w/ deck Simple	BT-72	120	Gross	Refined	Sectional Table B5
9.1c	Bulb T w/ deck Simple	BT-72	120	Transf.	Approx.	V_{ci}/V_{cw}
9.2	Bulb T w/ deck Cont. for LL	BT-72	110 120 110	Transf.	Refined	Sectional
9.3	Adj. Deck Bulb T – Simple Span	DBT-72	95	Transf.	Refined	Sectional
9.4	Noncomp. Adj. Box w/transv. PT. Simple Span	BIII - 48	95	Transf.	Refined	Sectional

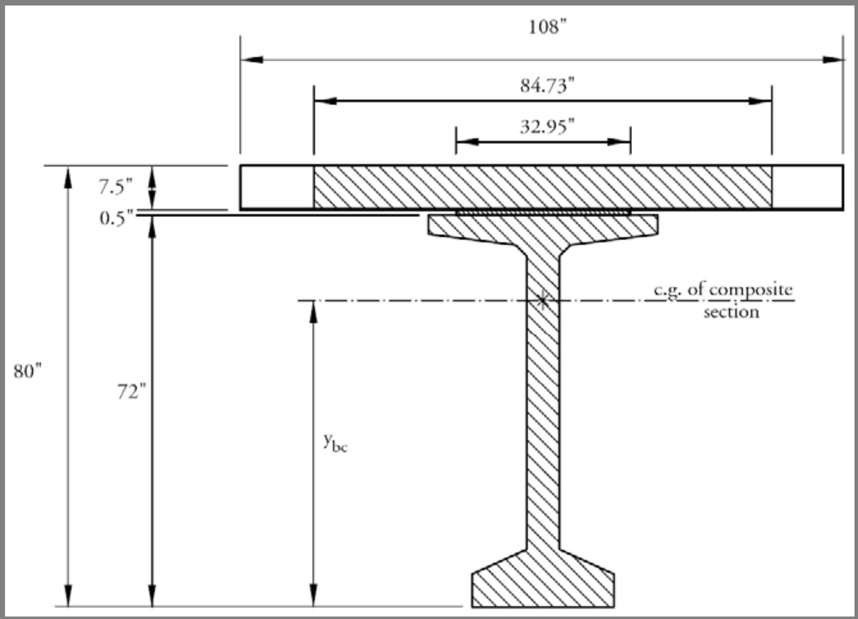
CHAPTER 9 – DESIGN EXAMPLES

9.1a Simple Span Bulb Tee



- **a) Transformed section**
- **b) Refined losses**
- **c) Sectional model for shear using equations.**

GROSS COMPOSITE SECTION PROPERTIES



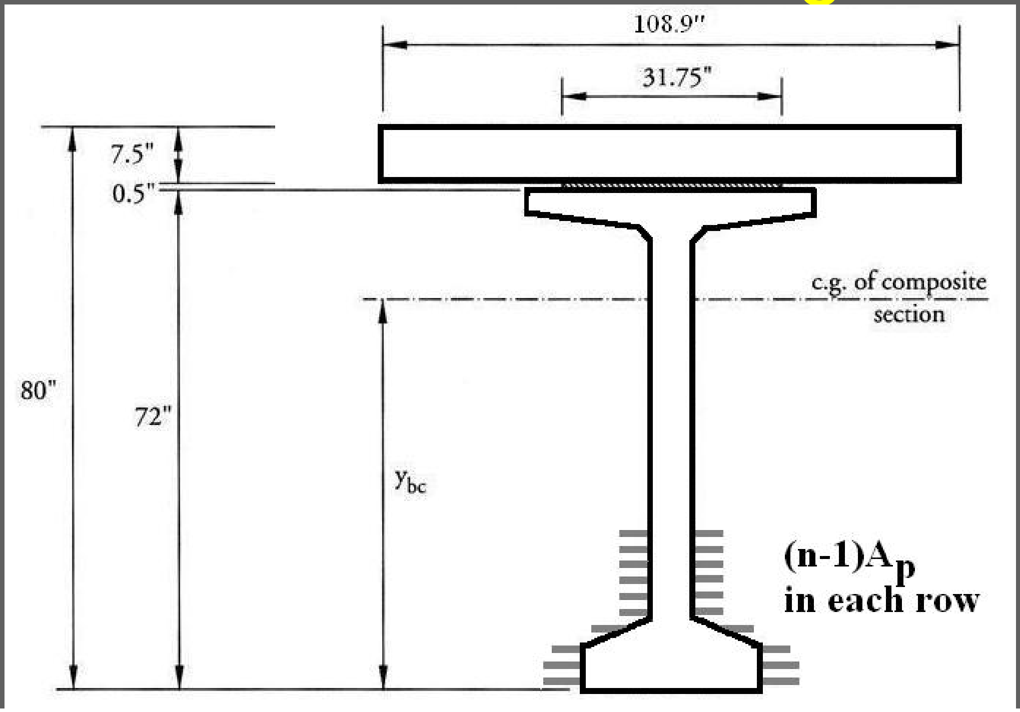
$$n = \frac{E_{slab}}{E_{Girder}} = \frac{3834ksi}{4888ksi} = 0.7845$$

Table 9.1a.3.2.3-1
Properties of Composite Section

	Transformed Area, in.^{2}	y_b, in.	Ay_b, in.^{3}	$A(y_{bc} - y_b)^2$, in.^{4}	I, in.^{4}	$I + A(y_{bc} - y_b)^2$, in.^{4}
Beam	767.00	36.60	28,072	253,224	545,894	799,118
Haunch	16.47	72.25	1,190	5,032	0.34	5,032
Deck	635.45	76.25	48,453	293,191	2,979	296,170
∑	1,418.9		77,715			1,100,320

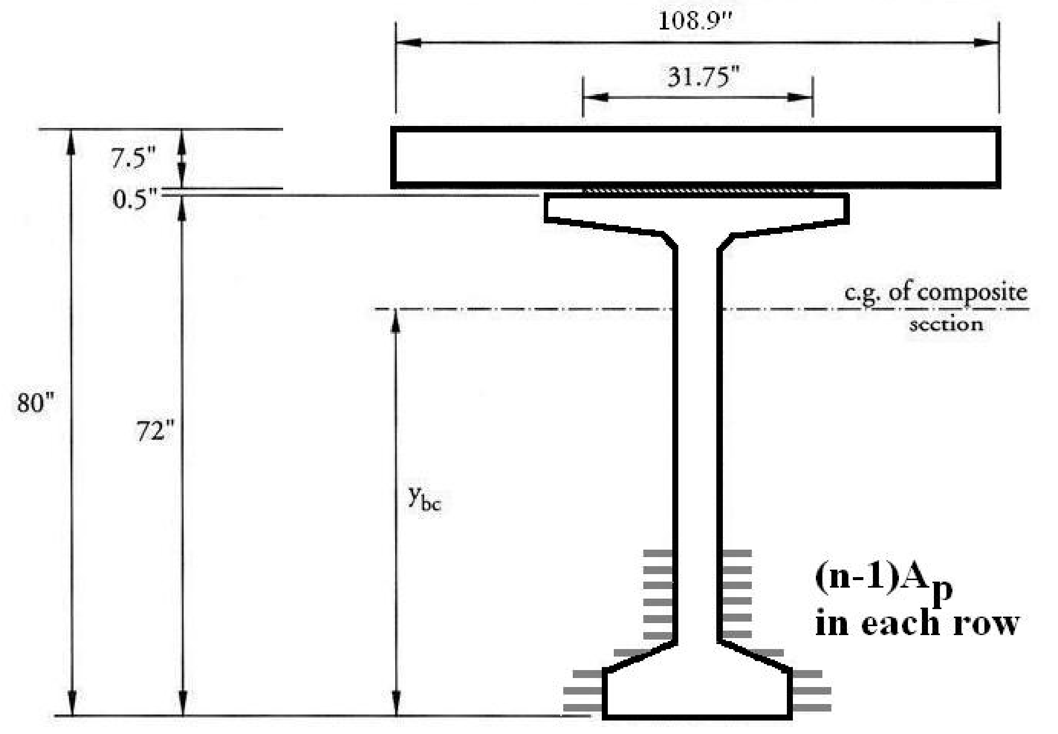
STOP If using gross properties!!

Transformed sections provide a more accurate service level stress calculation AND transformed sections implicitly account for elastic shortening losses!



CHAPTER 9 – DESIGN EXAMPLES

AASHTO says that if transformed sections are used, ES is taken as "0". This does not mean ES is ignored! Transformed section implicitly accounts for ES!



Note: ES still needs to be calculated for determining casting length.

This is the basic equation for the refined method:

$$\Delta f_{pLT} = (\Delta f_{pSR} + \Delta f_{pCR} + \Delta f_{pR1})_{id} + (\Delta f_{pSD} + \Delta f_{pCD} + \Delta f_{pR2} - \Delta f_{pSS})_{df}$$

(5.9.5.4.1-1)

CHAPTER 9 – DESIGN EXAMPLES

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Design example 9.1a is the same as Example 9.4 in the previous editions of the Bridge Design Manual. The previous example 9.4 used the approximate method. The table compares them:

Table 9.1a.8.4-1
Stresses at Midspan at Service Loads

Design Example	Top of Deck, ksi Service I		Top of Beam, ksi Service I		Bottom of Beam, ksiService III
	Permanent Loads	Total Loads	Permanent Loads	Total Loads	
9.1a	+0.114	+0.677	+1.737	+2.237	+0.154
9.4	+0.117	+0.694	+1.833	+2.335	-0.487

CHAPTER 9 – DESIGN EXAMPLES

IMPORTANT NOTE

The AASHTO Code method of applying refined losses is to calculate the losses and gains in the prestressing steel force and then find the concrete fiber stress.

However, PCI believes this maybe unconservative and offers an alternate approach.

The difference between the AASHTO *LRFD Specification* method and the method favored by PCI occurs when the gain due to deck shrinkage, Δf_{pSS} , is considered.

PCI suggests this should be found by considering deck shrinkage as a force applied to the gross composite section.

This is controversial.

Some believe the current presentation of elastic gain from deck shrinkage applied to prestress losses is unconservative because it does not correctly calculate concrete fiber stresses.

Some believe the proposed method of considering deck shrinkage as a force is too conservative; others disagree.

Some suggest using 50% of the force calculated by this method.

To apply this method, find the loss of prestressing force without the term for gain due to deck shrinkage:

$$\Delta f_{pLT} = (\Delta f_{pSR} + \Delta f_{pCR} + \Delta f_{pR1})_{id} + (\Delta f_{pSD} + \Delta f_{pCD} + \Delta f_{pR2})_{df}$$

Then, calculate the bottom fiber concrete stress, f_b, using this loss and the Service III Load Combination.

The force due to deck shrinkage is found:

$$\Delta P_{ds} = \frac{\varepsilon_{ddf} A_d E_{cd}}{1 + 0.7\Psi_d\left(t_f, t_d\right)}$$

The change in concrete fiber stress is:

$$f_{bds} = \frac{\Delta P_{ds}}{A_c} - \frac{\Delta P_{ds} e_d}{S_{bc}}$$

e_d = distance from the centroid of the deck to the centroid of the GROSS composite section.

A_c and S_{bc} are gross section properties.

The net tensile fiber stress is then found by subtracting f_{bds} from the stress calculated from the Service III Load Combination.

$$f_{b,net} = f_b - f_{bds}$$

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It is likely, however, that the full calculated force from deck shrinkage will not occur because of the presence of deck cracking and deck reinforcement. The Table summarizes the effect of applying 0, 50, or 100% of the calculated deck force on the stresses at load combination Service III.

Table 9.1a.8.5.4-1
Stresses at Midspan for Load Combination Service III Including the Effect of Deck Shrinkage.

Deck Shrinkage Force, %	Bottom of Beam, ksi Service III
0	+0.127
+50	−0.001
100	−0.128

CHAPTER 9 – DESIGN EXAMPLES

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Summary

- 11 Design Examples
- Various cross sections included
- Adjacent and stringer bridges.
- Simple span and continuous bridges
- Gross and transformed properties.
- Refined and simplified losses
- Sectional model and simplified model for shear.

CHAPTER 10 -BEARINGS

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- Chapter 10 has been completely rewritten.
- Both Methods A and B for bearing design are covered.
  - Design examples of each method are provided.
  - Method B information has been updated.

CHAPTER 11 – EXTENDING SPANS

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- Design example in Chapter 11 violates *AASHTO LRFD Specifications* duct to web thickness ratio.
  - T-10 is looking at new Swiss Research at this time. Changes are likely.
  - This example was based on older designs where steel ducts could take the grout pressure.
  - Newer plastic ducts may not take the pressure so larger webs are needed.

CHAPTER 12 – Skewed and Curved

Update to reflect recent developments in Colorado and the South East for Curved/Splice U Beams

CHAPTER 13- Integral Bridges

Incorporated PCI SOA on jointless bridges

CHAPTER 14 – SEGMENTAL BRIDGES

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CHAPTER 14 – SEGMENTAL BRIDGES

14.4 BALANCED CANTILEVER CONSTRUCTION

14.5 SPAN-BY-SPAN CONSTRUCTION

14.6 DIAPHRAGMS, ANCHOR BLOCKS AND DEVIATION DETAILS

14.7 GEOMETRY CONTROL

14.8 PRESTRESSING WITH POST-TENSIONING

14.10 PCI JOURNAL SEGMENTAL BRIDGE BIBLIOGRAPHY

CHAPTER 15- SEISMIC DESIGN Being totally Rewritten (4Q2012)

Chapter 16- Additional Bridge Products (1Q2012)

CHAPTER 17 – RAILROAD BRIDGES

17.0 – Introduction

17.1 – Typical Products and Details

17.2 – Construction Considerations

17.3 - The American Railway Engineering And Maintenance-of-way Association Load Provisions

17.4 – Current Design Practice

CHAPTER 18 – Load Rating

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- Completely rewritten
- ASD, LFD and LRFR information is now compliant with the *AASHTO Manual for Evaluation of Bridges .*
  - Replaces *AASHTO Manual for Condition Evaluation of Bridges*

CHAPTER 18 – Load Rating

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This Chapter provides the basic definitions for rating:

Inventory Rating — The load that can safely utilize the bridge for an indefinite period of time. Generally this analysis is performed in accordance with the design specifications.

Operating Rating — The absolute maximum permissible load to which the bridge can be subjected. This analysis may utilize posting avoidance techniques as specified by the jurisdiction.

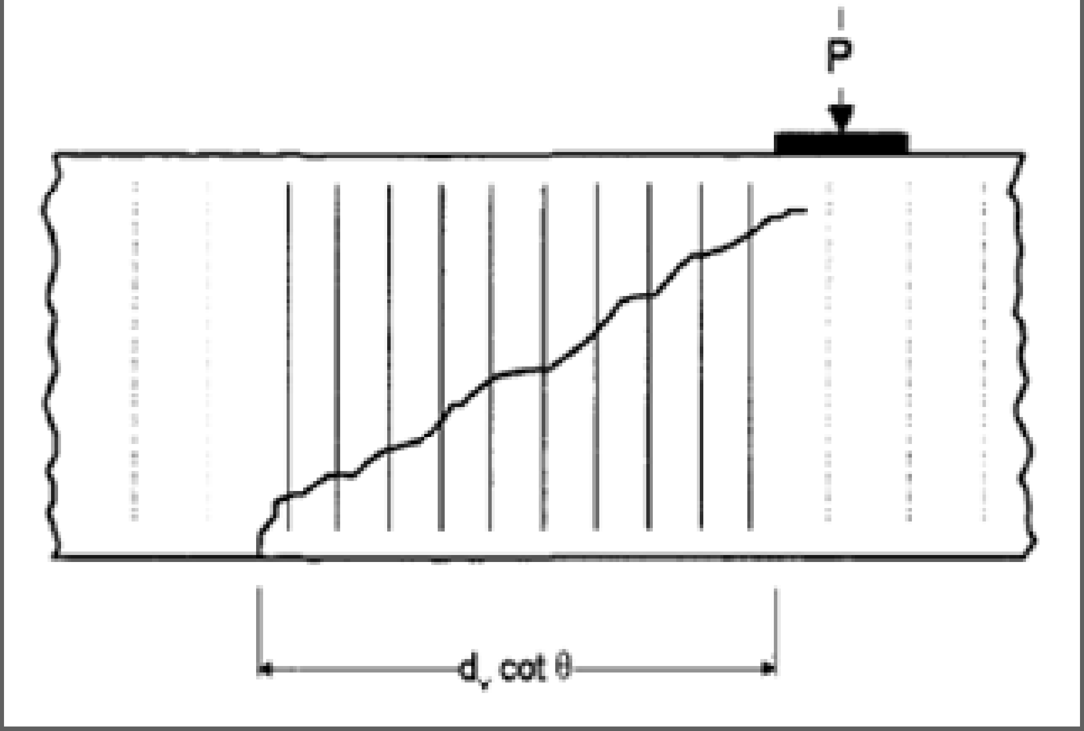
Load Rating — The process of determining the live load capacity of a bridge based on its current conditions through either analysis or load testing.

Rating Factor — The ratio of available live load moment or shear capacity to the moment or shear produced by the load being investigated.

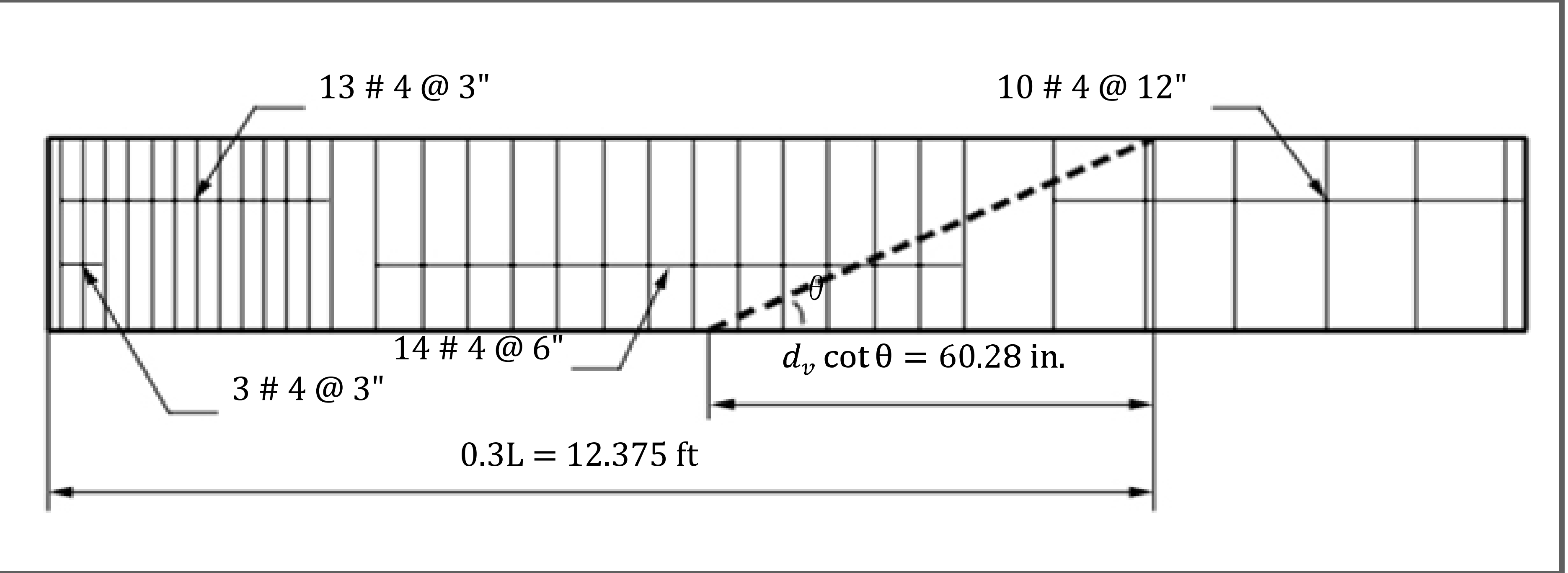
Routing Vehicle — A state defined permit truck that is used to create overload maps for using in prescribing which arterial maybe be used by a set fleet of Specialize Hauling Vehicles (SHV).

CHAPTER 18 – Load Rating

This chapter also covers the exact method of determining shear resistance by properly counting all the stirrups which cross the failure plane.



Here is a illustration of how the exact method is applied:



The difference is illustrated here:

$$V_c = 0.0316\beta\sqrt{f_c'}b_v d_v = 0.0316(2.399)\sqrt{8.5}(6)(40.6) = 52.07\text{kips}$$

Code:

$$V_s = \frac{A_v f_y d_v \cot\theta}{s} = \frac{(0.2(60)(40.6)\text{Cot } 33.67)}{12} = 60.28 \text{ kips}$$

Exact:

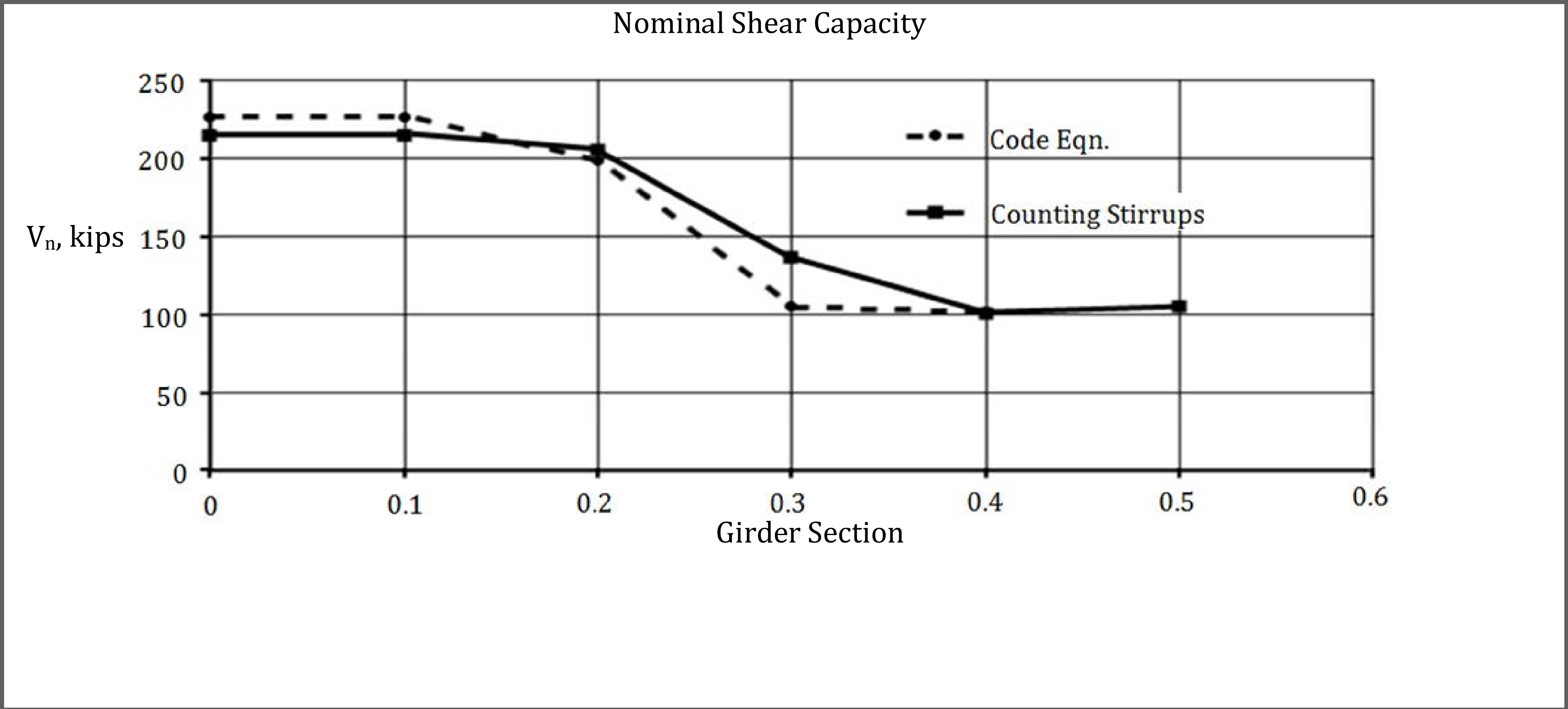
$$V_s = 8\text{stirrups}(0.2\text{in}^2/\text{stirrup})(60\text{ksi}) = 96\text{kips}$$

$$V_{n,code} = 112.4\text{kips}$$

$$V_{n,exact} = 148.1\text{kips}$$

$$\Delta = 32\%$$

CHAPTER 18 – Load Rating



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18.6.10 Summary of Ratings

In summary, looking at the older structure that was not designed with the new reliability based *LRFD Specifications*, one arrives at the following conclusions:

Standard Specifications Rating Factors

	Inventory Rating (Notional load)	Operating Rating
LFD Strength (HS20)	1.25	2.09 (HS41.4)
LFD Service (HS20)	1.21	
LFD Proof Test (HS20)	2.50	4.32 for interior use (HS33)

LRFD Specifications Rating Factors

	Inventory Rating	Operating Rating
LRFD Strength I (HL-93)	1.18	1.53
LRFD Service III (HL-93)	1.15	
LRFD Service I (HL-93)		2.06
LRFD Strength II (HL-93) Routine Blanket Permit in mixed traffic		1.00
LRFD Service I(HL-93) Routine Blanket Permit in mixed traffic		1.58
LRFD Strength II(FL-120) Escorted single trip without others lanes loaded		2.29
LRFD Strength II(FL-120) Escorted single trip with other lanes loaded		1.17 (HS39.1)

CHAPTER 19-
REPAIR AND REHABILITATION

CHAPTER 20-
Piles

CHAPTER 21-
Recreational Bridges

Issues in Next Release (1Q2012)

SUMMARY

- The PCI Bridge Design Manual has been completely updated through the AASHTO LRFD Specifications, 5th Edition with 2011 interim.
- The update includes the 2011 versions of other applicable specifications.
- Design Examples of Chapter 9 have been expanded to include more bridge types and to illustrate different design methods.

SUMMARY

PCI Precast/Prestressed Concrete Institute

- Chapter 10 has been rewritten with the most up-to-date information on bearing design Methods A and B.
- Chapter 18 on load rating has been extensively updated.

The new Bridge Design Manual is the perfect reference book for concrete bridge design.

It is also an excellent educational tool!

Background

- 1998-2000: FHWA PPCP Concept Developed
  - Feasibility Study (University of Texas at Austin)
  - Laboratory Testing


What is PPCP?

- *Precast* Prestressed Concrete Pavement
  - “Standardized” full-depth precast panels
  - Keyed panel joints for vertical alignment during assembly
  - Constructed over a prepared base (HMA, LCB, Aggregate Base, Pervious PCC, etc.)

Interstate 35 (FR) - Georgetown, TX

Background

- 2004-2006: Demonstration Projects in CA, MO, IA
  - Different pavement support conditions/base types
  - Variable cross-slope conditions
  - Heavy truck traffic
  - Full-width (two lanes plus shoulders) construction
  - IA: Bridge Approach Slab application
  - Roadway closed to traffic throughout construction

Interstate 10 - El Monte, CA

Background

- 2009: Additional “nighttime” Demonstration Projects in DE and VA
  - Heavily travelled corridors (>180k vpd)
  - 7-10 hour nighttime work windows
  - Reconstruction of existing PCC pavement and base
  - Single-lane and double-lane construction
  - Pavement open to traffic by 5am

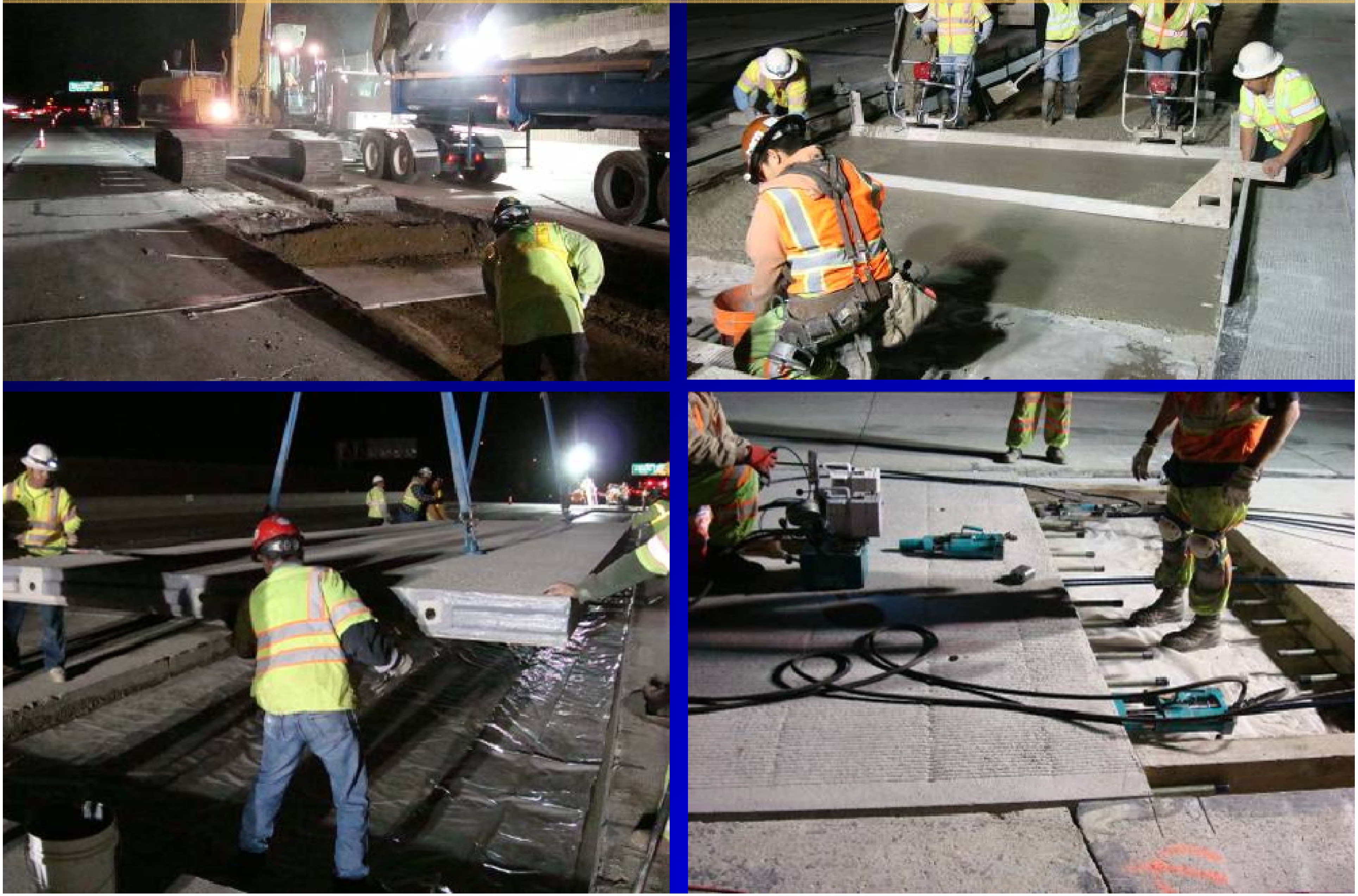
Route 896 - Newark, DE

Interstate 66 – Fairfax, VA

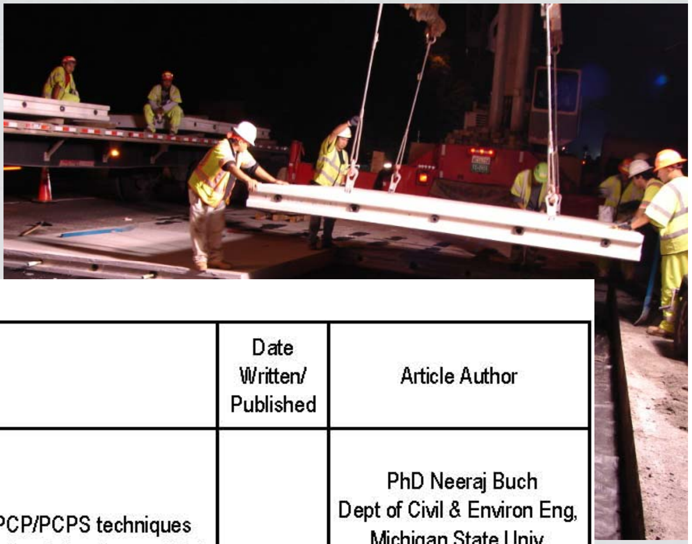
Background

- 2011: Caltrans I-680 Reconstruction Project
  - Heavily travelled corridor
  - 8 hour nighttime work windows
  - Reconstruction of existing PCC pavement and underlying lean concrete base
  - Single-lane construction
  - Unique design features:
    - 2-way pretensioning
    - Elimination of stressing blockouts
    - “Rotation” of panels 90 degrees for single lane construction

Interstate 680 – Danville, CA



Draft Repository



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PPCP#	File Name	Paper Title	Description	Date Written/ Published	Article Author
30	PPCP30 FHWA PC Pvmt Rept 07019.pdf	Precast Concrete Panel Systems for Full-Dept Pavement Repairs, Field Trials	The report summarizes a 3 year study on "in-service" roads where PPCP/PCPS techniques were used for joint repair and slab replacement. The report captures data relating to panel/slab performance and durability, makes recommendations for slab repair and slab construction specifications and the use of dowels to connect panels and transfer loading..	Feb 2007	PhD Neeraj Buch Dept of Civil & Environ Eng, Michigan State Univ, Sponsored by FHWA, Sam Tyson Available to public Nat Technical Info Serv, Springfield VA 22161
31	PPCP31 SovietPrecastPrestressedConstruction-Airfields_SapozhnikovRollings_FAA Conf_Apr2007.pdf	Soviet Precast Prestressed Construction for Airfields - Presented for the 2007 FAA Worldwide Airport Technology Transfer Conference, Atlantic City, NJ	This twelve page paper was presented at the FAA Worldwide Airport Technology Transfer Conference, Atlantic City, NJ, April 2007 by Ph D. Sapozhnikov and Ph D. Rollings The paper illustrates the Soviet Unions successful use of precast concrete slab pavement in current airfield construction. Further, it details the Soviet Unions standardization to PCPS design, panel/slab specifications and installations. There are several examples of precast prestressed concrete panels with well over 25 years of service life depicted. The Soviets use PPCP/PCPS type construction during freezing conditions, rapid construction is required, when PPCP applications upgrade existing facilities and when soil conditions are problematic. PPCP techniques are used extensively in military airfield applications.	Apr 2007	Naum Sapozhnikov, PhD & Raymond Rollings, PhD,PE nsapozhnikov@hotmail.com rollingseng@earthlink.net
32	PPCP32 Summary of FHWA Demo Projects-January 2008.pdf	Summary of FHWA Precast Pavement Demonstration Projects Completed to Date	This two page paper lists the FHWA sponsored Precast Pavement Demonstrations Projects completed as of 2008. They include: Georgetown, TX, I-10 El Monte, CA, NB I-57 near Charleston, Missouri, and State HWY 60, Sheldon, Iowa.	Jan 2008	

How can PCI help you?

PCI-FHWA Cooperative Agreement

Four "Guidance Documents"

1) Selecting Applications for Precast Concrete pavements
2) Design, Layout and Maintenance of Precast Concrete Pavements
3) Precast Pavement Panel Fabrication Recommendations
4) Construction Recommendations for Precast Concrete Pavements

How can PCI help you?

Selecting Applications for Precast Concrete Pavements (Volume1 of 4)

- Considerations for Selection
- Types of Applications
- Site Selection
- Agency Considerations
- Resources
- Appendix - Projects

How can PCI help you?

Design, Layout and Maintenance of Precast Concrete Pavements (Vol. 2 of 4)

- Key Features
- Design Considerations
- Pavement Management Considerations
- Performance Monitoring
- Appendix – Details and Specifications

How can PCI help you?

Precast Pavement Panel Fabrication Recommendations (Vol. 3 of 4)

- Producer Qualifications
- Formwork
- Materials
- Prestressing
- Expansion Joints
- Concreting
- Lifting/Handling
- Acceptance Testing

How can PCI help you?

Construction Recommendations for Precast Concrete Pavements (Vol. 4 of 4)

- Installation-Staging
- Base Preparation
- Materials
- Installation-Equipment & Methods
- Post-Tensioning
- Final Surface Finish
- Final Inspection

Guidance information from FDBDR

- The contractor's designer or construction engineer must provide design computations that include the following information:
- Losses for each tendon such as creep and shrinkage of concrete, elastic shortening, relaxation of steel, losses due to the sequence of tensioning, friction and anchor set, and other losses peculiar to the method or system of prestressing that may take place or have been provided for.
- Jacking and effective force for each post-tensioning strand or bar system.
- Anchorage bearing stress at service load.
- All other computations required for the system of post-tensioning being used, including all reinforcement required to resist local bursting zone stresses.