Development of ASTM A1096 Test Protocol and Use By Concrete Tie Producers

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Origin Of Test Procedure

- 2008 – Pretensioned tie producers observed splitting cracks at de-tensioning that were attributed to the wire source and believed to be related to bond
- There was not a standard test for wire-to-concrete bond like there is for strand

ASTM A1081

Designation: A1081/A1081M – 12

Standard Test Method for Evaluating Bond of Seven-Wire Steel Prestressing Strand[1]

This standard is issued under the fixed designation A1081/A1081M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes procedures for determining the bond of seven-wire steel prestressing strand. The bond determined by this test method is stated as the tensile force required to pull the strand through the cured mortar in a cylindrical steel casing. The result of the test is the tensile force measured on the loaded-end of the strand corresponding to a movement of 0.1 in. (2.5 mm) at the free-end of the strand.

1.2 This test method is applicable either in inch-pound units (as Specification A1081) or SI units (as Specification A1081M).

1.3 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. Within the text,

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C1437 Test Method for Flow of Hydraulic Cement Mortar

3. Terminology

3.1 *Definitions:*

3.1.1 *bond*—the adhesion of strand to concrete or mortar.

3.1.2 *bond breaker*—a product wrapped around strand to prevent strand-to-concrete bond over the installed length. Extruded polystyrene foam pipe insulation is commonly used for this purpose.

3.1.3 *manufactured length*—a length of strand that is manu-

Origin Of Test Procedure

- RJ Peterman & Associates, Inc. began working on a pullout test for indented wire that is similar to ASTM A1081 for strand
- Differences in bond-slip curves and maximum pullout forces were noted for different wire sources
- In 2011, Kansas State University received FRA funding for project titled “Quantifying The Effect Of Prestressing Steel And Concrete Variables On The Transfer Length In Pretensioned Concrete Crossties”

Funded By

Federal Railroad Administration

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

LBFoster
CXT® Concrete Ties

Other Partners

Kansas State University Transportation Center
K-State UTC
Sustainability and safety of rural transportation systems and infrastructure

PCI

UNION PACIFIC RAILROAD

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Engineering Success

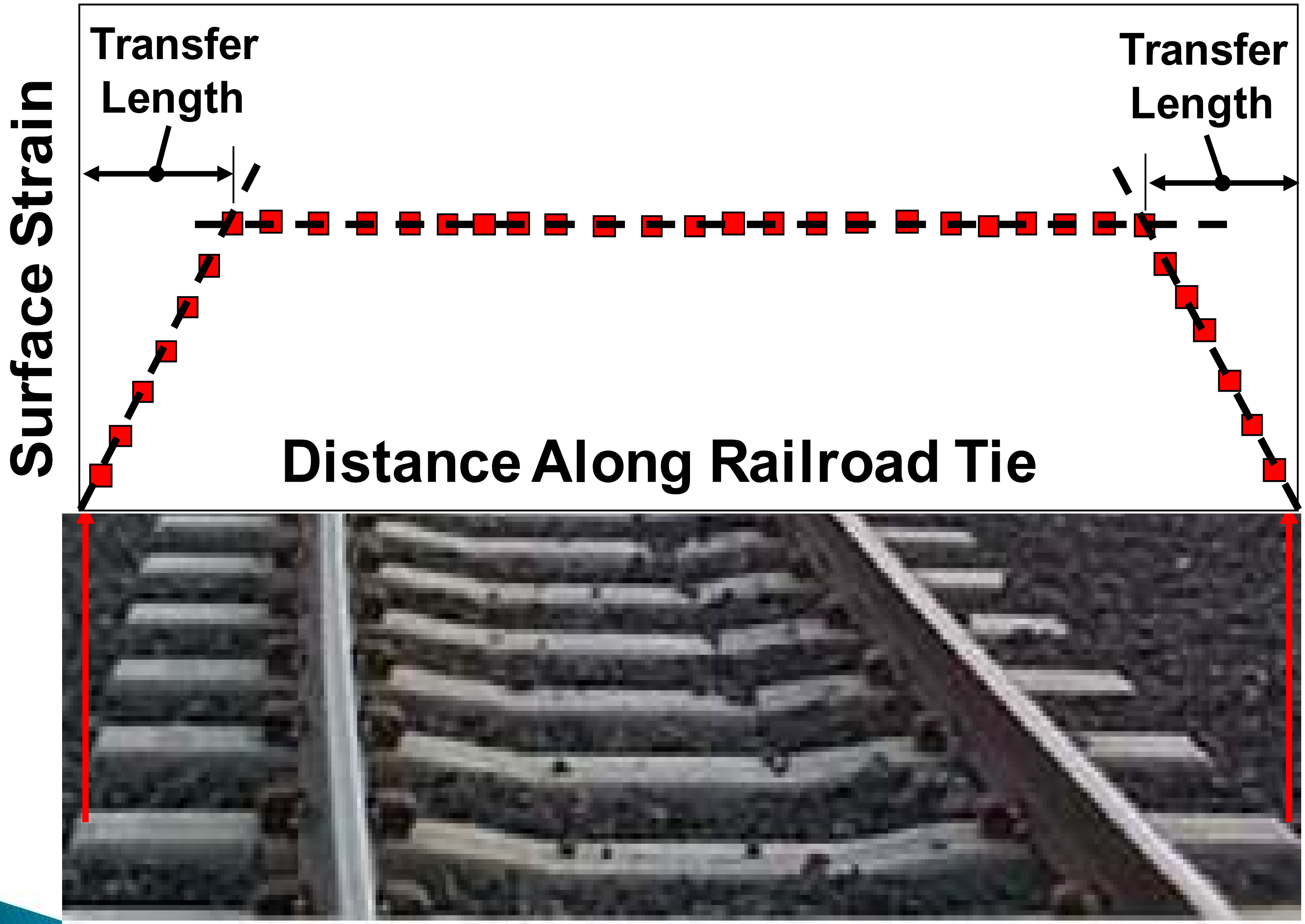
Goal of Quality Control Bond Test

Proper bond here…

… indicates good performance here.

Transfer Length

- The transfer length (or transmission length) is the length required to transfer the effective prestress force to the concrete.
- It must be less than the distance to the rail seat location for the tie to have the maximum shear and moment capacity.
- Transfer lengths that are too short can result in excessive busting demand at the ends of the pretensioned members


Surface Strain
Transfer
Length
Transfer
Length
Distance Along Railroad Tie

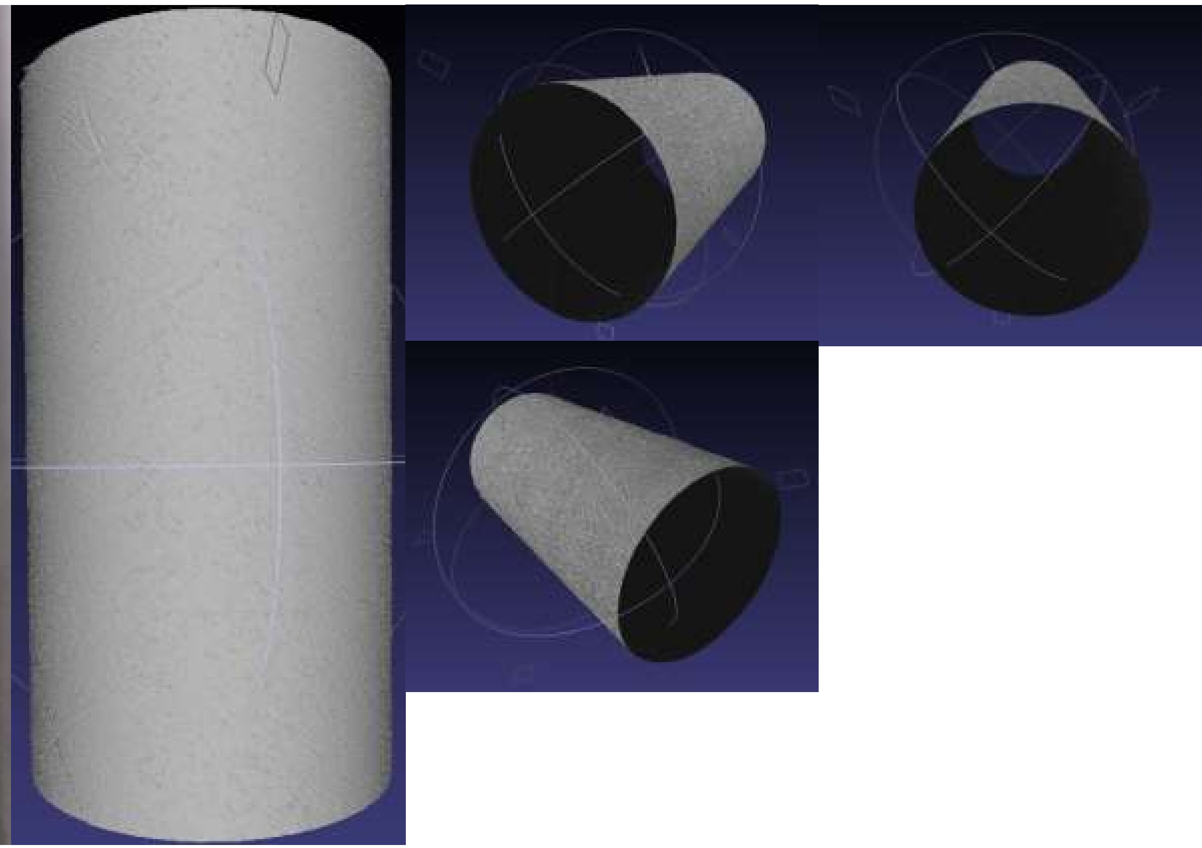

10
5

Pullout Test Lab Work Conducted by…

Matthew Arnold
Former M.S. Student
Kansas State University
Department of Civil Engineering

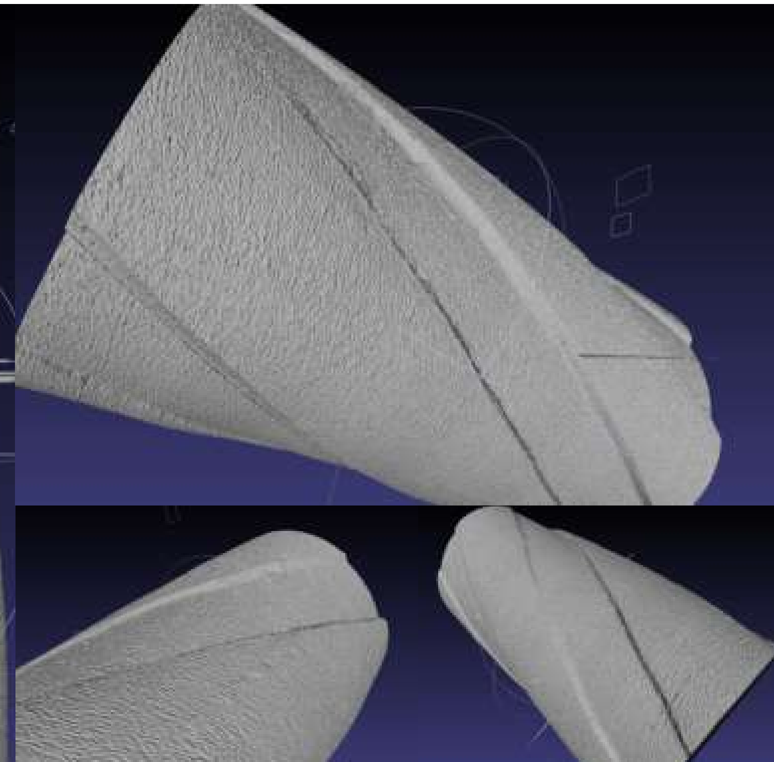
13 Wires (12 Original + 1 Added)

WA (smooth)

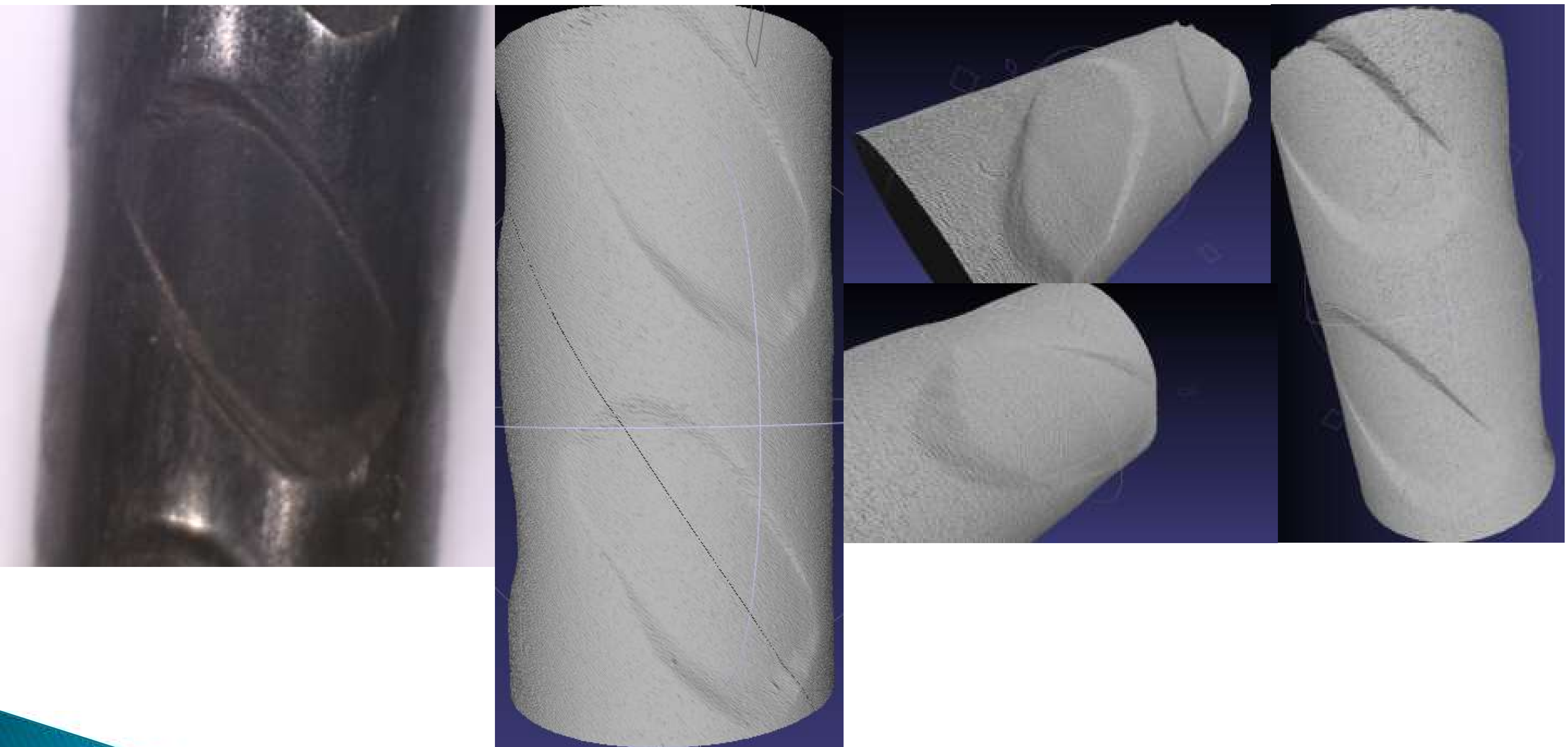


WB (chevron)

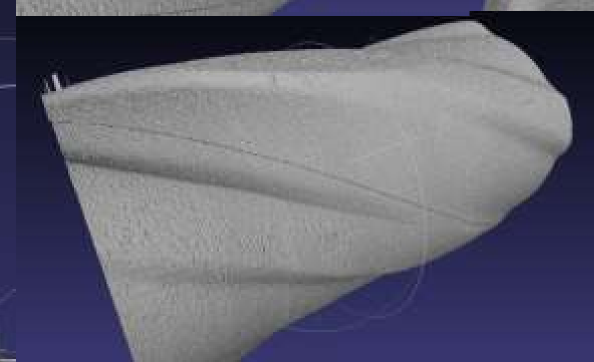
WC (spiral)



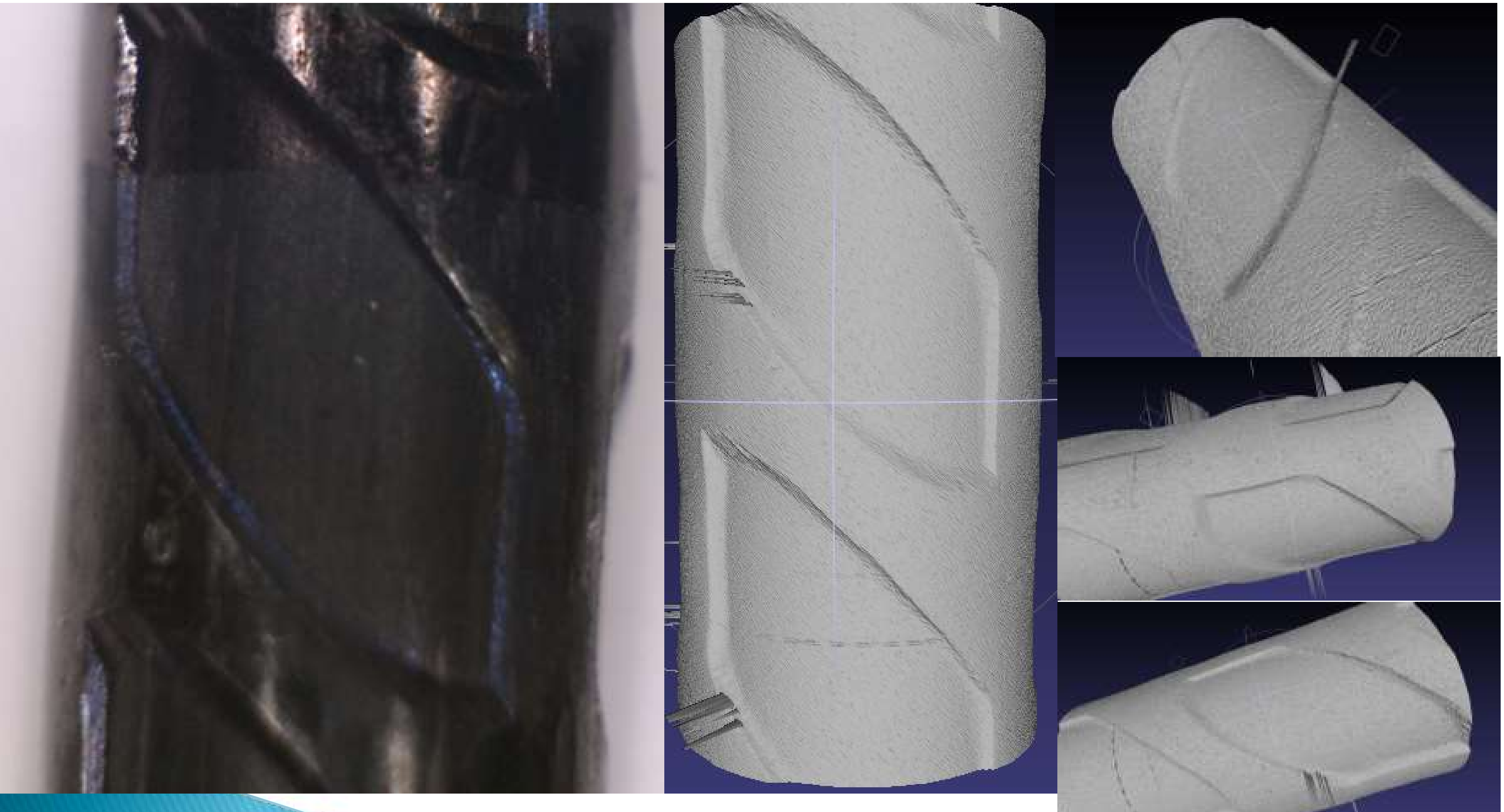
WD (chevron)



WE (spiral)

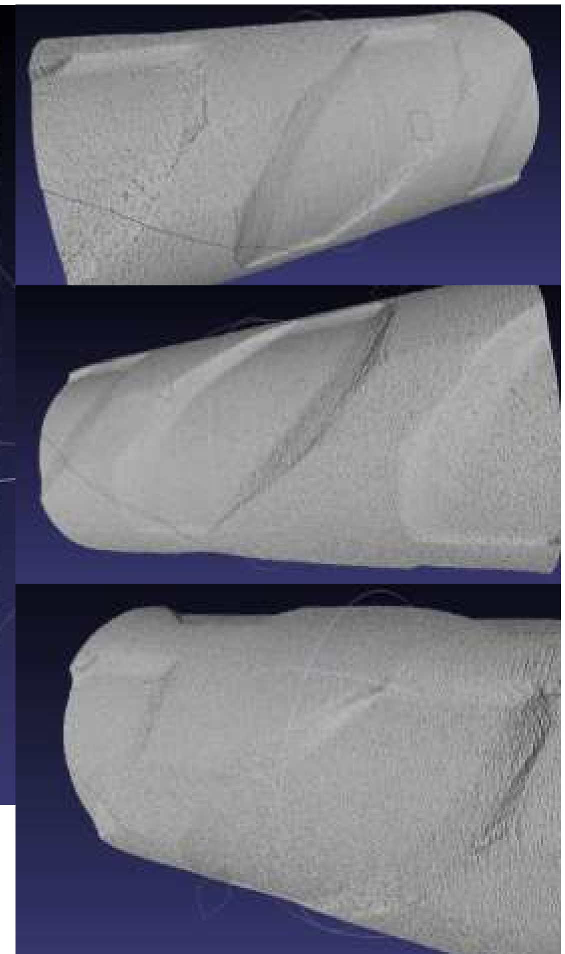


WF (diamond)



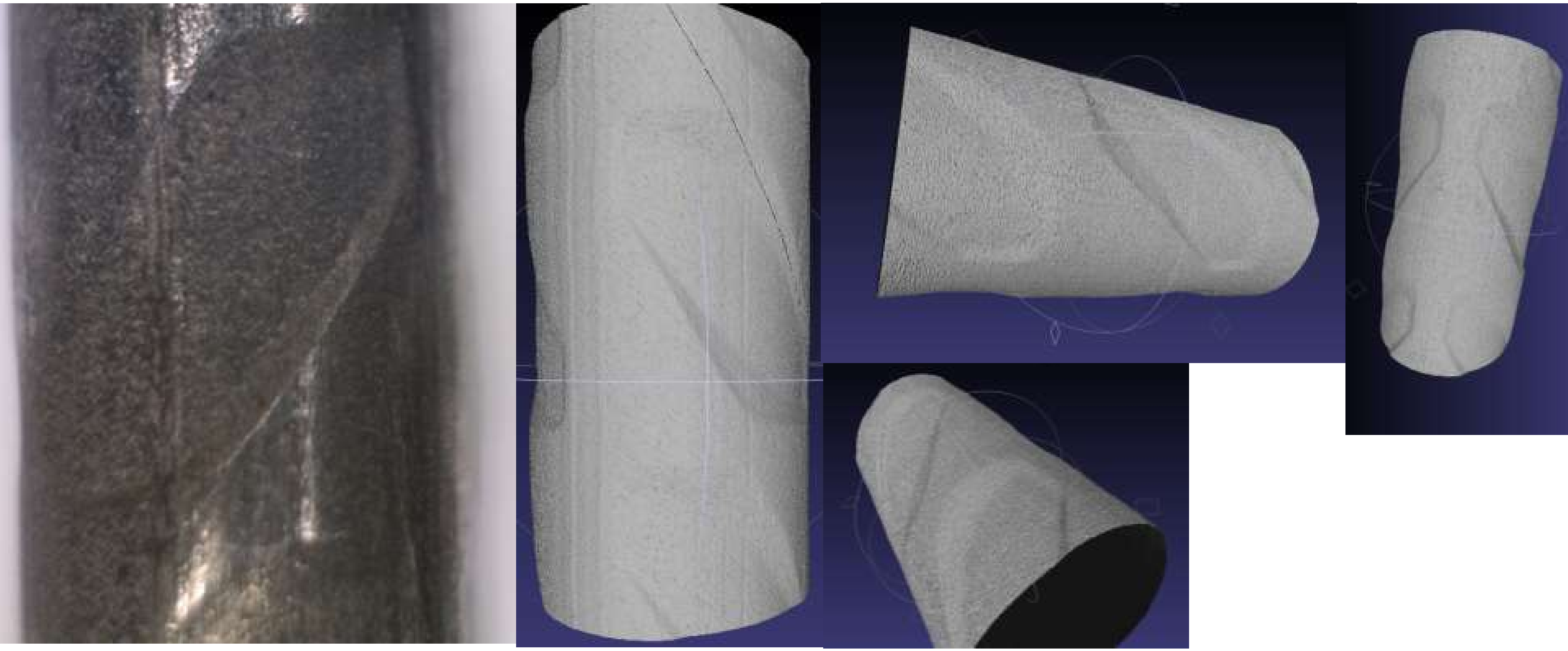
WG (chevron)

WH (chevron)

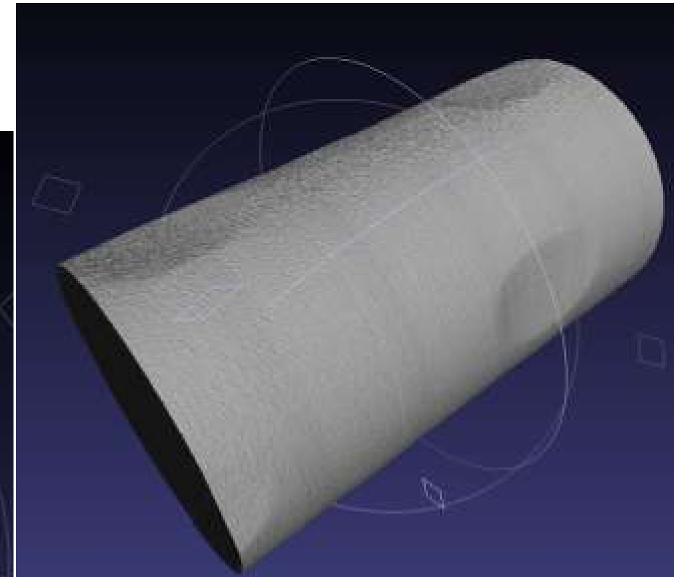


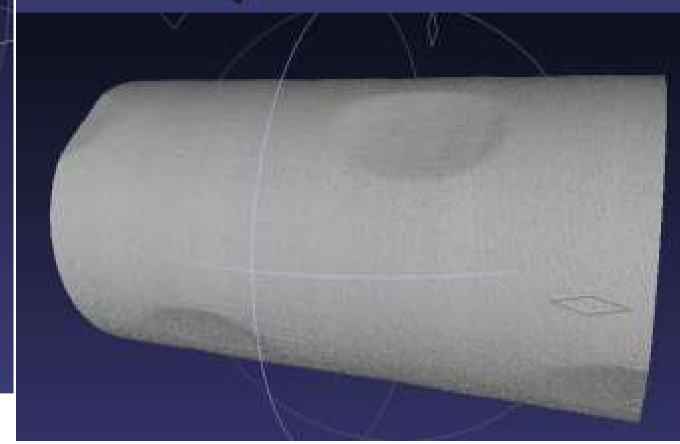
WI (chevron)

WJ (chevron)

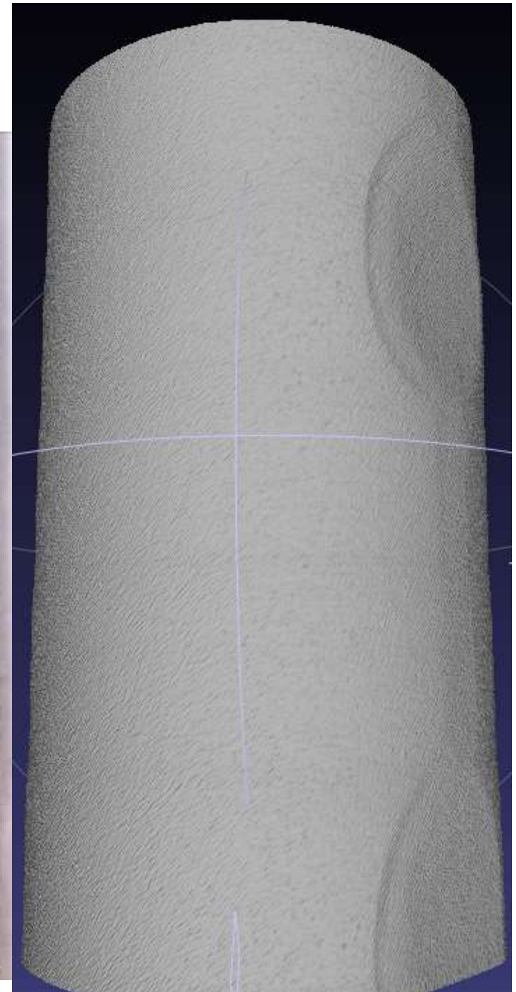


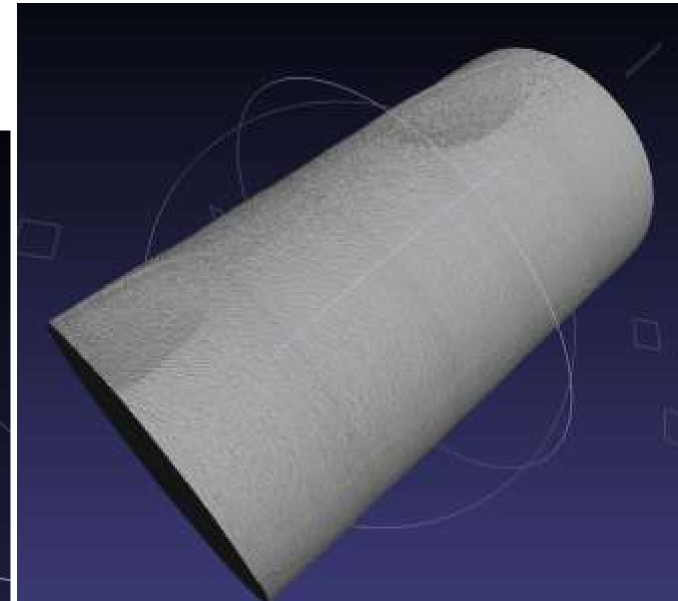
WK (4 DOT)



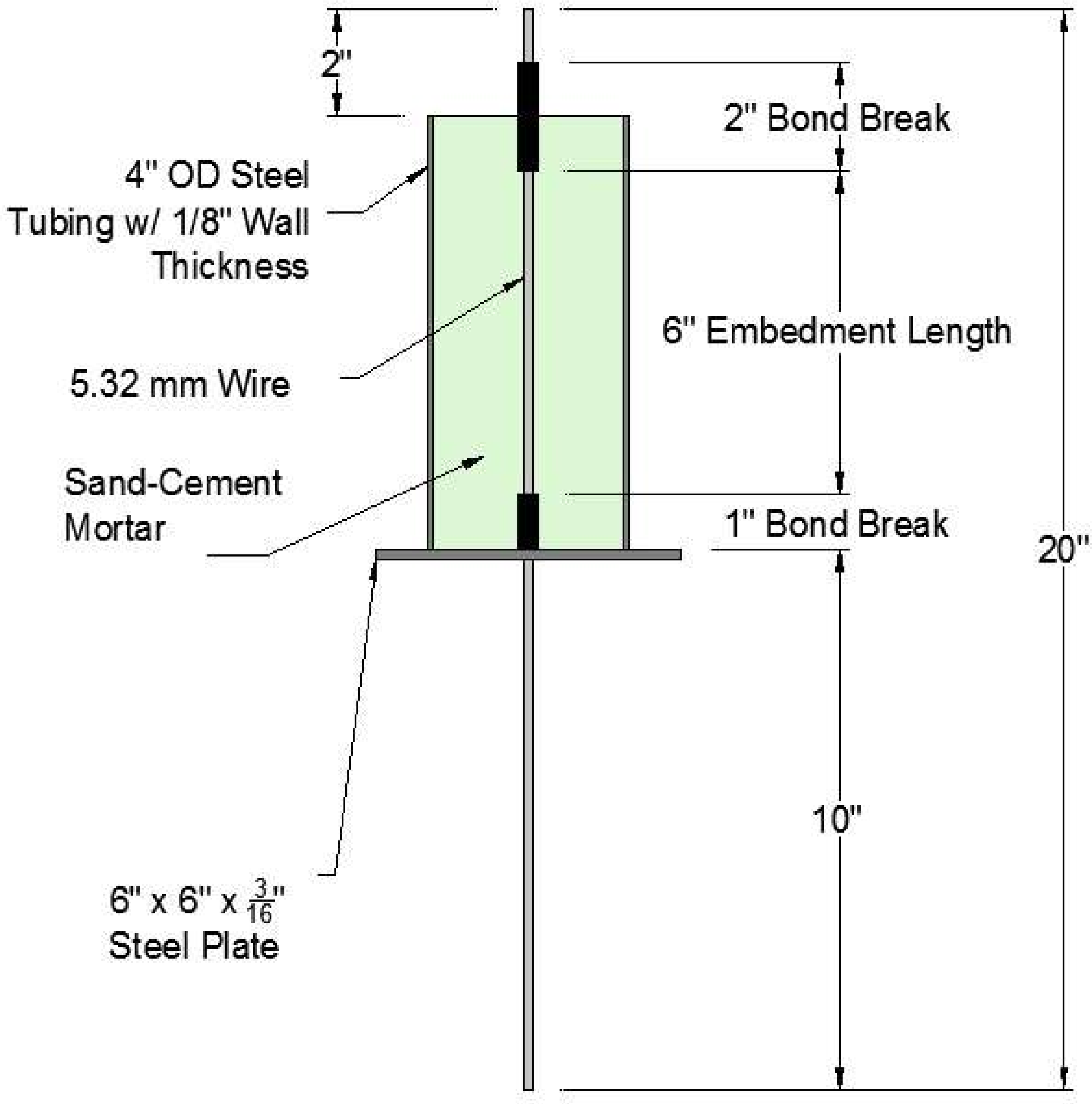


WL (2 DOT)





Wire Specimen Dimensions



Standard Materials and Mix Proportions

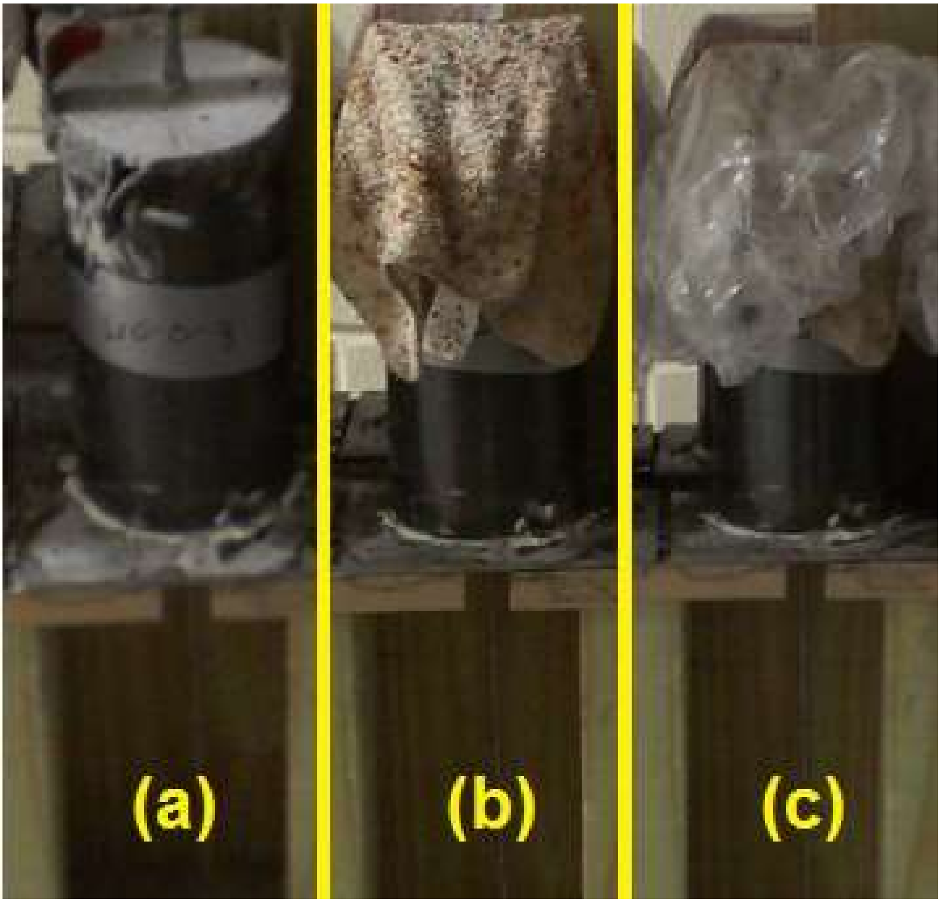
- Type III cement (ASTM C150)
- ASTM C778 Sand (Ottawa Sand)
  - Pre-sieved, 50-pound bags

- s/c = 2.0
- w/c = 0.427

Casting

- Wire is secured in can
- Mortar places in 2 lifts
- Vibrate each lift

Curing Method



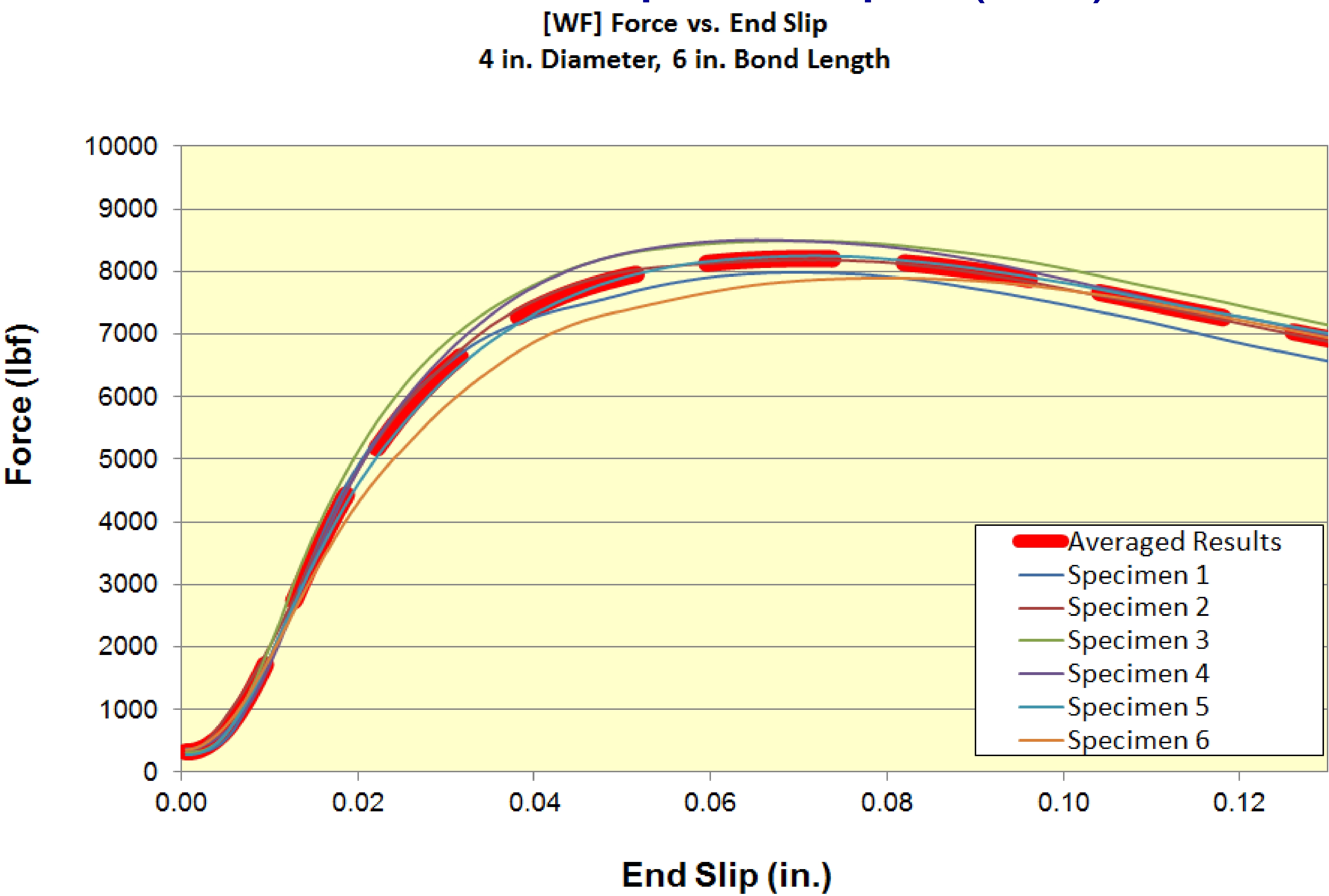
Before After

Specimens made and stored at room temperature ($73.5 \pm 3^{o}F$) and in a humidity controlled environment)

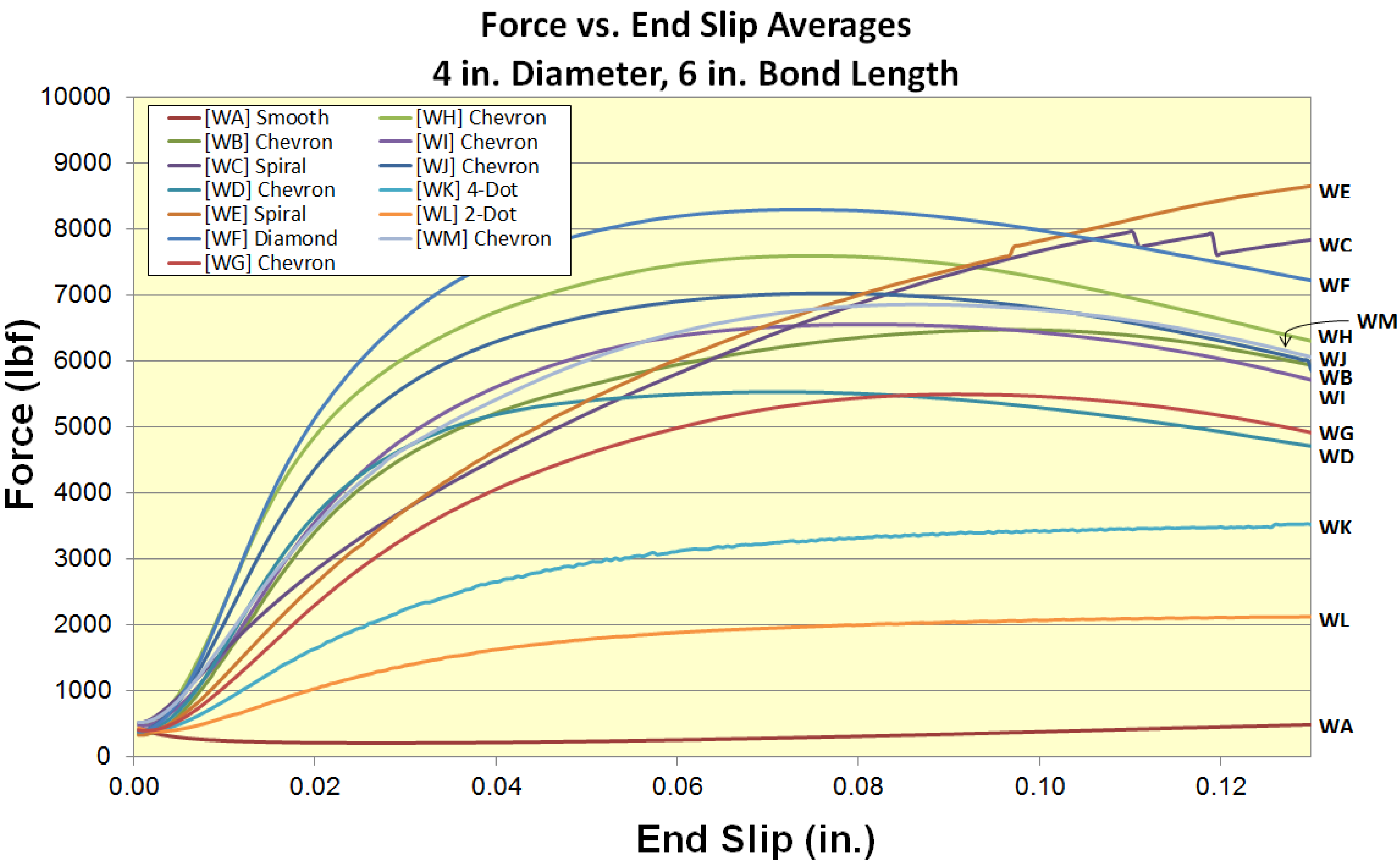
Testing Protocol

- Tested when mortar compression strength between 4500-5000 psi
- Force-controlled loading rate of 2000 lbf/min.
- Measure end slip and force in real time

Force vs. End Slip Example (WF)

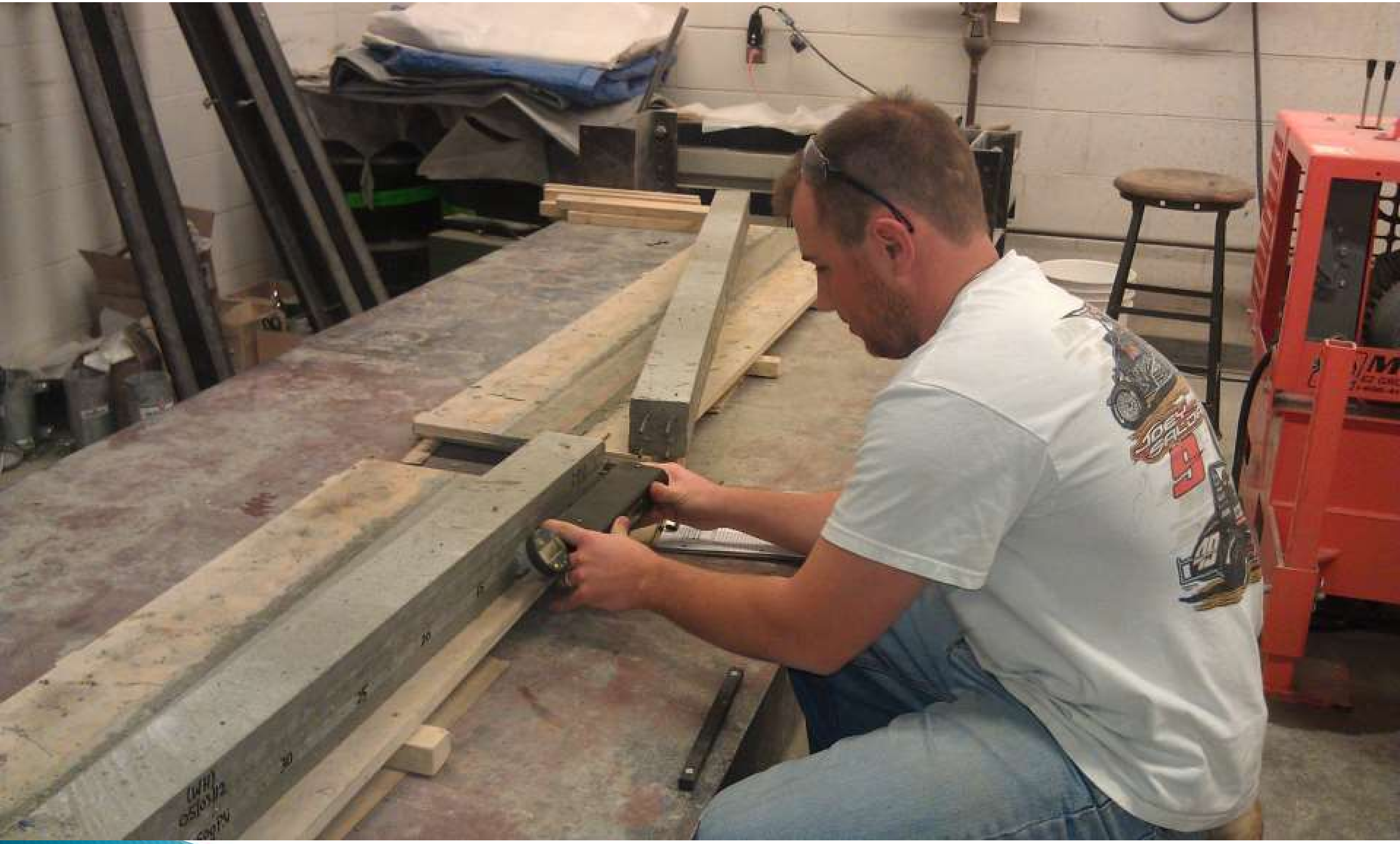


Force vs. End Slip Averages

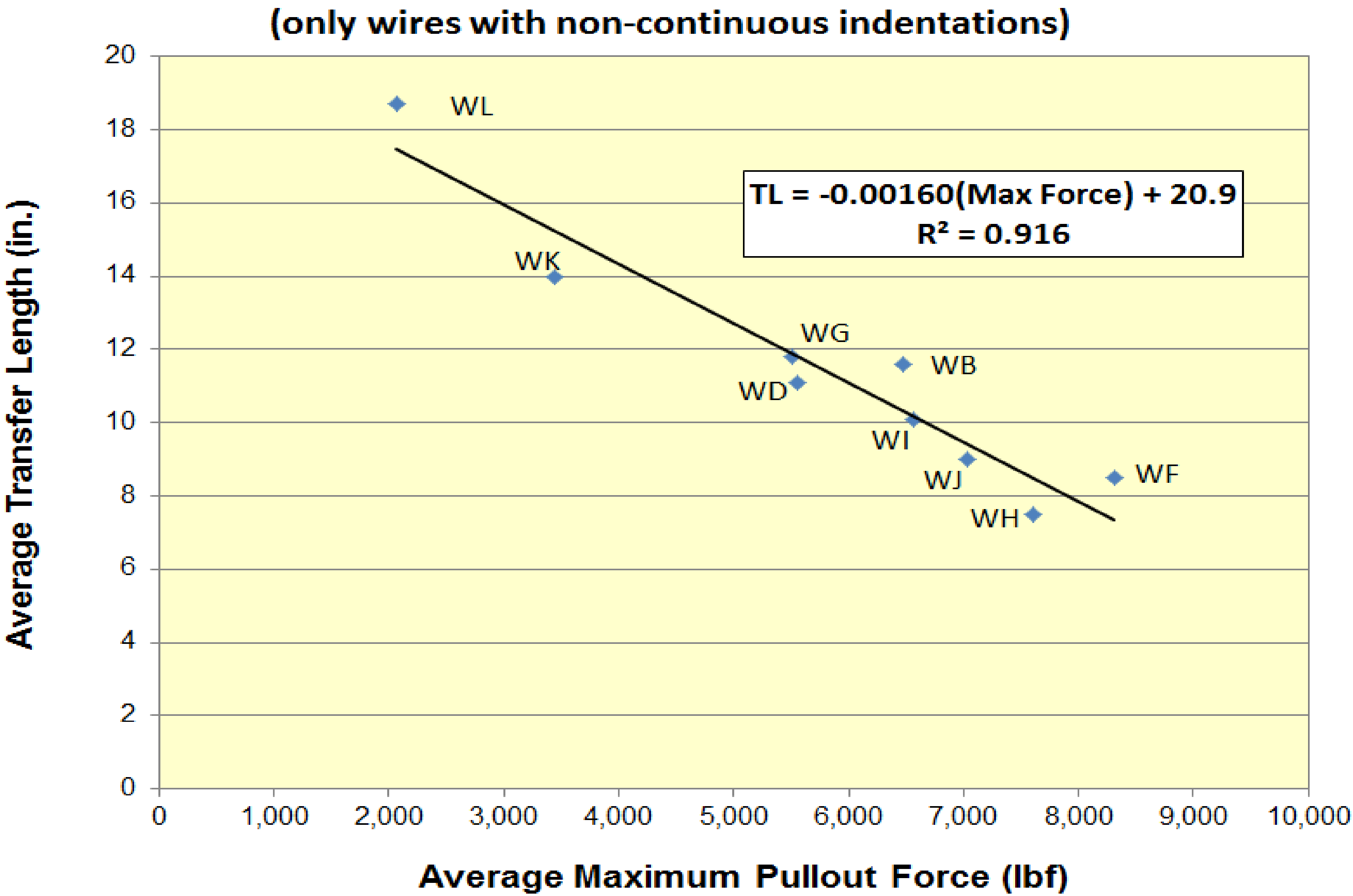


Compare KSU Pullout Tests to KSU Transfer Lengths

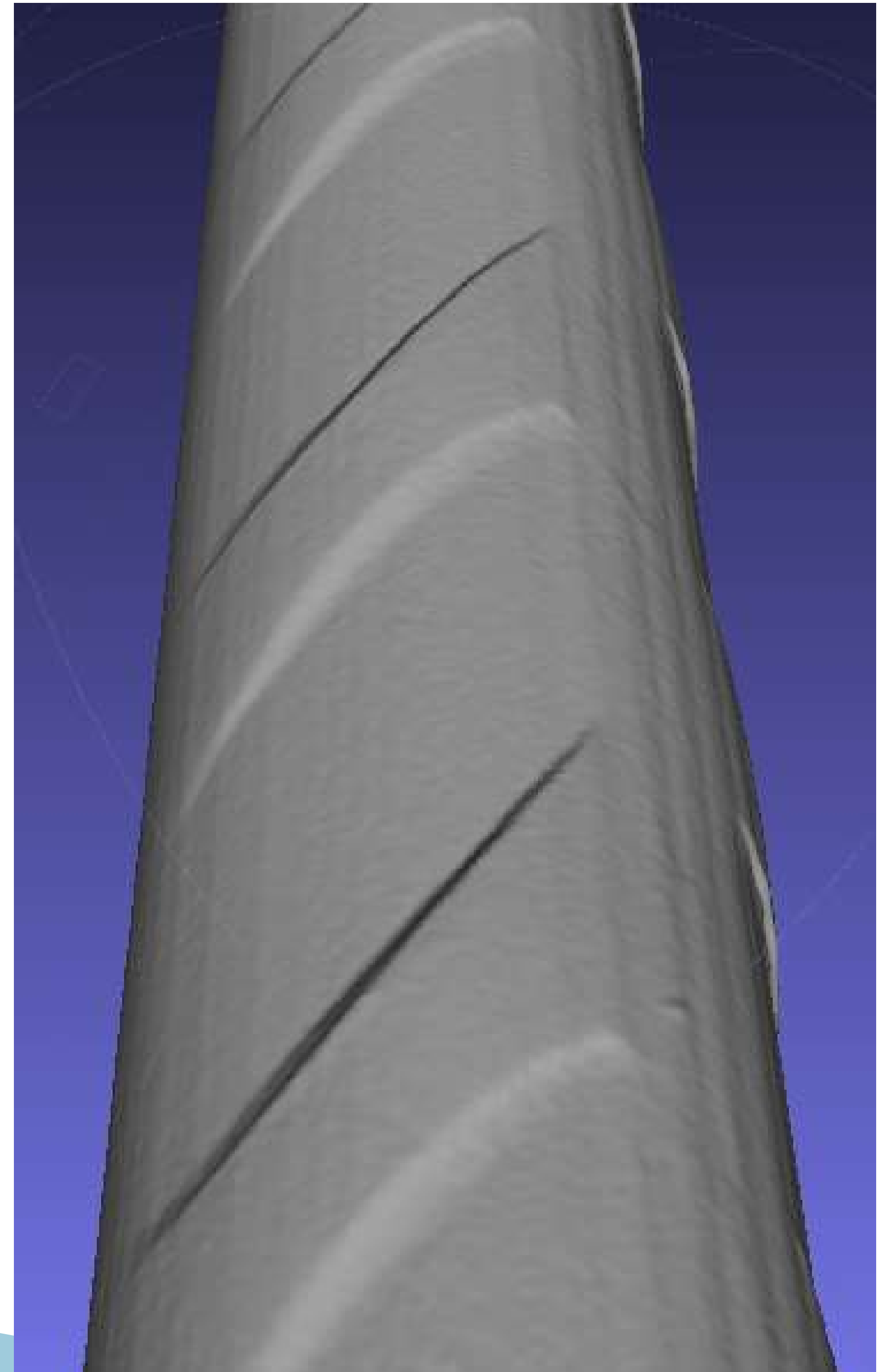
3 pretensioned concrete prisms cast with each wire (6 Transfer Lengths)



Predictive Model



Wire WM



Verification of Wire Model

$$TL = -0.00160(Max\ Force) + 20.9$$

where TL = expected as-received transfer length from prisms

$Max\ Force$ = maximum force ≤ 0.10 in. end slip

- (Avg. max force) $_{WM}$ = 6879 lbf
- Expected TL $_{WM}$ from prisms = 9.9 in.
- Actual Average Transfer Length for WM was 9.8 inches

As- Received [WM]	
Specimen #	Max Force (lbf)
1	6734
2	7642
3	6063
4	6651
5	6857
6	7325
Average	6879

Std. Dev. (lbf) = 503

Coeff. of Variation, C.V. (%) = 7.3

ASTM A1096 Was Officially Adopted By ASTM Committee A01.05 In November 2015

Designation: A1096 – 15

Standard Test Method for Evaluating Bond of Individual Steel Wire, Indented or Plain, for Concrete Reinforcement[1]

This standard is issued under the fixed designation A1096; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes procedures for evaluating bond of individual steel wire, indented or plain, for concrete reinforcement. The bond determined by this test method is stated as the tensile force needed to pull the wire through the cured mortar in a cylindrical steel casing.

1.2 The result of the test is the maximum tensile force measured on the loaded end of the wire recorded at a free-end slip less than or equal to 0.10 in. [2.5 mm].

1.3 *Units*—The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appro-*

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C778 Specification for Standard Sand

3. Terminology

3.1 *Definitions:*

3.1.1 *bond, n*—longitudinal components of adhesion, friction, and mechanical interlock between wire and mortar or concrete.

3.1.2 *bond breaker, n*—product wrapped around wire to prevent wire-to-mortar bond over a certain length.

3.1.2.1 *Discussion*—Duct tape is commonly used for this purpose.

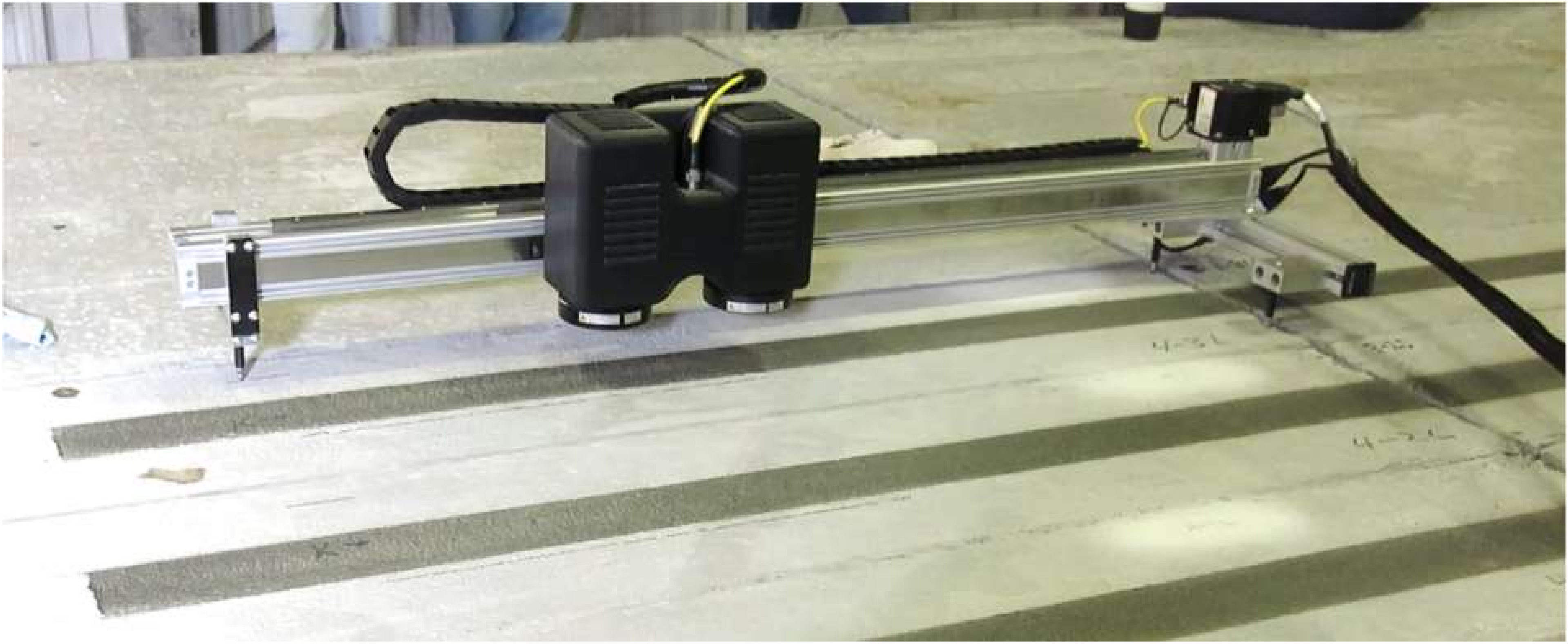
3.1.3 *mortar, n*—mixture of cement, fine aggregate, and water.

3.1.4 *test specimen, n*—assembly consisting of one steel

Opportunities

- Tie manufacturing facility can develop a relationship between A1096 pullout test results and transfer length (for their individual mix and release strength).
- An acceptable bond range (A1096 value) can be established and specified in the purchasing agreement as part of standard quality control measures, so that the targeted transfer length range is achieved.

Transfer-Length Measurements at a Tie Plant in Fall 2015

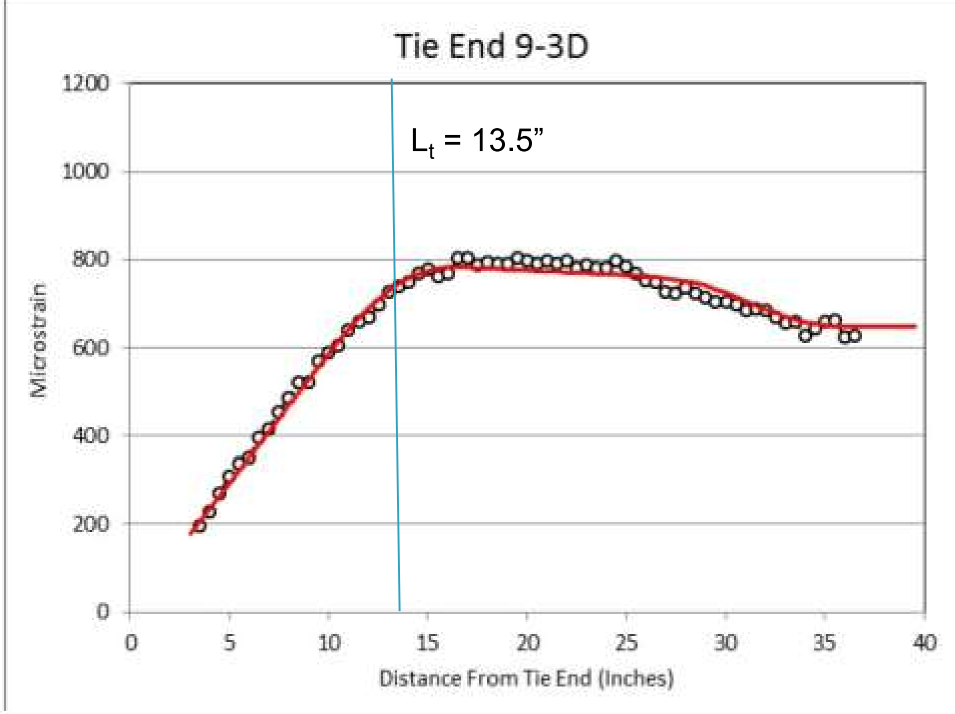


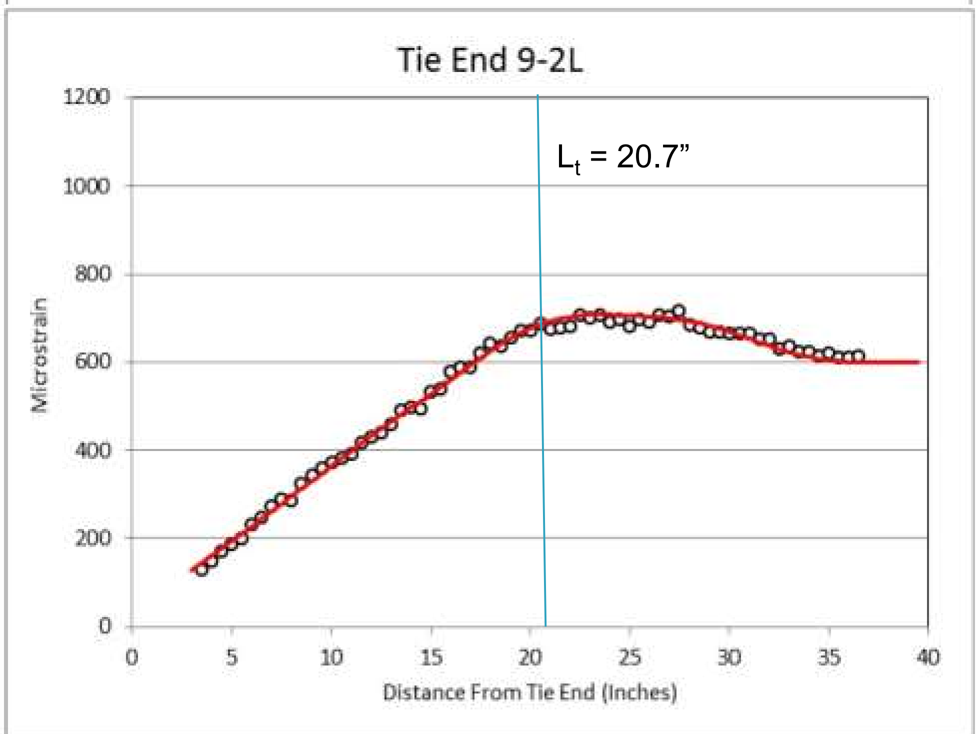
Transfer Length Measurements with Limestone Mix

11-3L	10-3D	10-3L	9-3D	9-3L		
11-2L	10-2D	10-2L	9-2D	9-2L		
11-1L	10-1D	10-1L	9-1D	9-1L		

					Avg. by Cavity
12.8	13.7	13.6	13.5	16.3	14.0
13.3	17.3	16.0	18.0	20.7	17.1
16.8	14.2	18.7	20.1	17.7	17.5

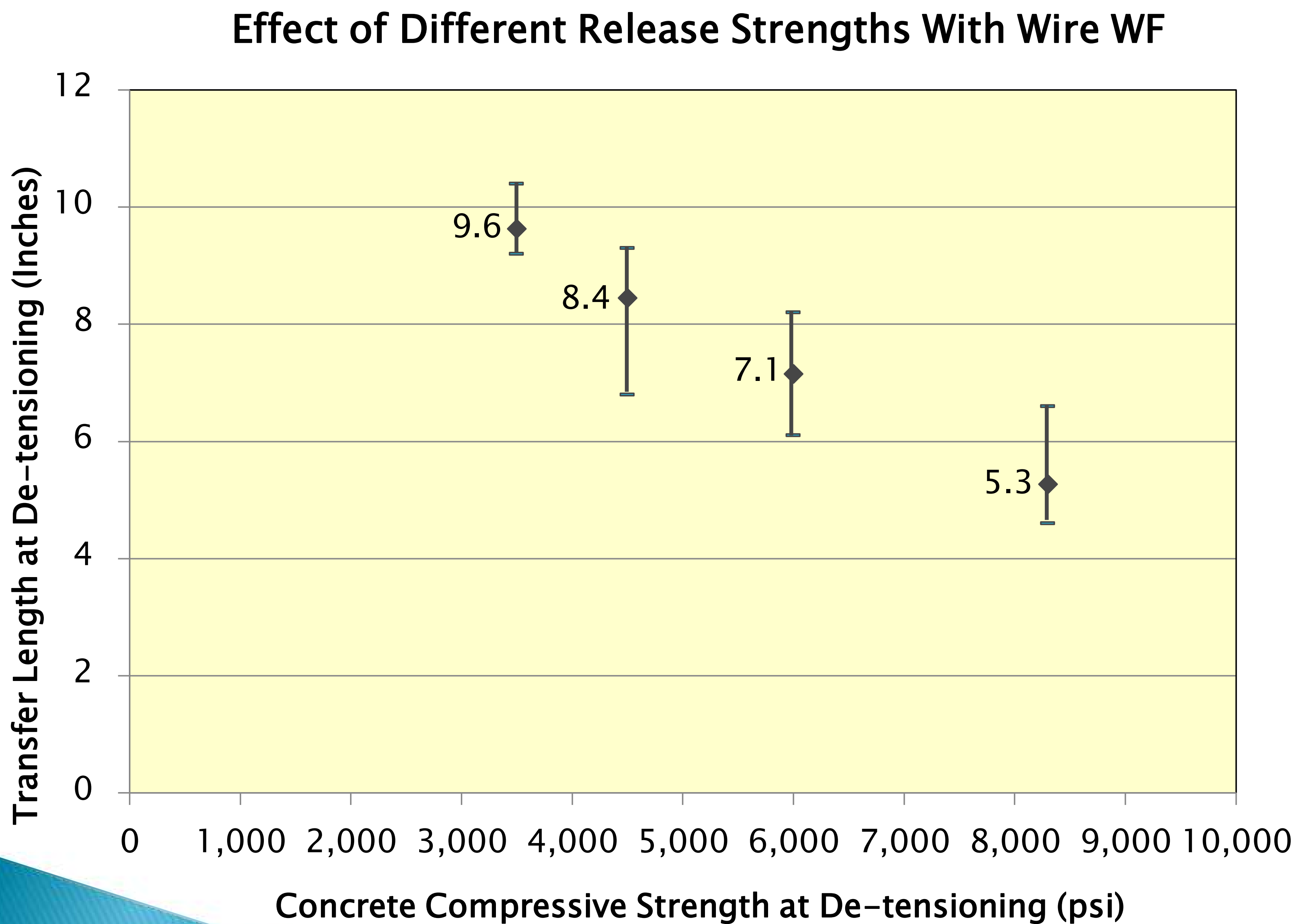
Min.	12.8	in
Max.	20.7	in
Average	**16.2**	in
St Dev.	2.5	in
Coeff. Var.	15.4%	


Tie End 9-3D
L_t = 13.5”
Microstrain
Distance From Tie End (Inches)
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40

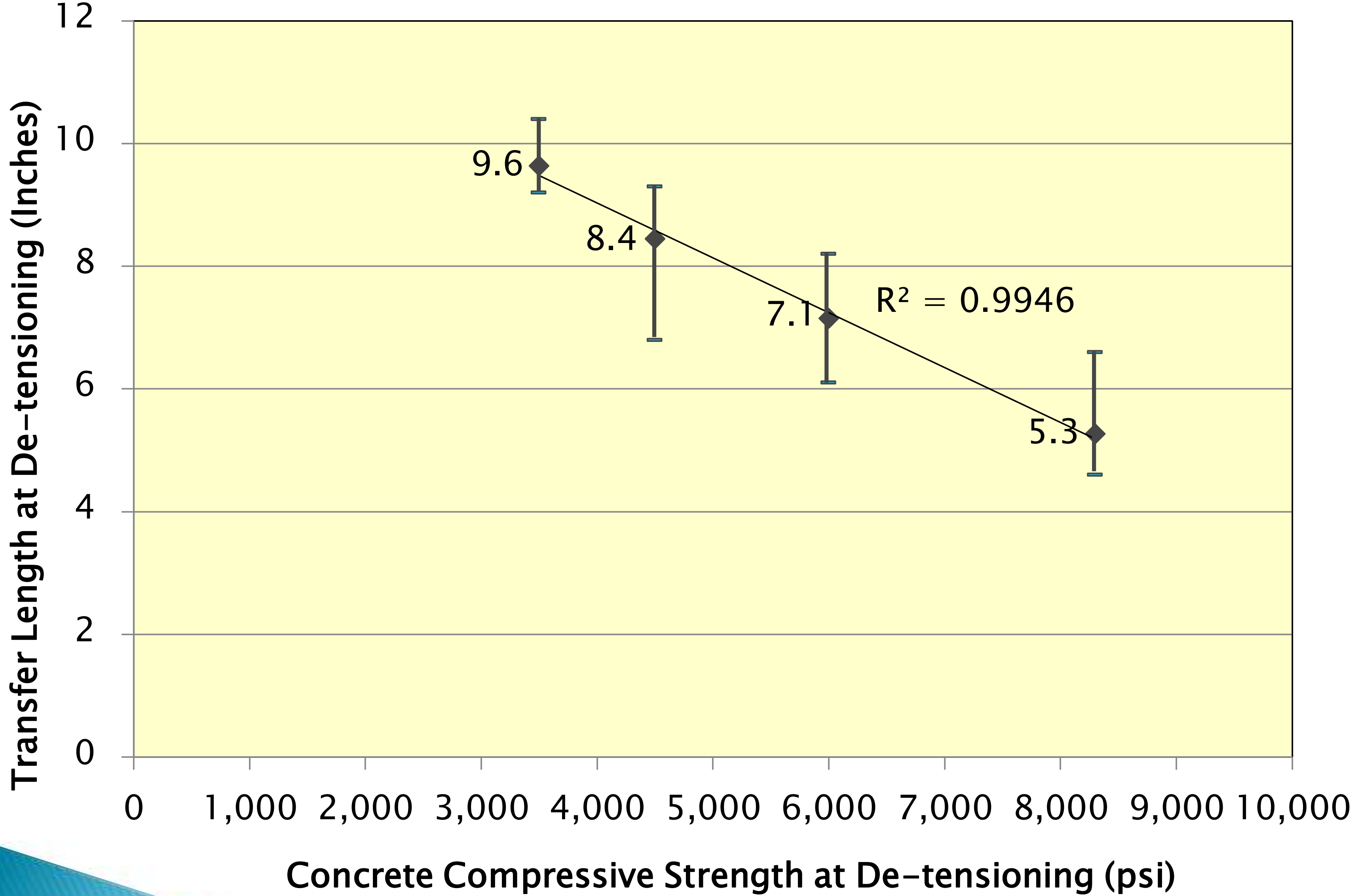

Tie End 9-2L
L_t = 20.7”
Microstrain
Distance From Tie End (Inches)
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40

How can a plant adjust the mean transfer length to the targeted value?

- Specify wires with a different A1096 pullout value in purchasing agreement
- Change the concrete strength at de-tensioning


Effect of Different Release Strengths With Wire WF
Transfer Length at De-tensioning (Inches)
0
2
4
6
8
10
12
9.6
8.4
7.1
5.3
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Concrete Compressive Strength at De-tensioning (psi)

Effect of Different Release Strengths With Wire WF

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How can a plant adjust the mean transfer length to the targeted value?

- Specify wires with a different A1096 pullout value in purchasing agreement
- Adjust the concrete strength at de-tensioning
- Adjust the mix design (change the aggregates)

ECISS/TC 19

Date: 2009-04

prEN 10138-2:2009

ECISS/TC 19

Secretariat: DIN

Prestressing steels — Part 2: Wire

Spannstähle — Teil 2: Draht

Armatures de précontrainte en acier — Partie 2 : Fils

ICS:

Descriptors:

Document type: European Standard
Document subtype:
Document stage: Formal Vote
Document language: E

J:\Intcom\ECISS\ECISS 019\SC 2\Projects\10138-2\FV_preparation\Final\EC0019008_FprEN10138-2_E_Stage_45-99.doc STD Version 2.2

prEN 10138-2:2009 (E)

Table 2 — Specified indentation dimensions for indent type T1

Dimensions in mm

Nominal wire diameter d	Indentation depth a_{max}			Length l	Spacing c
	Range of nominal values		Tolerance on chosen nominal depth		
	from	to			
≤ 5	0,06	0,13	± 0,03	3,5 ± 0,5	5,5 ± 0,5
> 5 to 8	0,09	0,16	± 0,04	5,0 ± 0,5	8,0 ± 0,5
> 8 to 11	0,10	0,20	± 0,05	5,0 ± 0,5	8,0 ± 0,5

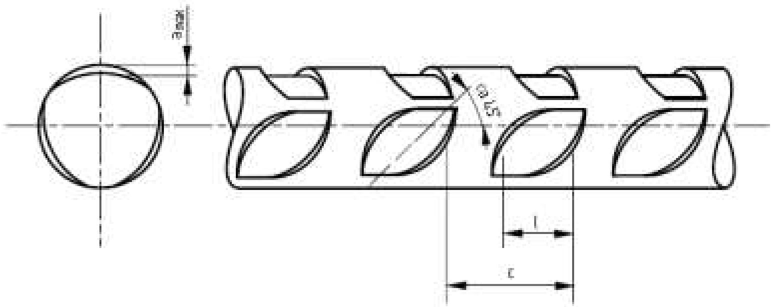

Figure 1 — Indentation type T1

Table 3 — Specified indentation dimensions from indent type T2

Dimensions in mm

Nominal wire diameter d	Indentation depth a_{max}			Length l	Spacing c	Sum of indentation distances $\sum e$
	Range of nominal values		Tolerance on chosen nominal depth			
	from	to				
> 5 to 6	0,10	0,20	± 0,05	3,5 ± 0,5	5,5 ± 0,5	$\sum e \leq 0,2\pi \cdot d$
> 6 to 11	0,12	0,22	± 0,05	3,5 ± 0,5	5,5 ± 0,5	$\sum e \leq 0,2\pi \cdot d$

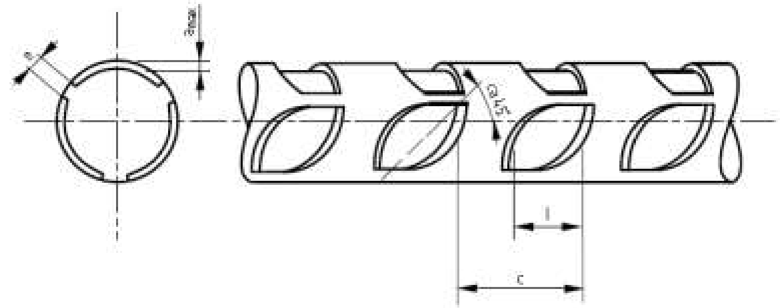

Figure 2 — Indentation type T2

NOTE Indentation type T3 is used where aggregates dictate that transmission length is required to be slightly longer than that produced by the indentation pattern specified in Figures 1 and 2. Indentations on one side should be midway between the indentation positions on the opposite face. (see Figure 3).

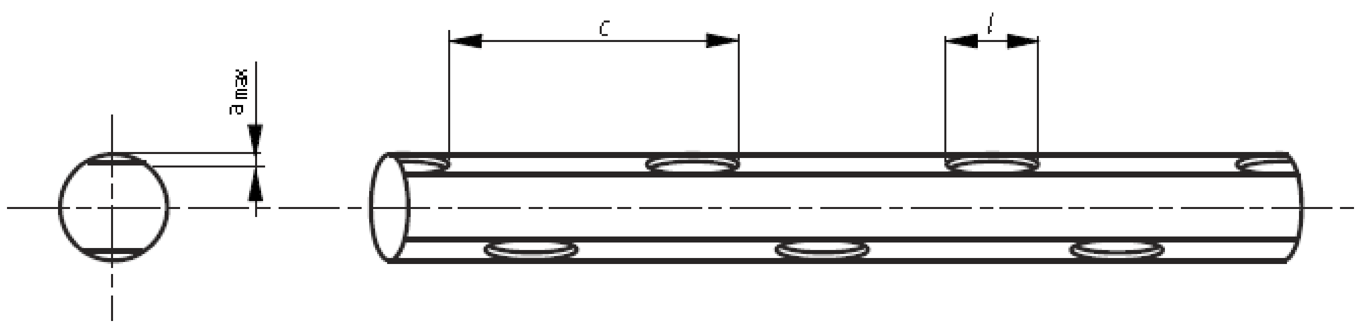

Figure 3 — Indentation type T3

Recommendations

- Concrete tie producers should require wire manufacturers to supply ASTM A1096 test values at least quarterly (the frequency for strand) and probably more since bond in pretensioned concrete railroad ties is extremely important
- In addition, we recommend that the wire indent depth be kept below 0.006 inches (0.15 mm) and the indent sidewall angle should be greater than 25 degrees and ideally between 30-60 degrees


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