EXPERIMENTAL INVESTIGATION OF PRESTRESSING STRAND LIFTING LOOPS

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PCI Convention – Tech 7 – Innovations in Precast Concrete Materials
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OUTLINE

1. Introduction and Motivation
2. Industry Survey
3. Experimental Testing
4. Upcoming Work

INTRODUCTION AND MOTIVATION

Photos Courtesy of Dr. Richard Miller, University of Cincinnati

INTRODUCTION AND MOTIVATION

- Prestressing Strand (ASTM A416/ A416M)

✓ Readily available
✓ High strength
✓ Ductility
✓ Flexibility
✓ Inexpensive

INTRODUCTION AND MOTIVATION

PCI Design Handbook

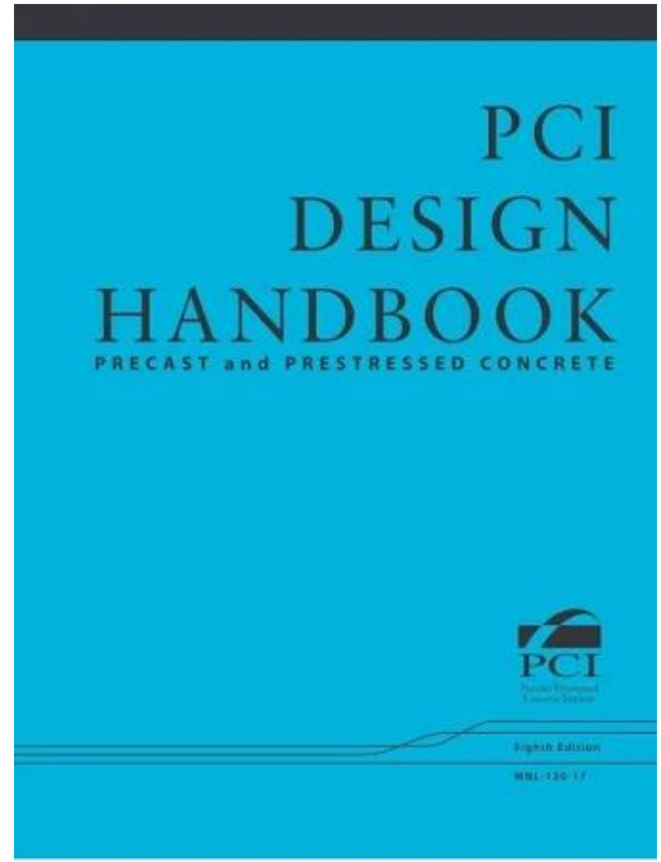
8Th Edition

Safety factor = 4

In lieu of test data:

- Min. embedment = 24-in.
- ½-in. diam. strand = 10 kips
- Factor for double loops: 1.7

  Factor for triple loops: 2.2
- Diameter of hook ≥ four times strand diameter



Wilden, H. (2017). PCI Design Handbook: Precast and Prestressed Concrete, Eighth Edition. Chicago: Precast/Prestressed Concrete Institute.

INTRODUCTION AND MOTIVATION

Moustafa: Pullout Strength of Strand Lifting Loops (1974)

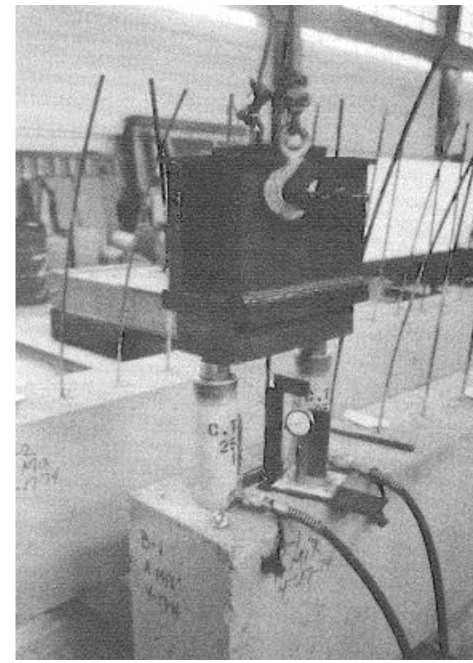
Strand Pullout Tests

200 + tests

3/8-in., 7/16-in., and ½-in. strands

Bright and rusted

Straight, broom and 90^{o} bend orientations



Determined development lengths and ultimate pullout strengths for 6000 psi and 3000 psi concrete

Moustafa, S.E. (1974). Pullout Strength of Strand Lifting Loops, Technical Bulletin 74-B5, Concrete Technology Associates, Tacoma, Washington.

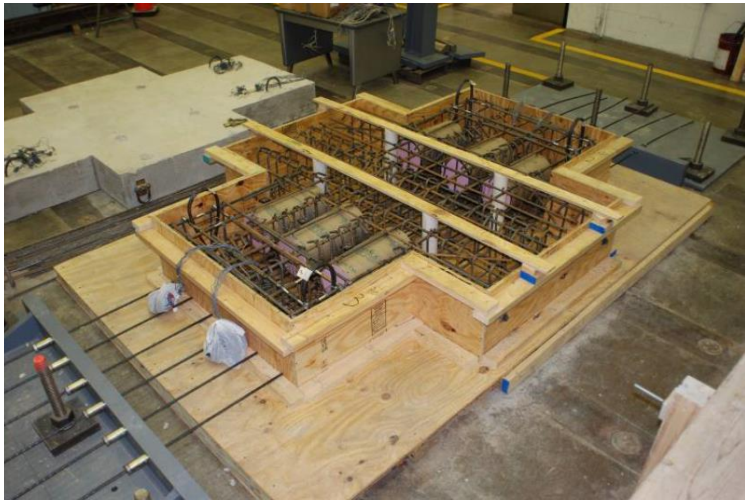
INTRODUCTION AND MOTIVATION

Kuchma: Development of Standard for Lifting Loops in Precast Deck Beams *Illinois Center for Transportation*

Tested members shallower than 24”

Test variables:

- Lifting loop shape
- Depth of embedment
- Side edge distance
- Number of strands per loop
- Number of loops in a corner
- Angle of pull



Kuchma, D. and C.R. Hart (2009). Development of Standard for Lifting Loops in Precast Deck Beams, Research Report ICT-09-056. Illinois Center for Transportation, Urbana, IL.

RESEARCH GOAL & OBJECTIVES

Overarching goal:

Further the development of strength and detailing guidelines for the safe use of prestressing strand lifting loops in precast bridge beams.

Objectives:

Determine current lifting loop practices, best practices, and areas of confusion or ambiguity in the current design guidelines.

Fill gaps in knowledge about the pullout strength of **0.6-in. diameter strand lifting loops** through experimental testing.

RESEARCH PLAN

Mertz Project

TASK I: Survey PCI-Certified Precast Producers

TASK II: Pullout Tests of 0.6-in. Diameter Strand

Upcoming Testing

PRECAST PRODUCER SURVEY

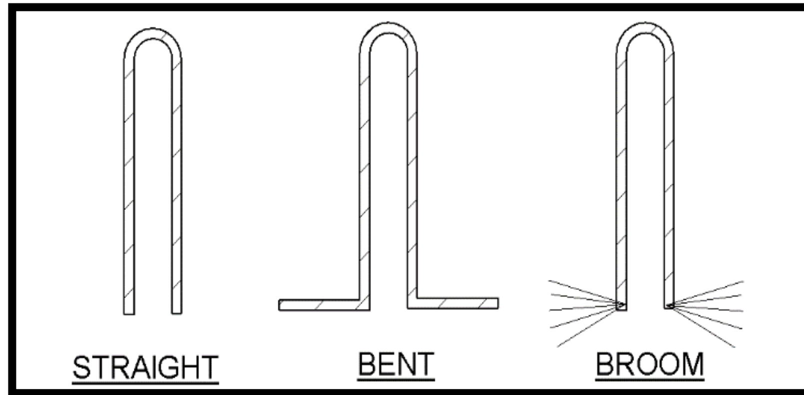
Sandip Chhetri, Rachel A. Chicchi, and Stephen Seguirant

Industry survey results on the use of prestressing strand lifting loops

PCI Journal (ISSN 0887-9672) V. 65, No. 4, July–August 2020.

PCI Journal is published bimonthly by the Precast/Prestressed Concrete Institute, 8770 W. Bryn Mawr Ave., Suite 1150, Chicago, IL 60631.

SURVEY RESULTS



- Formal testing is not performed by producers
  - Design Handbook is primary means of determining capacity
- Minimum concrete strength before lifting from forms : 3500 – 4500 psi
- Parallel configurations with straight / bent ends
- 0.5-in. diameter strand still most prevalent
  0.6-in. diameter strand being used frequently
- Minimum no. of loops in bundle : 2
  Maximum no. of loops in bundle : 4
  Use of conduit around strands

EXPERIMENTAL TESTING

Experimental investigation of 0.6 in. diameter strand lifting loops

Sandip Chhetri, Rachel A. Chicchi, and Andrew E. N. Osborn

PCI Journal (ISSN 0887-9672) V. 66, No. 2, March–April 2021.

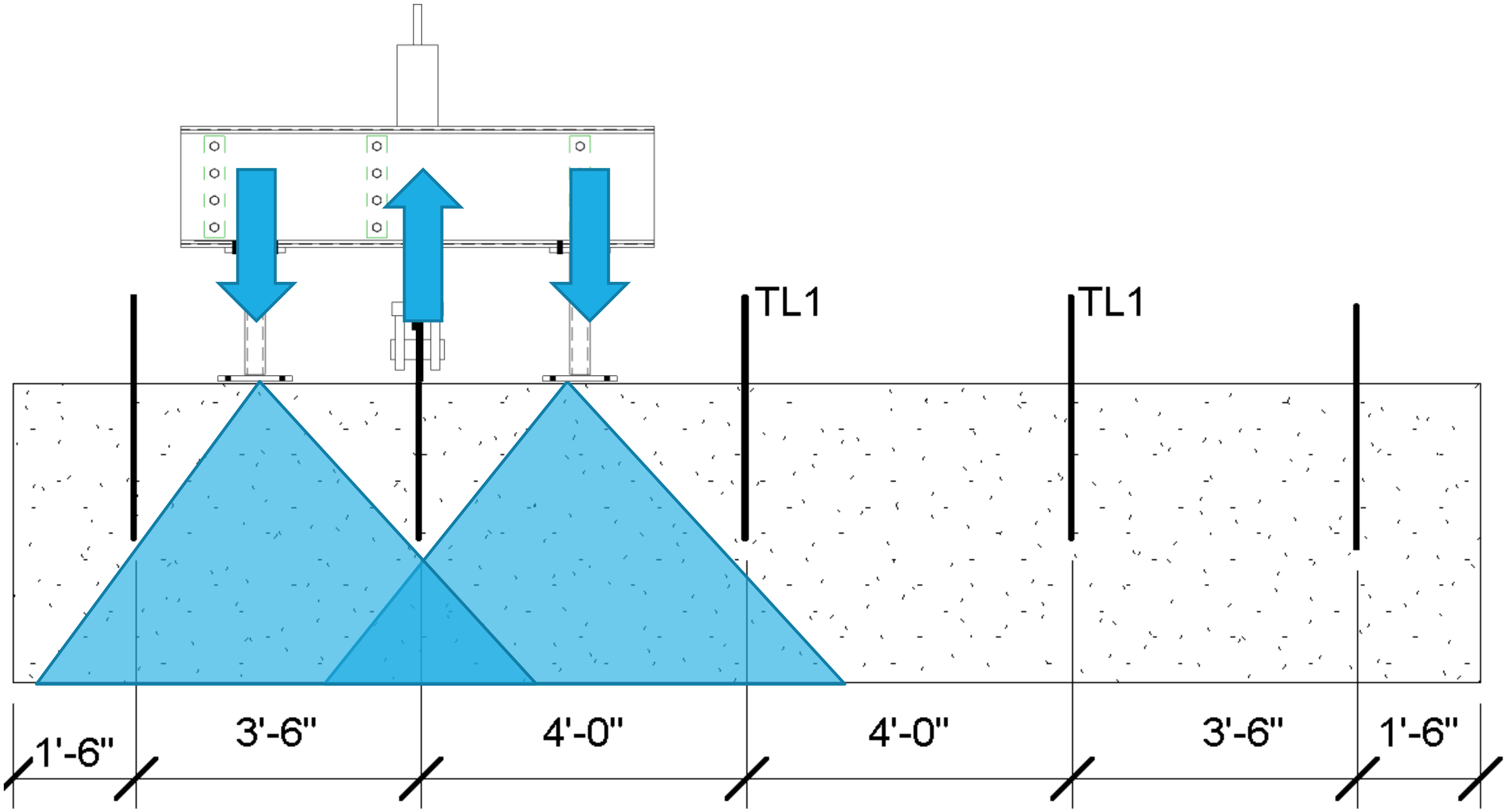
PCI Journal is published bimonthly by the Precast/Prestressed Concrete Institute, 8770 W. Bryn Mawr Ave., Suite 1150, Chicago, IL 60631.

EXPERIMENTAL TESTING

Orientation	Embedment Length (in.)	Number of Tests
Straight	32	3
	36	3
	42	2
6-in. 90° bend	24	2
	30	3
	TOTAL:	13

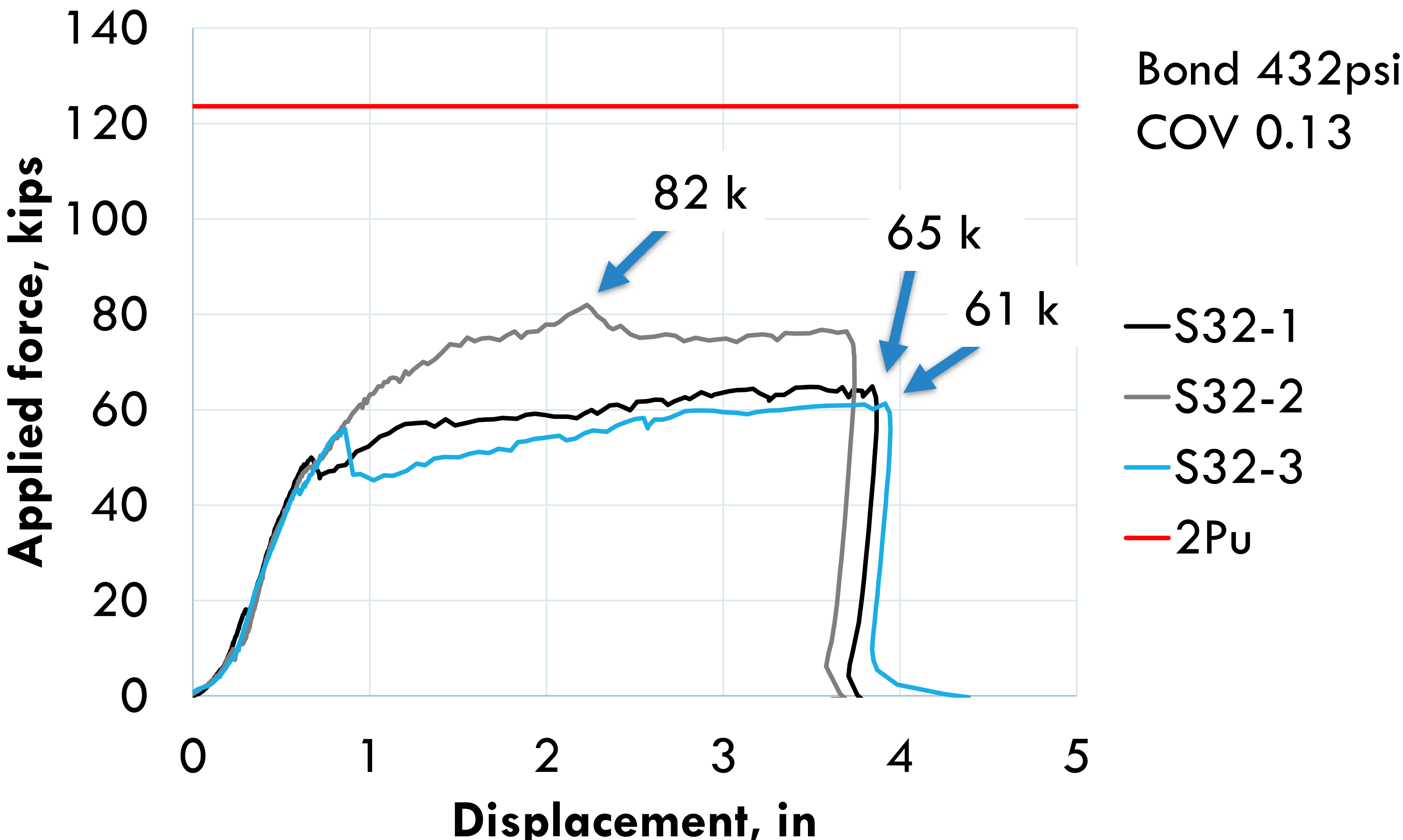
0.6-in. Diameter Strand

TEST SETUP




Brace
Hydraulic cylinder
Cha
Pull-out assembly
Pin
HSS
Beam specimen
Wire connecting potentiometer to clevis plate

Test Series 3 - 32-in. embedment, straight legs

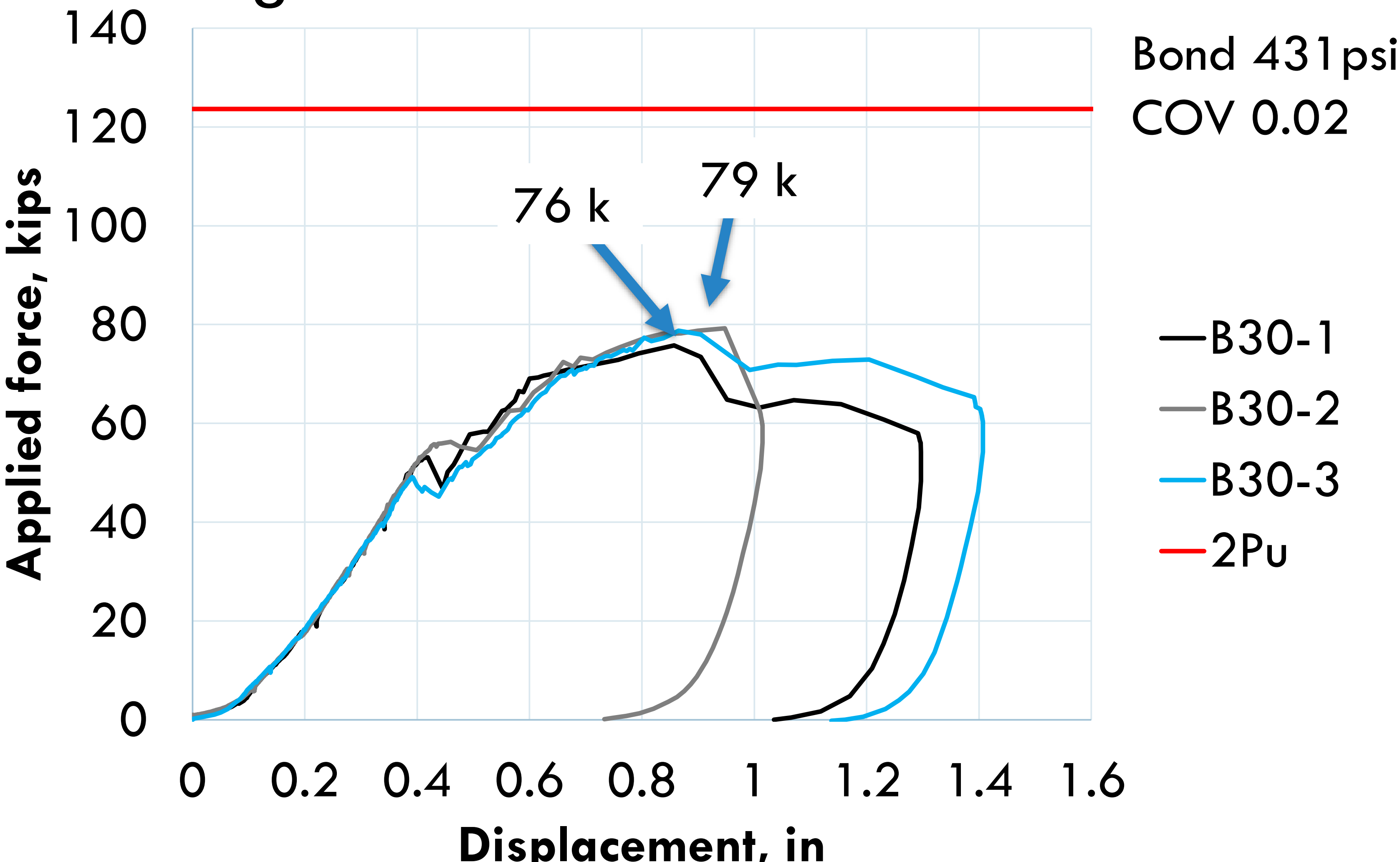


<u>**Test Series 3**</u> **-** 32-in. embedment, straight legs

Test Series 4 - 36-in. embedment, straight legs, transverse orientation

Test Series 4 - 36-in. embedment, straight legs

Test Series 2 - 30-in. embedment, bent legs



<u>Test Series 2</u> **-** 30-in. embedment, bent legs


FABRICATION MISCELLANEOUS METALS
TINCHER'S WELDING

Test Series 2 - 30-in. embedment, bent legs

RESULTS SUMMARY

Test Series	L_b (in)	Peak Load (k)	Failure type	$P/2P_u$	Bond Stress (psi)
1	24B	63.5	Pullout	0.52	420
2	30B	77.9	Side-face blowout	0.63	431
3	32S	69.4	Pullout	0.56	432
4	36S	65.8	Pullout	0.53	364
5	42S	70.6	Pullout	0.57	334

PRIMARY FINDINGS

- Edge effects prevalent
  Sideface blowout
  Test 3 - 32-in. embedment → 69.4 k (Long)
  Test 4 - 36-in. embedment → 65.8 k (Trans)

BOND STRESS

- Average bond stress → 396 psi

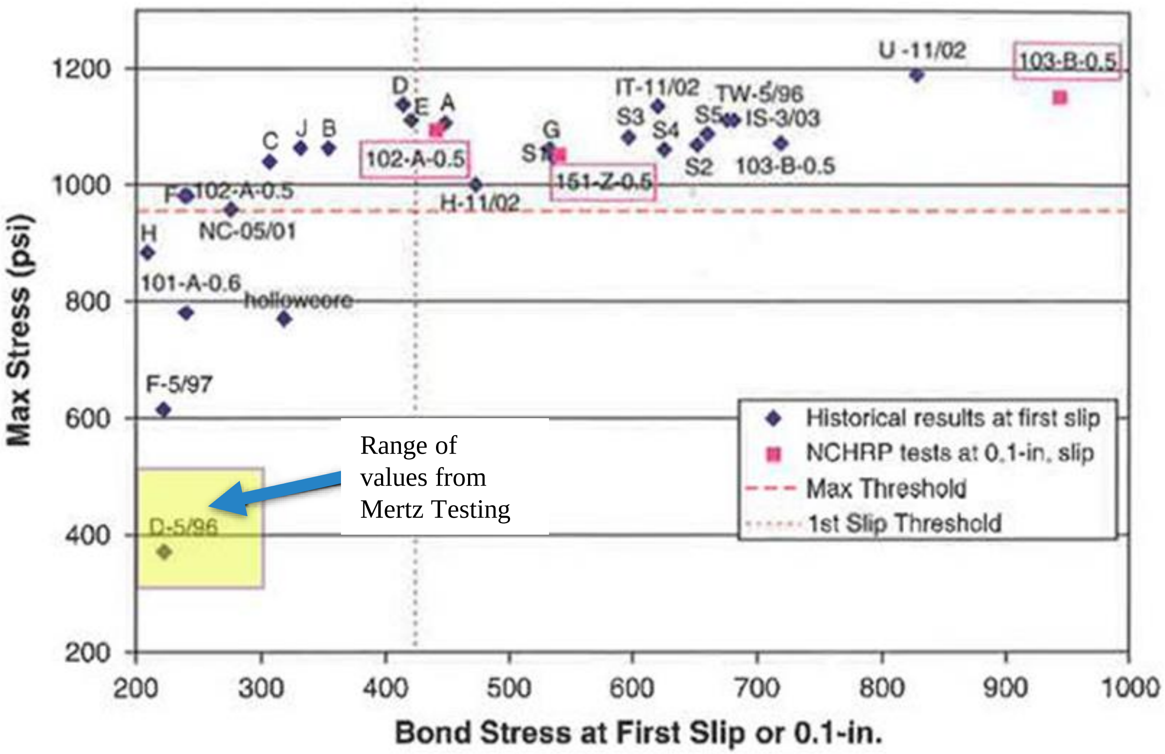
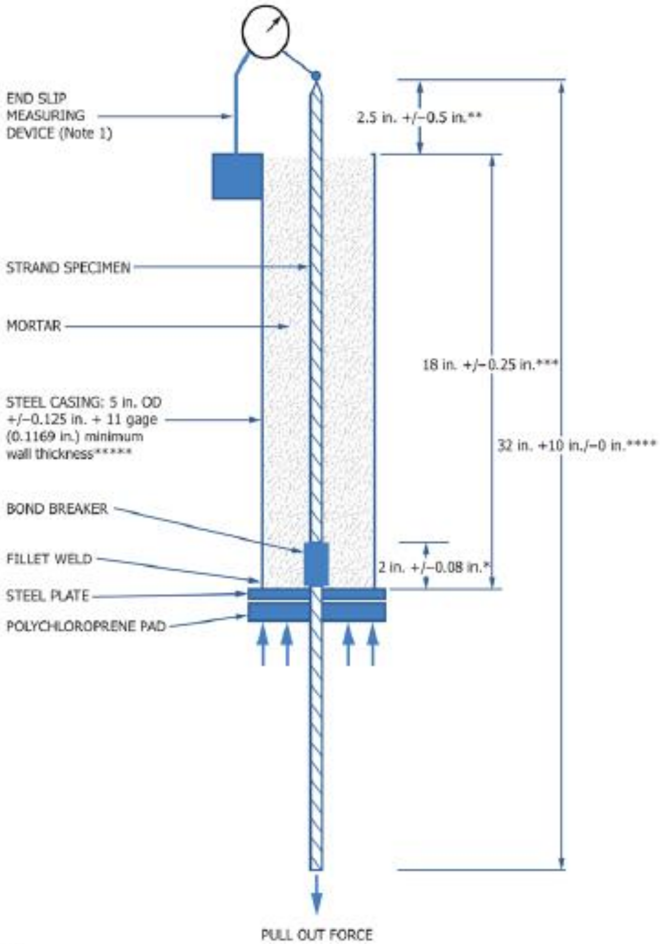


Figure B-1. Correlation between maximum stress and first observed or 0.1-in. slip stress for historic and recently manufactured strand.

Osborn, A.E.N., Lawler, J.S., and Connolly, J.D. (2008). NCHRP Report 621: Acceptance Tests for Surface Characteristics of Steel Strands in Prestressed Concrete, Transportation Research Board.

CAVEATS – STRAND BOND BEHAVIOR



*SI equivalent: 50 mm ± 2.0 mm
**SI equivalent: 64 mm ± 13 mm
*** SI equivalent: 450 mm ± 6.4 mm
**** SI equivalent: 800 mm +250 mm −0 mm
*****SI equivalent: 130 mm ± 3 mm (OD) × 3 mm min (wall thickness)

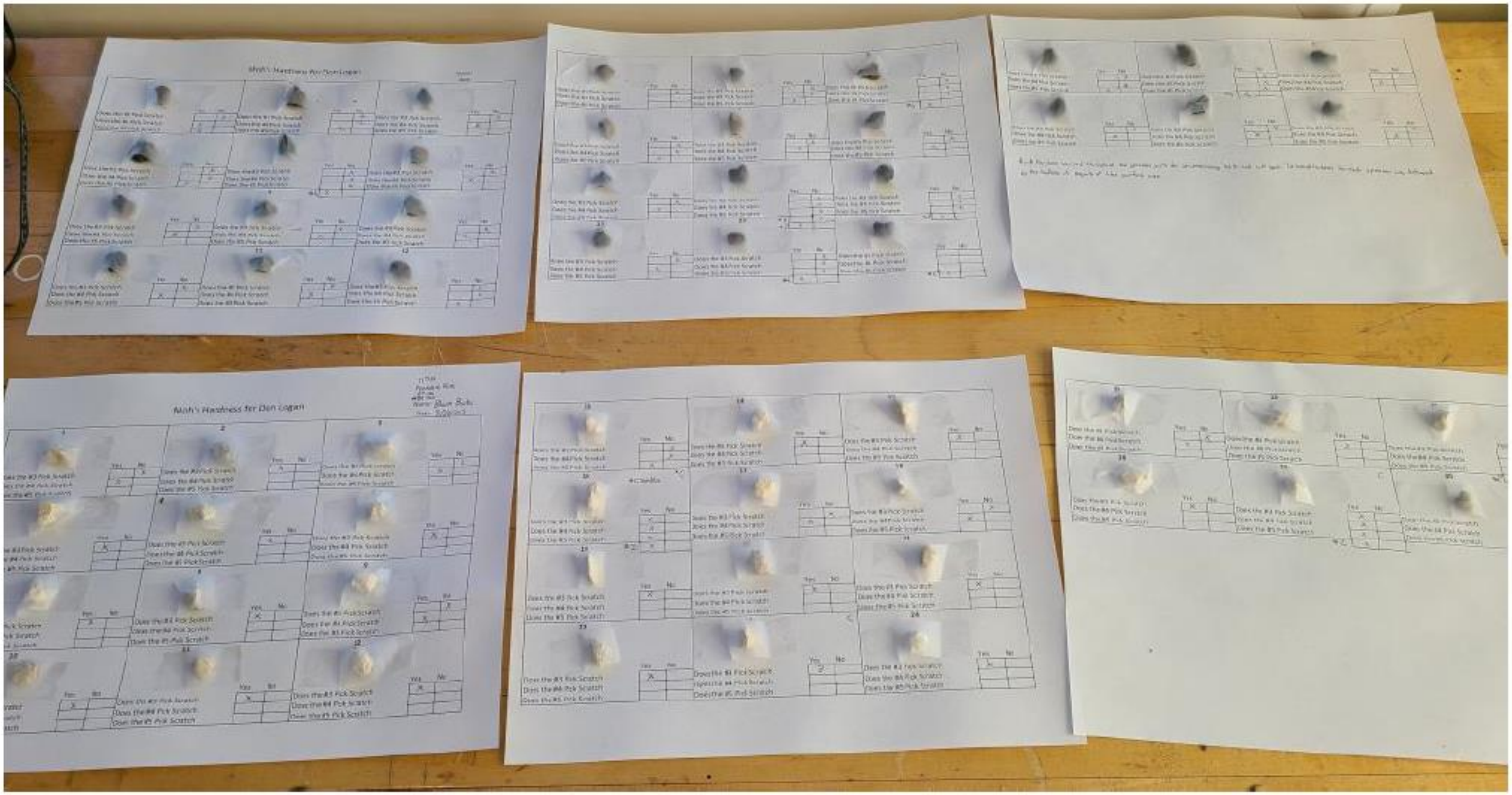
NOTE 1—The "Electronic End Slip Measurement" apparatus shown here is an example of one type of measurement set-up. Other configurations and devices can be used. A mold release agent may be sprayed onto the canister ID walls before pouring mortar.

FIG. 1 Longitudinal Cross-Section Diagram of Strand Test Specimen in a Mortar-Filled Cylinder

ASTM A1081- Evaluating Bond of Seven-Wire Steel Prestressing Strand

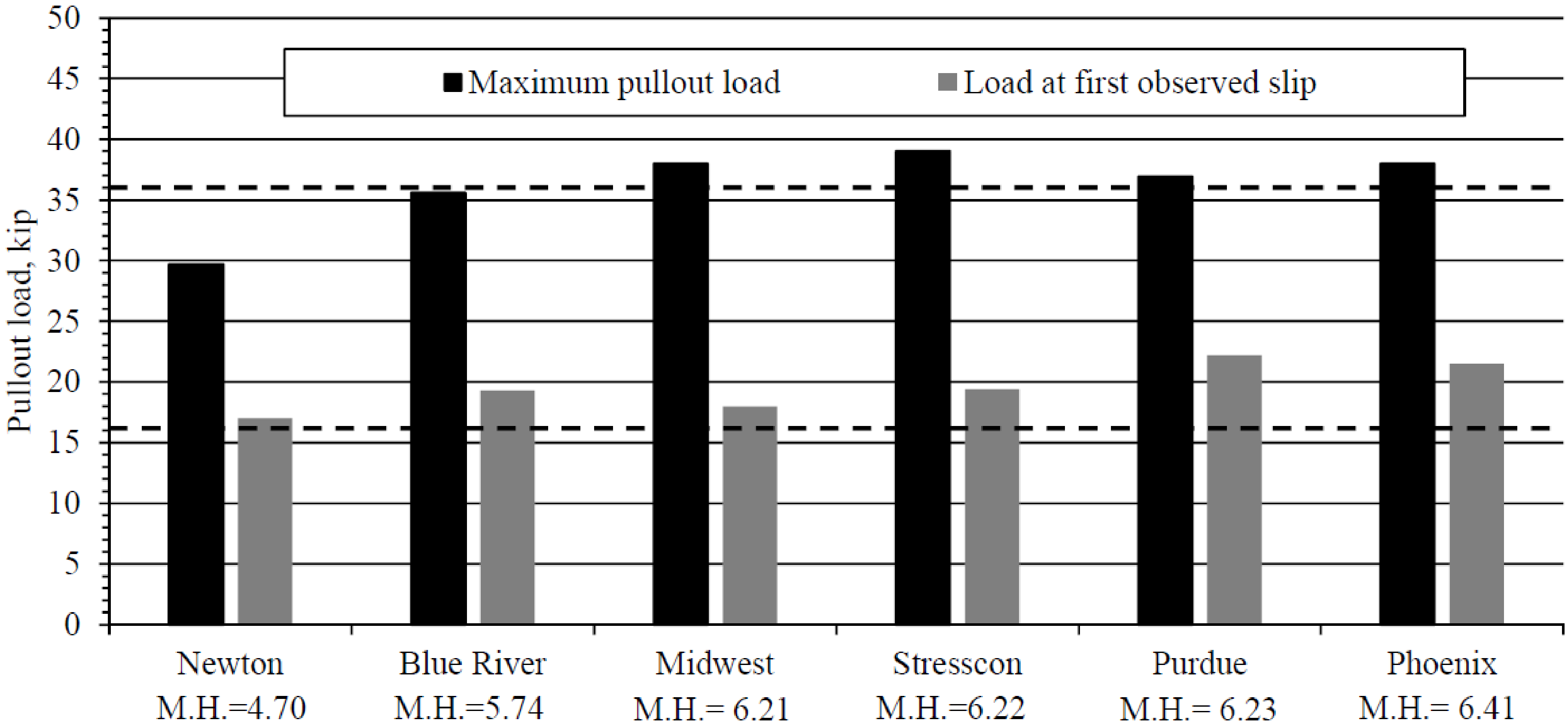
18.2 k – Mertz testing
17.5 k (recommended min. per Kansas State study)

CAVEATS – MOHS HARDNESS



Harker, C. (2003) "Evaluation of the Bond Capacity of Prestressed Strand Through Moustafa Pullout Tests." Kansas State University, MS Thesis.

CAVEATS – MOHS HARDNESS



CAVEATS – MOHS HARDNESS

Mertz Testing = 3.8

Lightweight Aggregate = 4.1

Florida Limestone = 2.6

RECOMMENDATIONS

If …

- ASTM A1081 strand $\geq$ 18.2 k
- Moh's Hardness $\geq$ 3.8
- 6" min. edge distance
- Pin diam. not less than 4 times the strand diam.

Then…

- Safe working load = 12 kips for 24" embedment
- Safe working load = 16 kips for 32"+ embedment

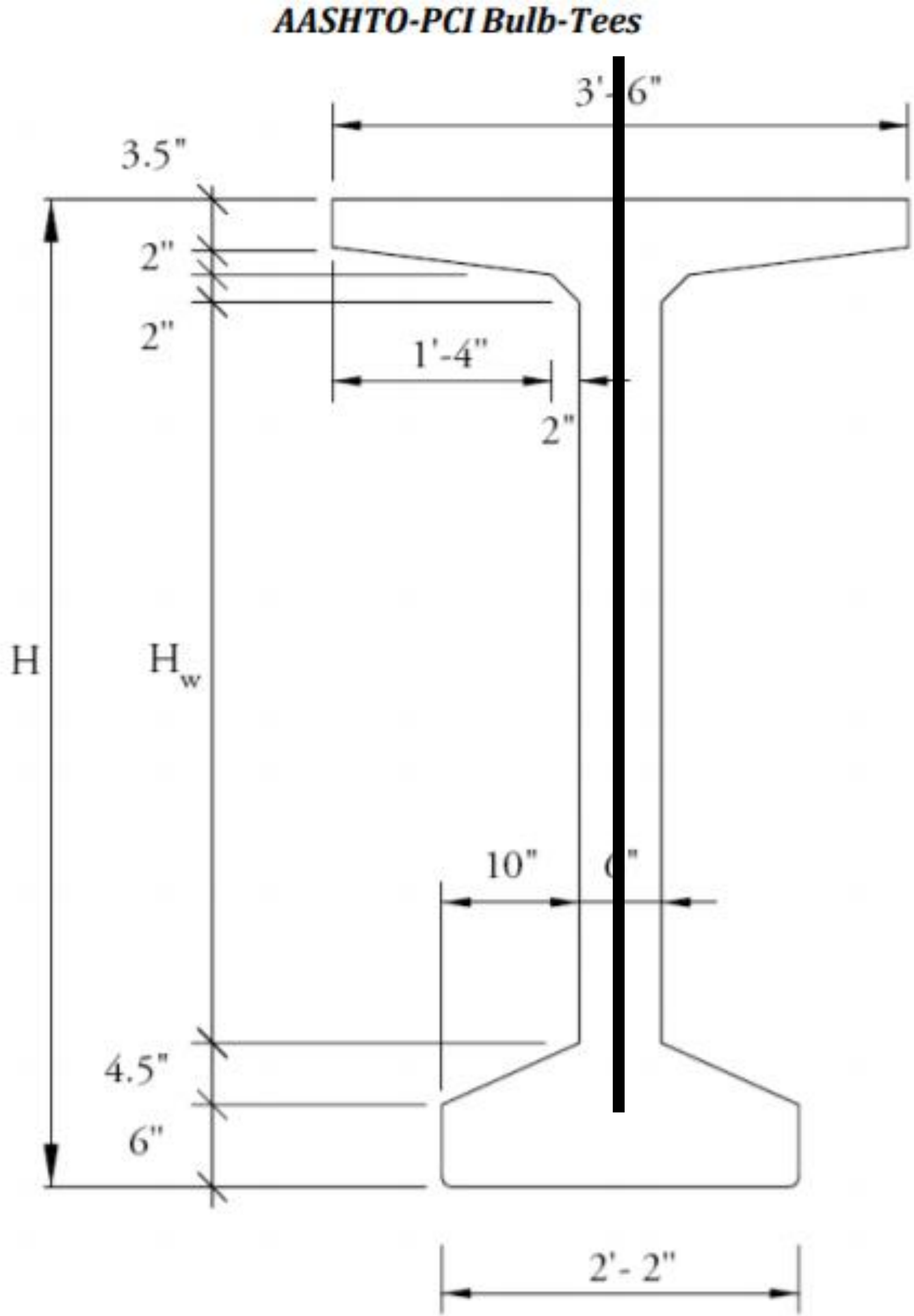
(Safety Factor of 4 maintained)

UPCOMING WORK

Expanded experimental testing:

- Stainless steel loops
- Lightweight concrete
- Investigate multiple loops
- Investigate edge effects (bulb tee)

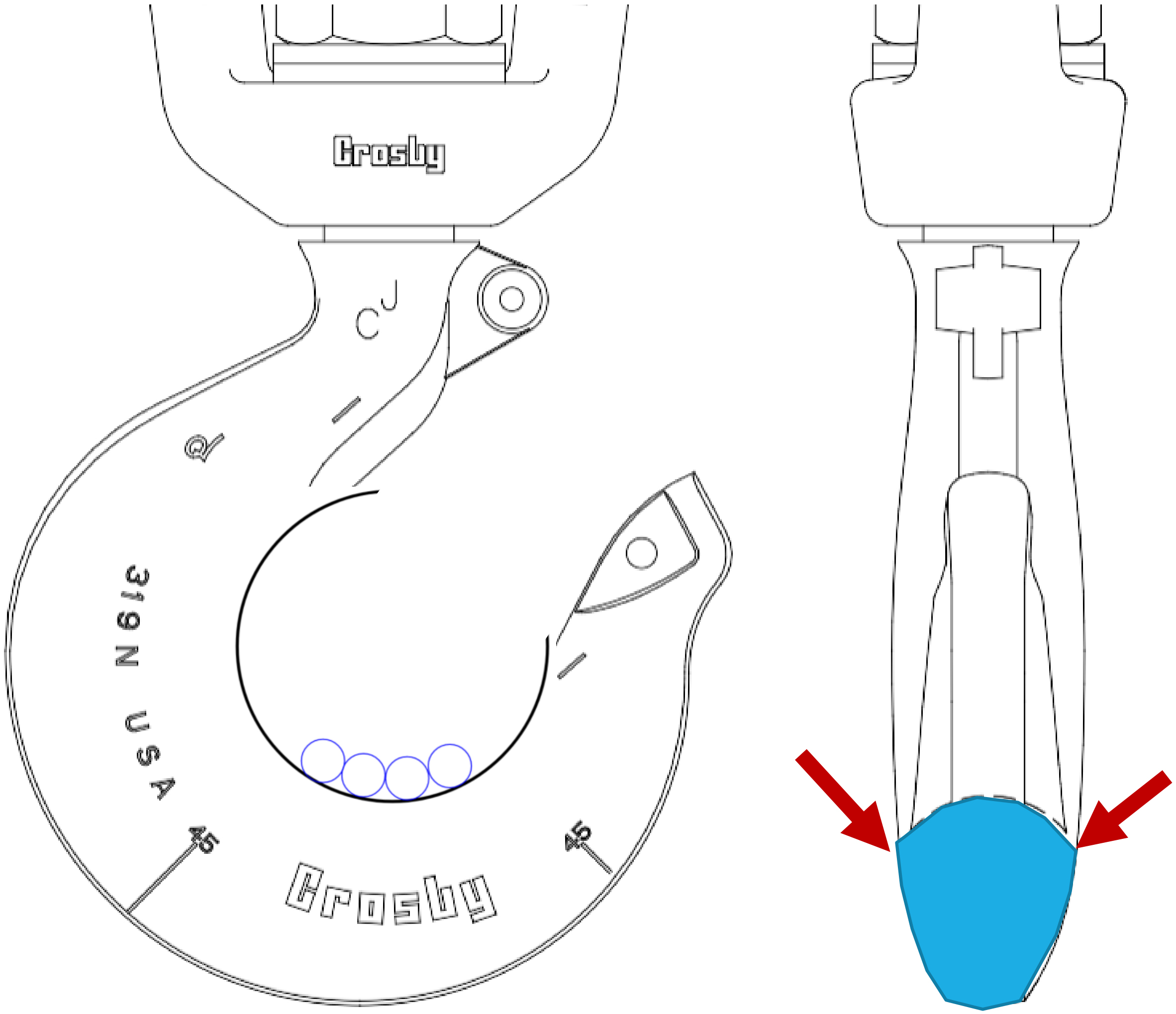
EDGE EFFECTS



MULTIPLE LOOPS

Moustafa, S.E. (1974). Pullout Strength of Strand Lifting Loops, Technical Bulletin 74-B5, Concrete Technology Associates, Tacoma, Washington.

HOOKS VS PINS



Number of Loops	Conduit around Strands	Attachment Hardware	Number of Proposed Tests
1	Without	3” Pin	1
	Without	2” Pin	1
	Without	Hook	1
2	With	3” Pin	2
		2” Pin	2
		Hook	2
3	With (No crushing)	3” Pin	2
	With	3” Pin	2
		Hook	2
	Without (No offset)	3” Pin	2
		Hook	2
	Without (1/2” offset)	3” Pin	2
		Hook	2
6	With .	Pin	2
	With [1]	Pin	2
	With [2]	Pin	2

SPECIAL THANKS TO…

PCI Precast/Prestressed Concrete Institute

Industry Advisory Group Members:

- Andy Osborn (Chair)
- Don Logan
- Mary Ann Griggas-Smith
- Glenn Myers
- Roy Eriksson
- Jim Fabinski
- Steve Seguirant

Logan Structural Research Foundation

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QUESTIONS?

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