OFFICE OF RESEARCH & DEVELOPMENT

2012 R&D REVIEW

Quantifying the Effect of Prestressing Steel and Concrete Variables on the Transfer Length in Pretensioned Concrete Crossties

U.S. Department of Transportation
Federal Railroad Administration

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Kansas State University (KSU)

Project Goal

"To develop a comprehensive understanding of the variables affecting the transfer length in prestressed concrete crossties, and to apply this knowledge to ensure the proper design and fabrication of these members for high speed railway applications."

Project Team

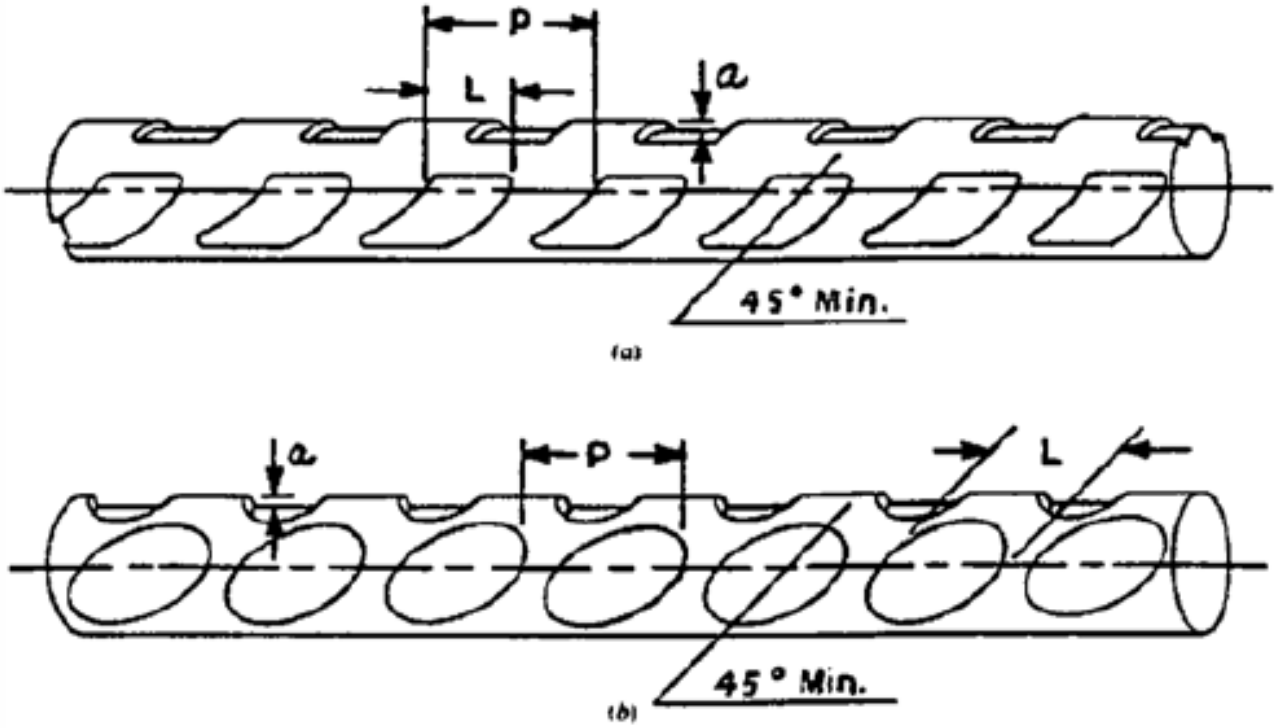
Dr. Robert Peterman	KSU Dept. of Civil Engineering
Dr. Terry Beck	KSU Dept. of Mechanical Engineering
Dr. John Wu	KSU Dept. of Industrial Engineering
Pelle Duong	Chief Engineer, CXT Concrete Ties, Inc.

Most Crossties use either indented wire or indented strand

Conforms to ASTM A-881

Designation: A881/A881M – 10

Standard Specification for Steel Wire, Indented, Low-Relaxation for Prestressed Concrete Railroad Ties[1]



7.2 *Type*—Two acceptable types of indented wire are shown in Fig. 2(*a*) and (*b*), with dimensions in Table 2.

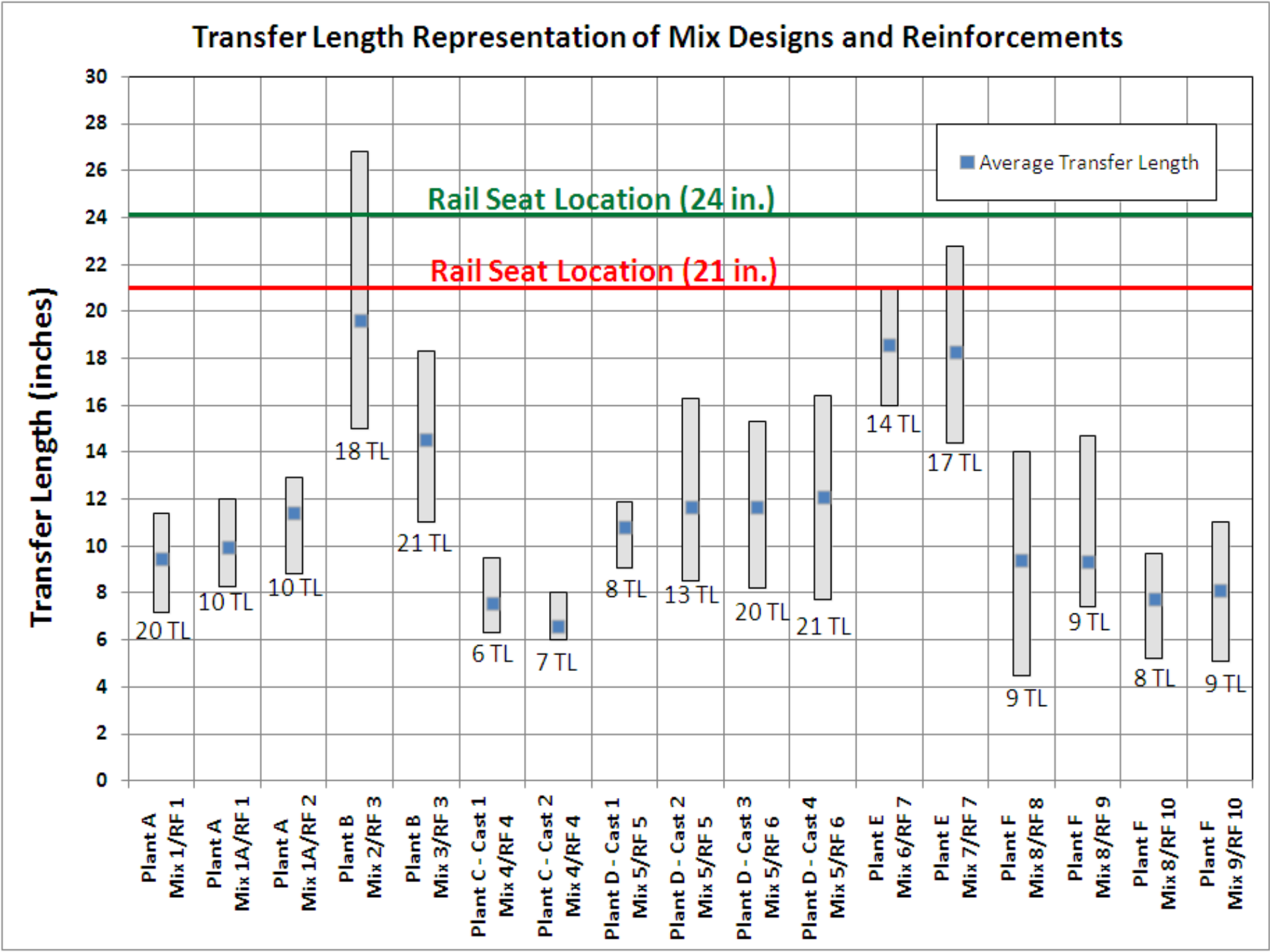
7.3 *Options*—Other types of indented wire are permitted by agreement, provided the wire is comparable with the accepted types in mechanical properties and bond with concrete.

Investigation of Transfer Lengths at 6 Concrete Tie Producers in USA

- Funded by Mid-America Transportation Center (MATC)
- First coordinated effort to measure transfer lengths of concrete railroad ties that has ever been conducted in the industry
- 220 Transfer Lengths Measured

Plants and Locations

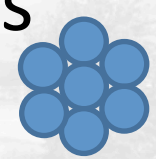
- CXT Concrete Ties (Grand Island, NE)
- CXT Concrete Ties (Spokane, WA)
- CXT Concrete Ties (Tucson, AZ)
- Koppers-KSA (Sciotoville, OH)
- Rocla Concrete Tie (Denver, CO)
- VAE Nortrak (Cheyenne, WY)


Transfer Length Representation of Mix Designs and Reinforcements
Transfer Length (inches)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Average Transfer Length
Rail Seat Location (24 in.)
Rail Seat Location (21 in.)
20 TL
10 TL
10 TL
18 TL
21 TL
6 TL
7 TL
8 TL
13 TL
20 TL
21 TL
14 TL
17 TL
9 TL
9 TL
8 TL
9 TL
Plant A Mix 1/RF 1
Plant A Mix 1A/RF 1
Plant A Mix 1A/RF 2
Plant B Mix 2/RF 3
Plant B Mix 3/RF 3
Plant C - Cast 1 Mix 4/RF 4
Plant C - Cast 2 Mix 4/RF 4
Plant D - Cast 1 Mix 5/RF 5
Plant D - Cast 2 Mix 5/RF 5
Plant D - Cast 3 Mix 5/RF 6
Plant D - Cast 4 Mix 5/RF 6
Plant E Mix 6/RF 7
Plant E Mix 7/RF 7
Plant F Mix 8/RF 8
Plant F Mix 8/RF 9
Plant F Mix 8/RF 10
Plant F Mix 9/RF 10

18 Different Reinforcing types

- 11 different indented 5.32-mm round wires
- 1 smooth 5.32-mm round wire

- 3 different indented 7-wire 3/8” strands
- 1 smooth 7-wire strand 3/8” strand



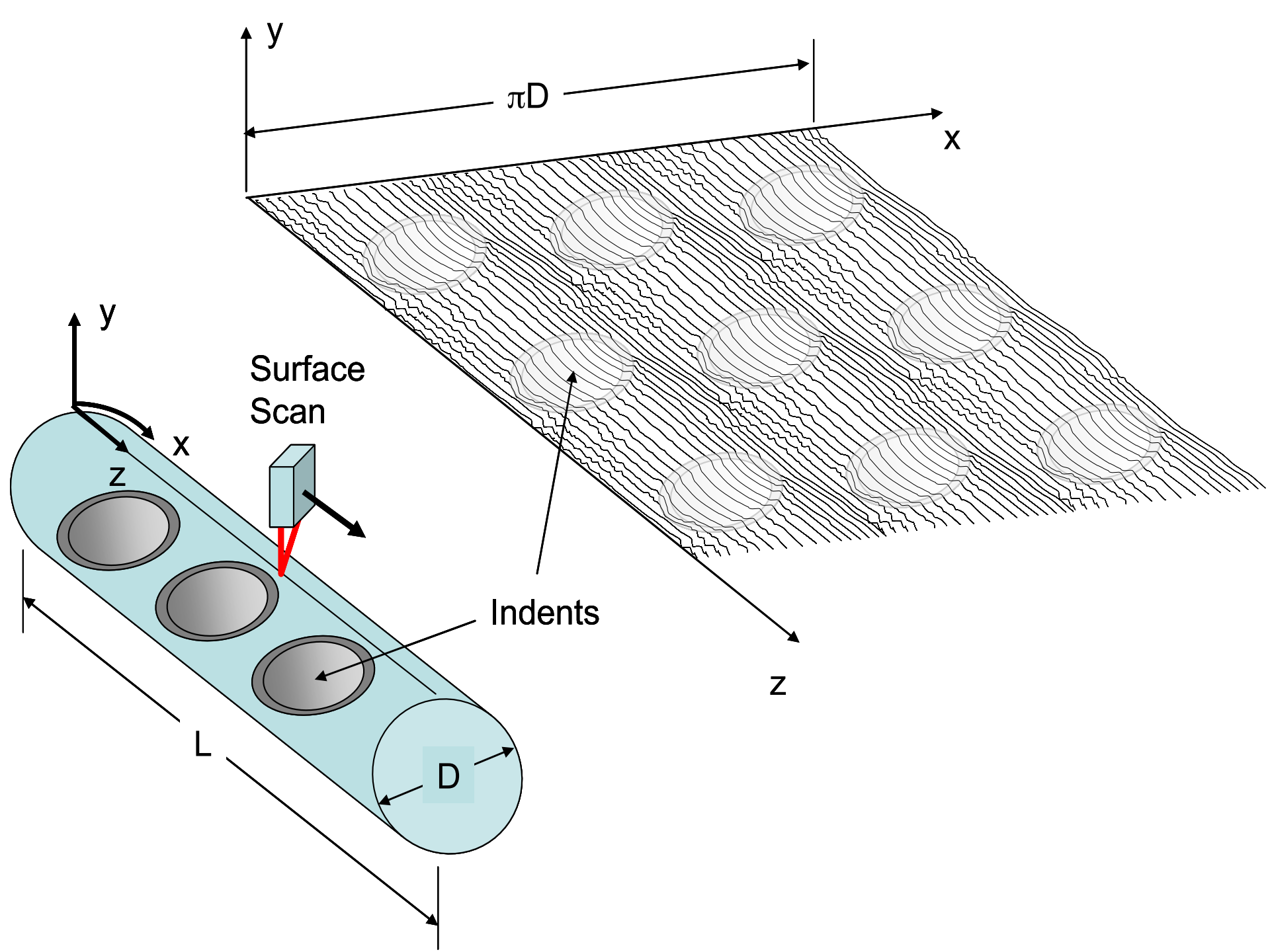
- 1 indented 3-wire 5/16” strand
- 1 smooth 3-wire 5/16” strand

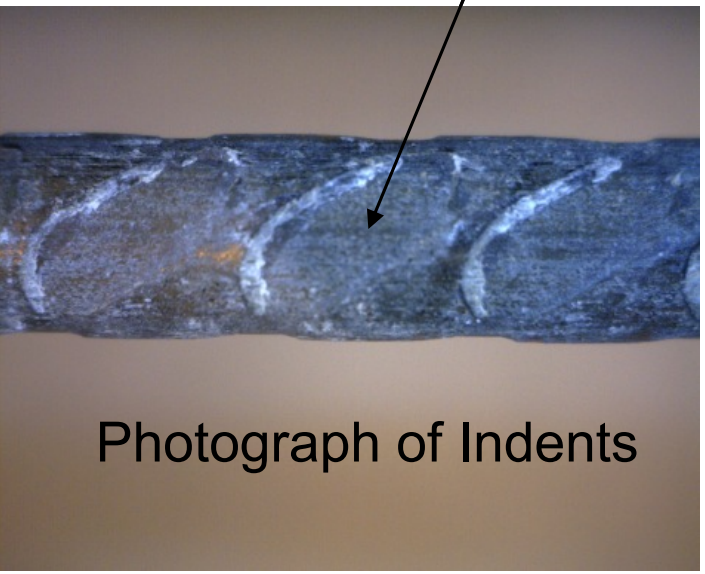
Laboratory Phase

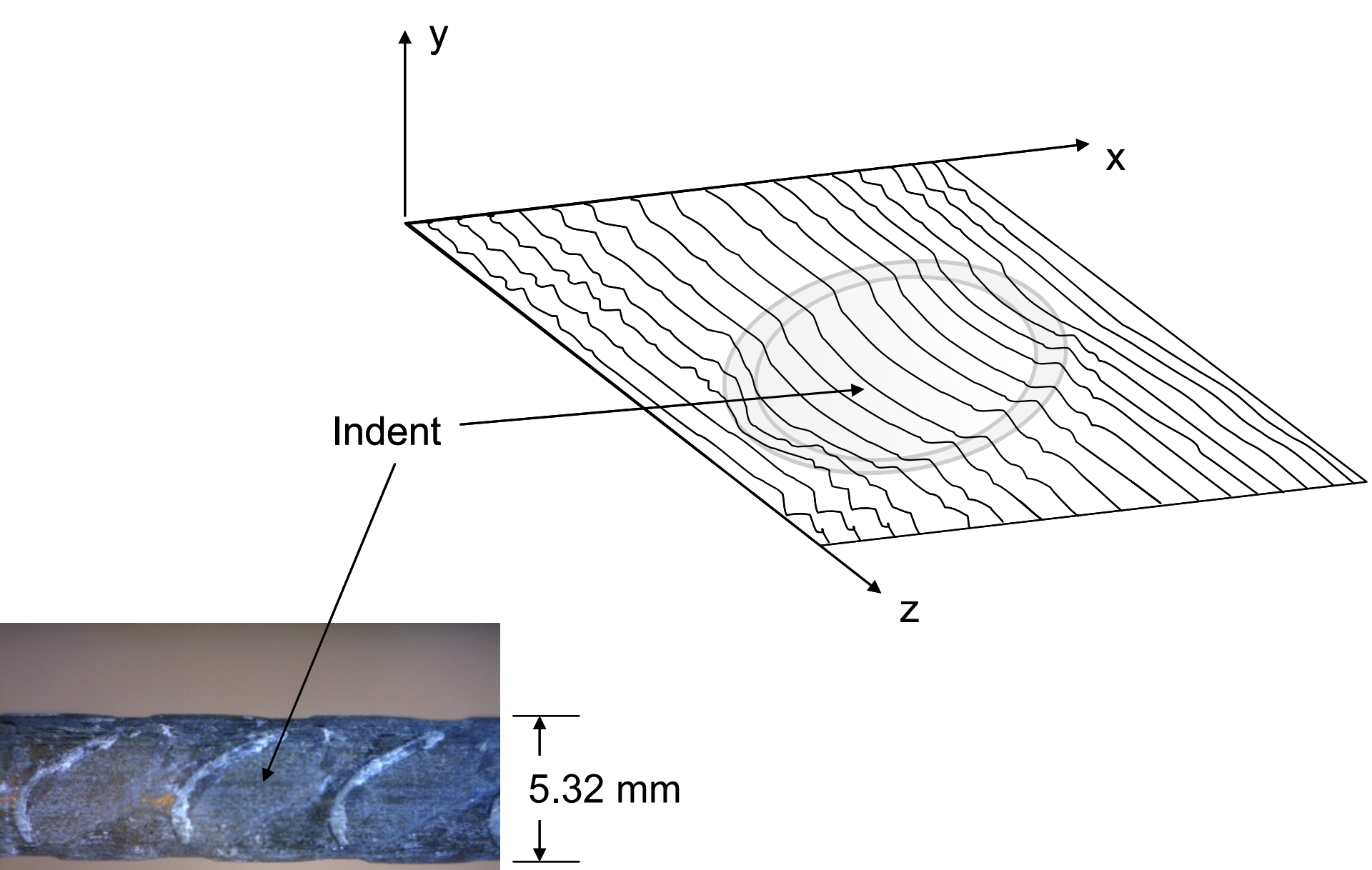
- Measurements of Reinforcement and Indent Geometry
- Transfer Length Measurements on Pre-tensioned Concrete Prism
- Pull-out Tests in Mortar

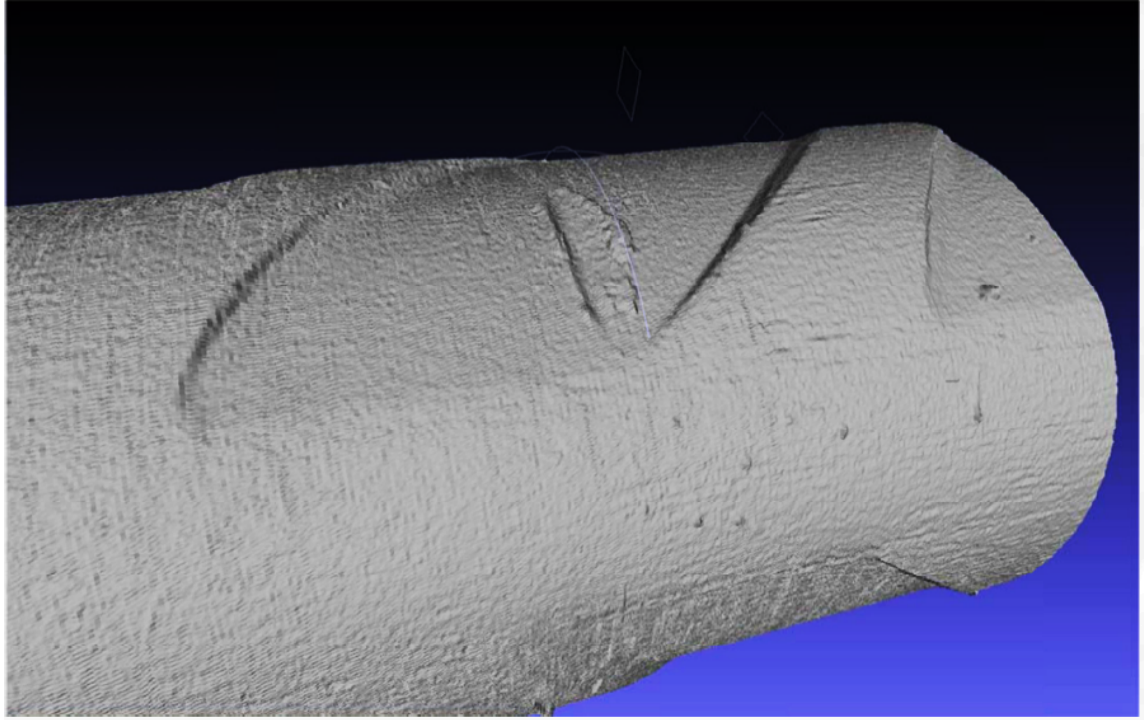
Measurements of the Reinforcement and Indent Geometry

Indent Rollers

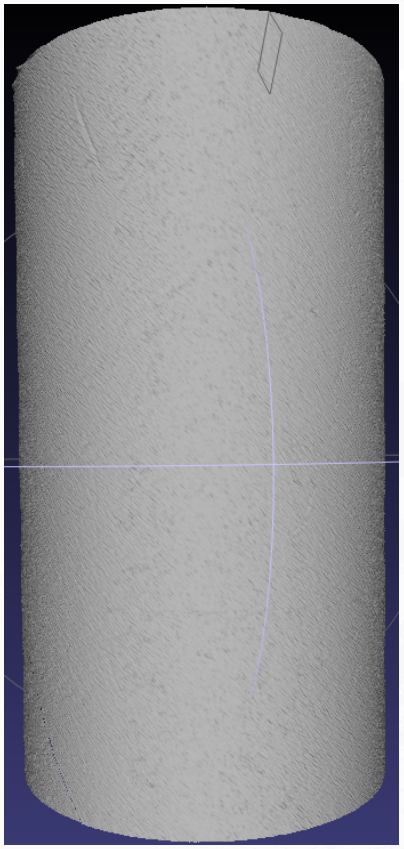

y
πD
x
y
Surface
Scan
x
z
Indents
z
L
D

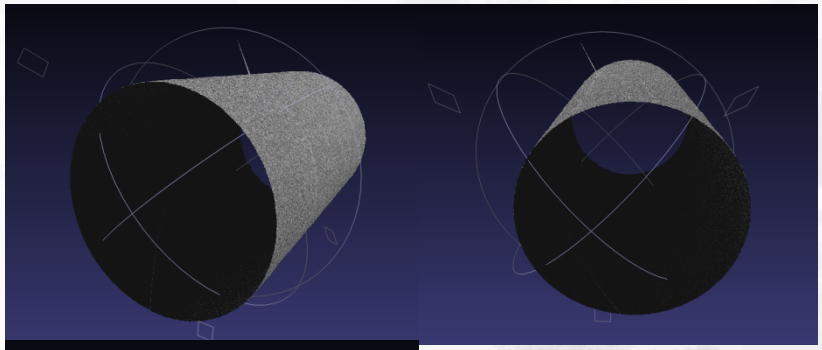

Photograph of Indents

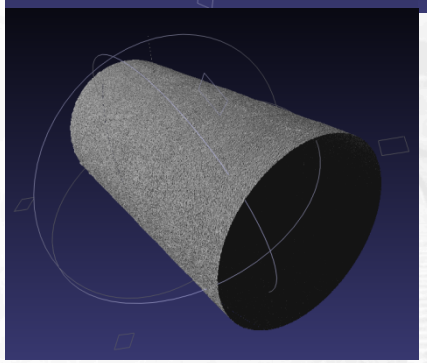

y
x
z
Indent
5.32 mm



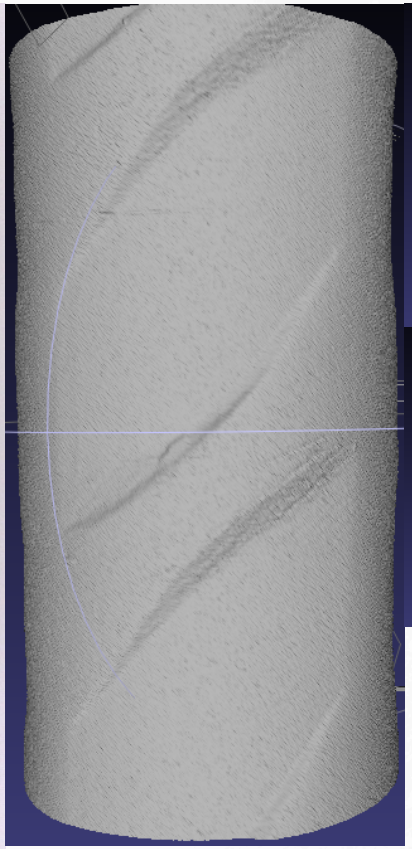
WA (smooth)

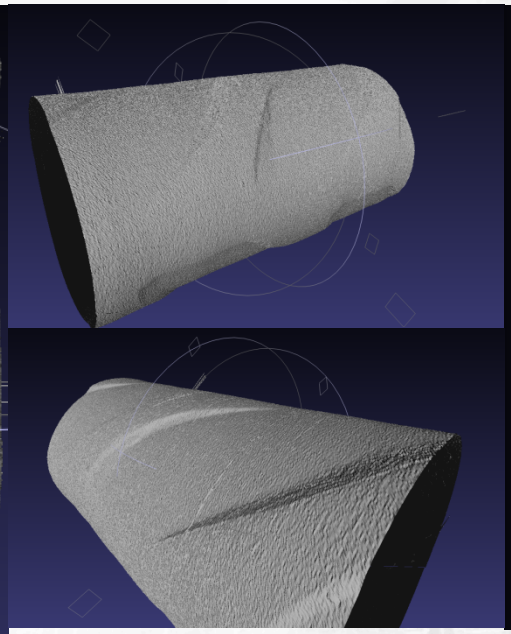




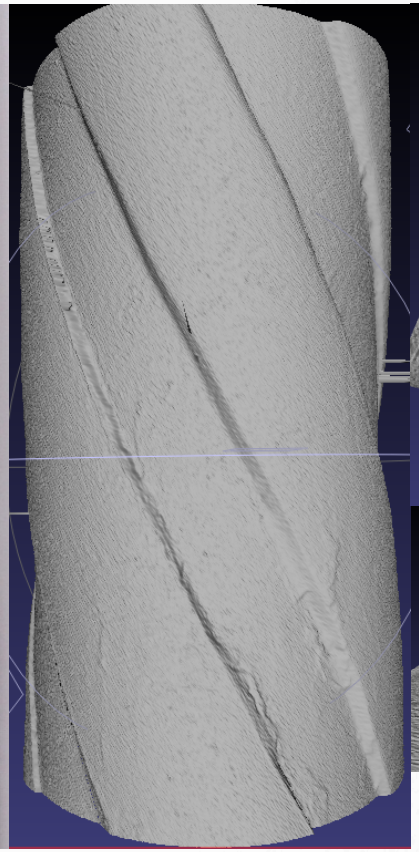


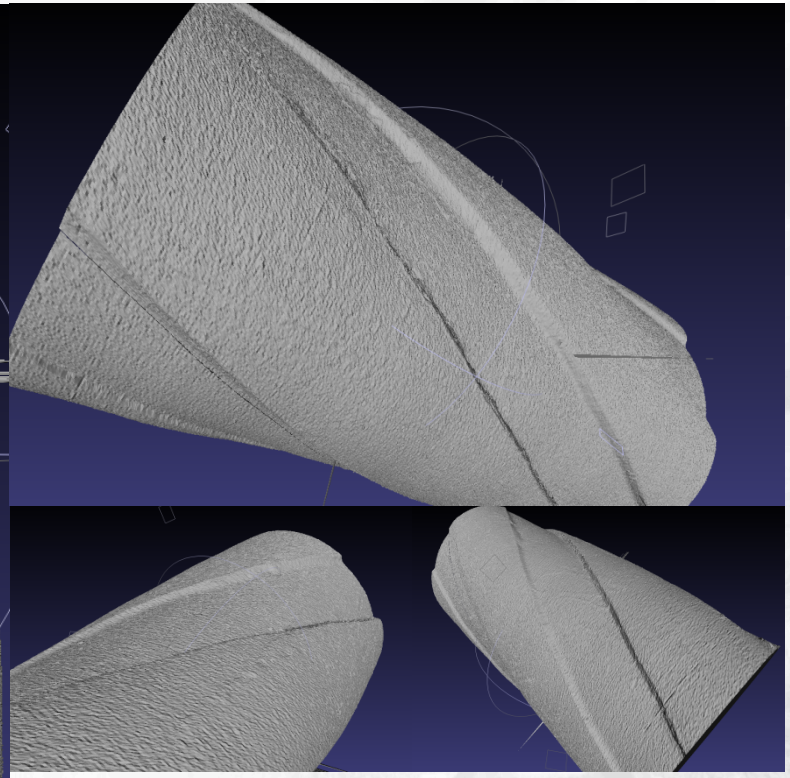
WB (chevron)



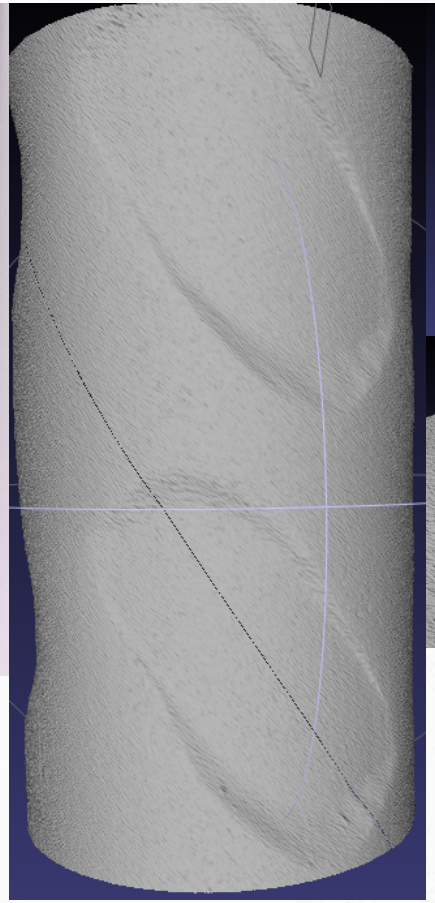


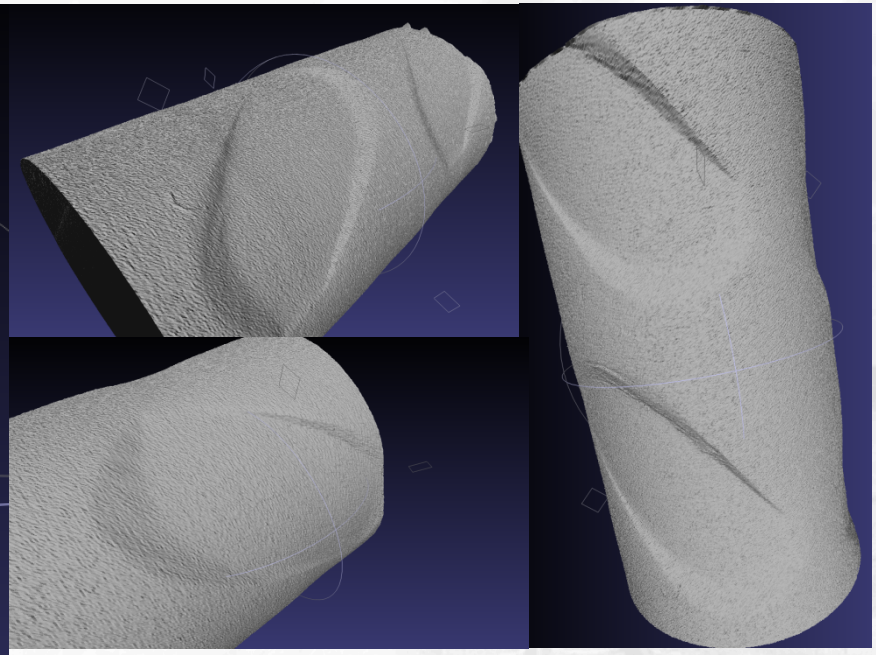
WC (spiral)



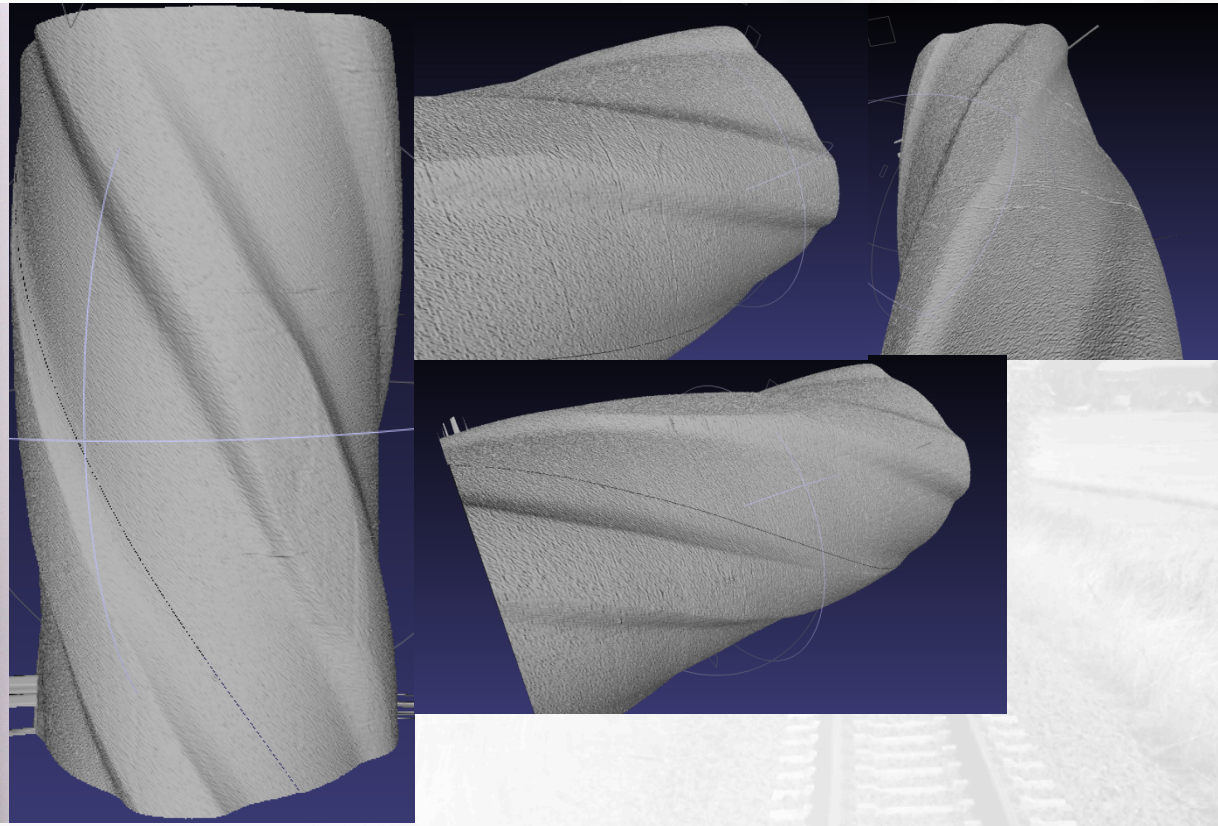


WD (chevron)

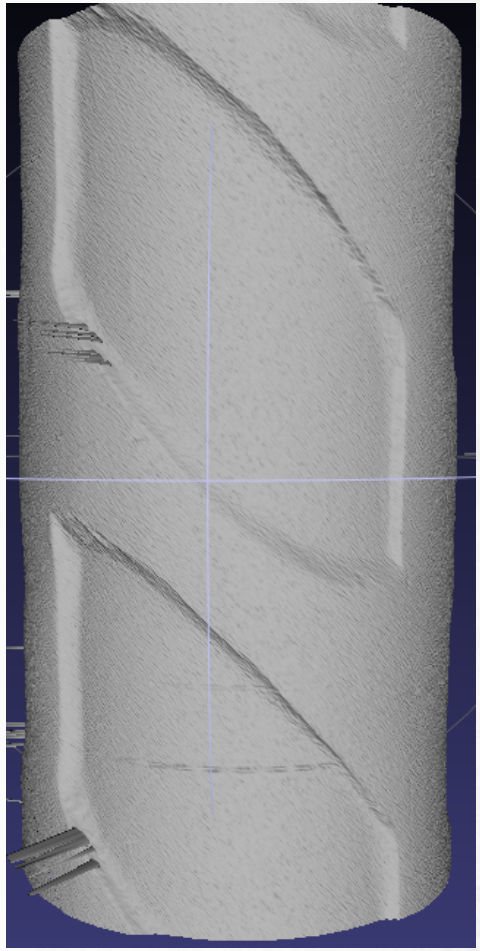


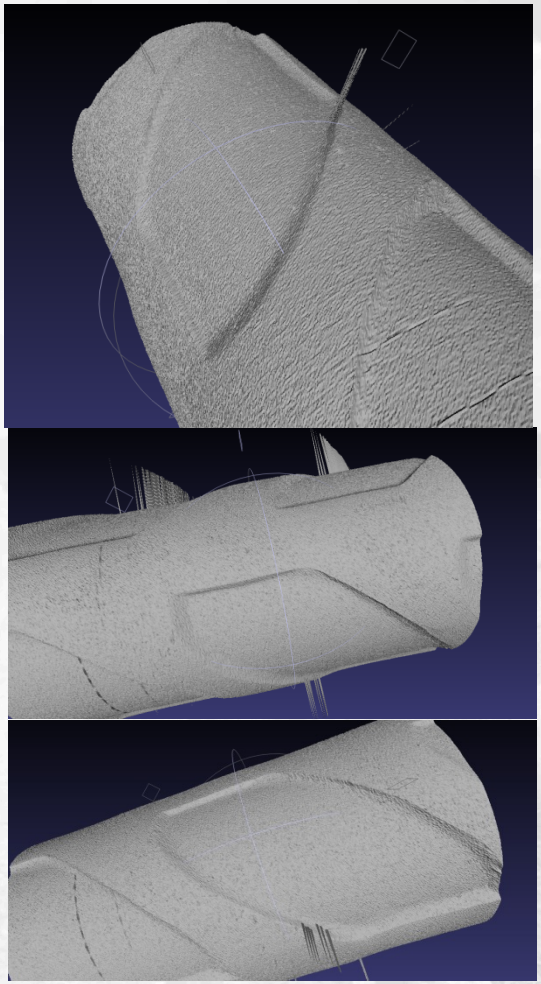


WE (spiral)

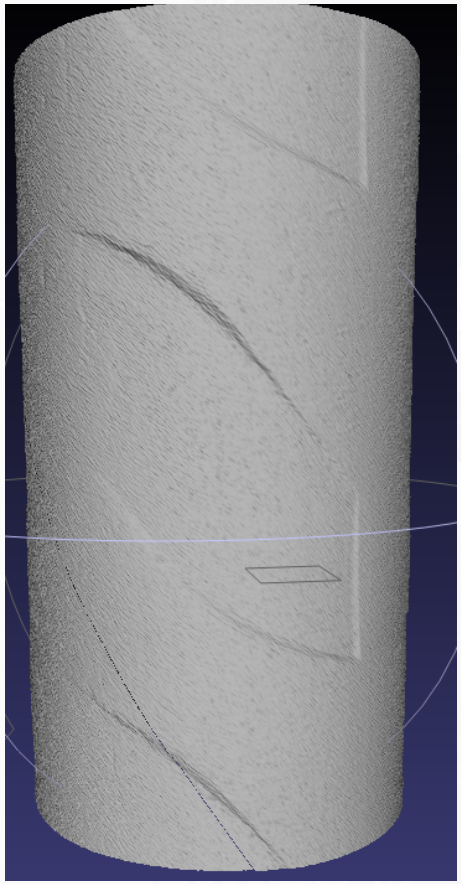


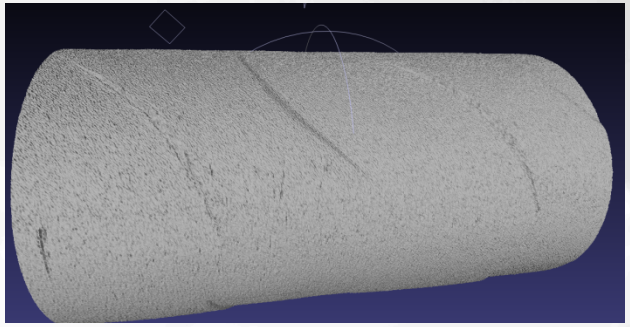
WF (diamond)

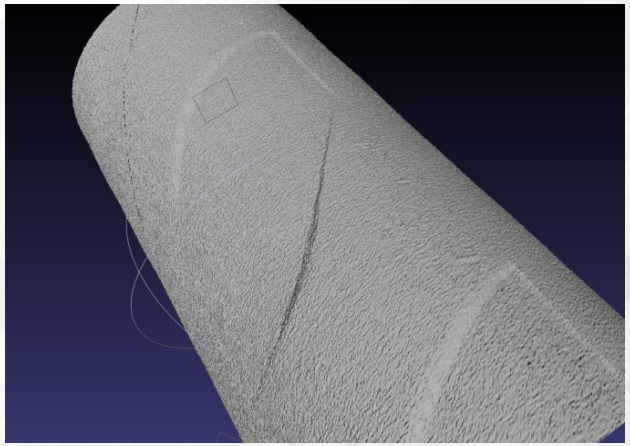


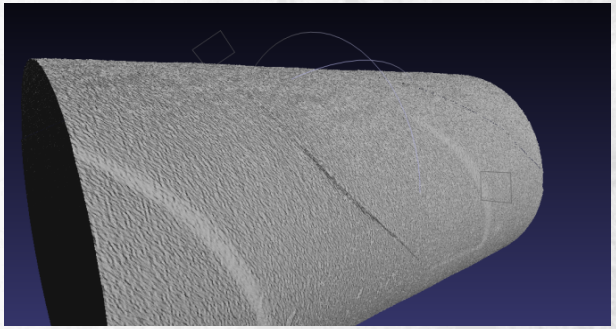


WG (chevron)

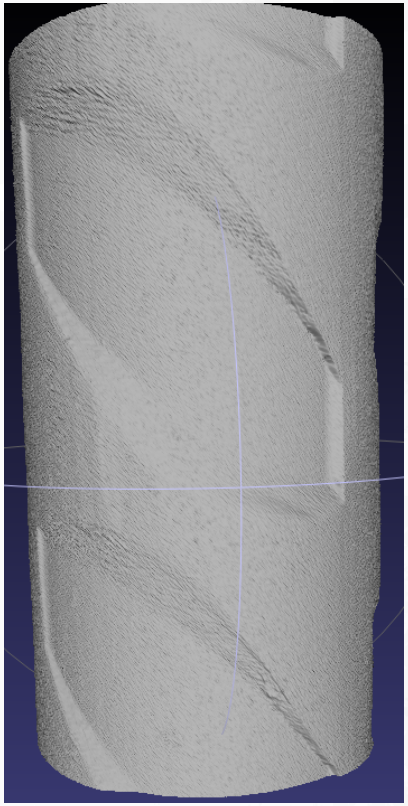


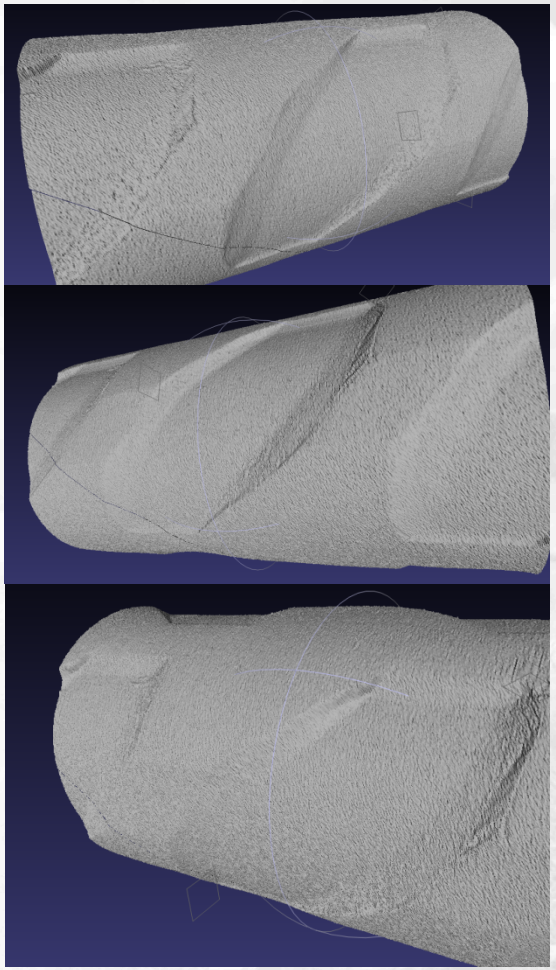




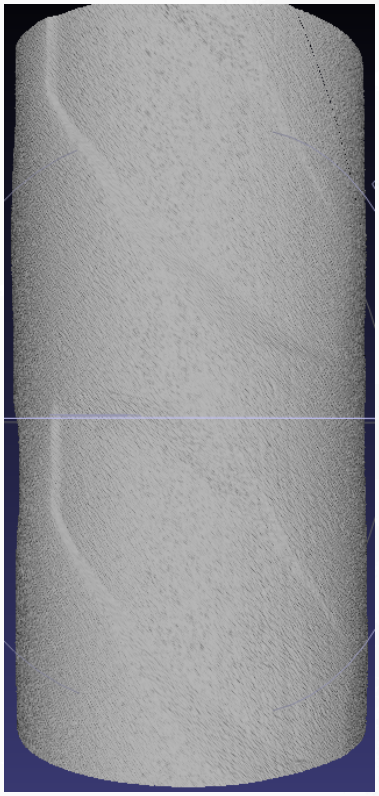


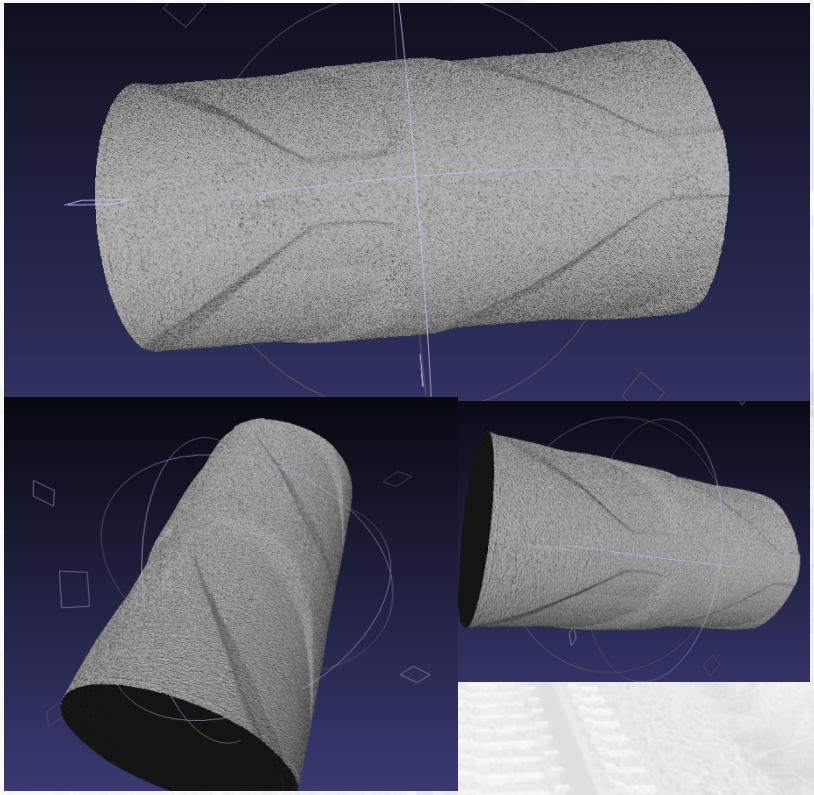
WH (chevron)



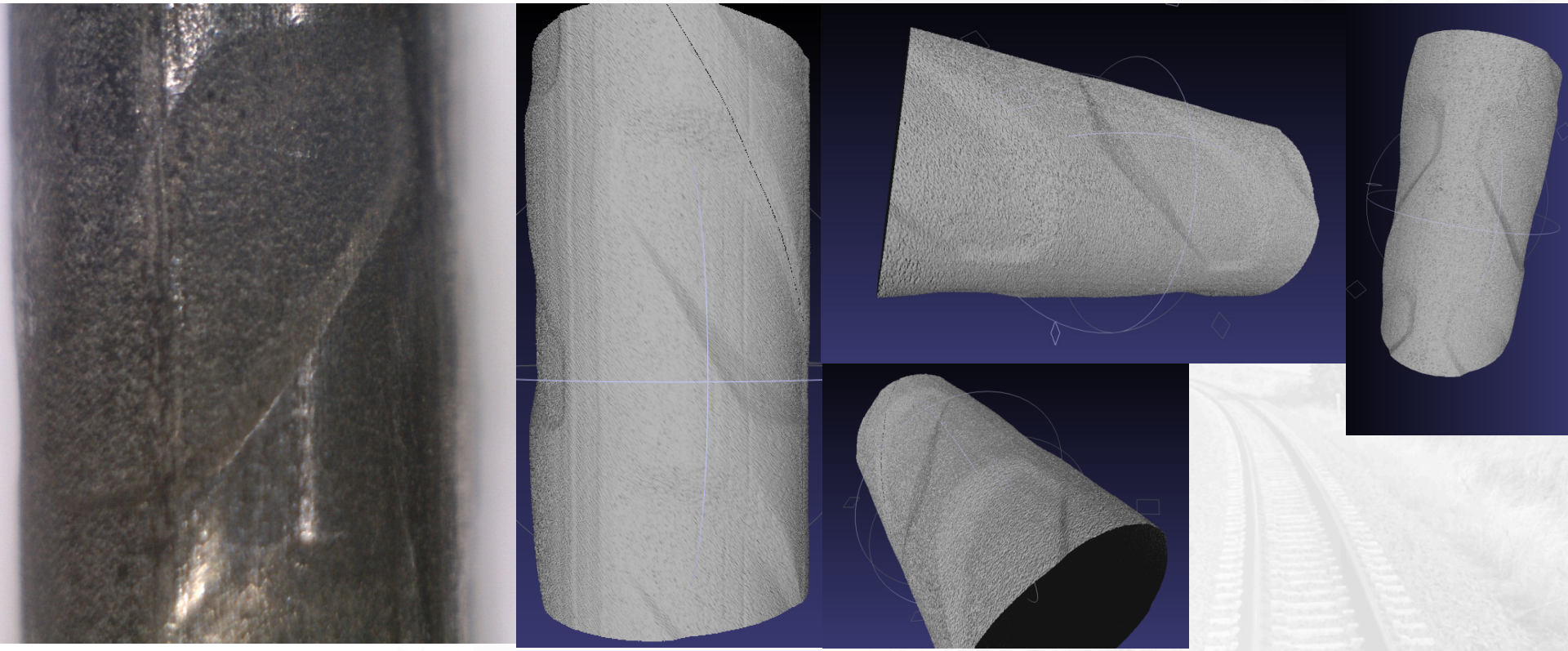


WI (chevron)

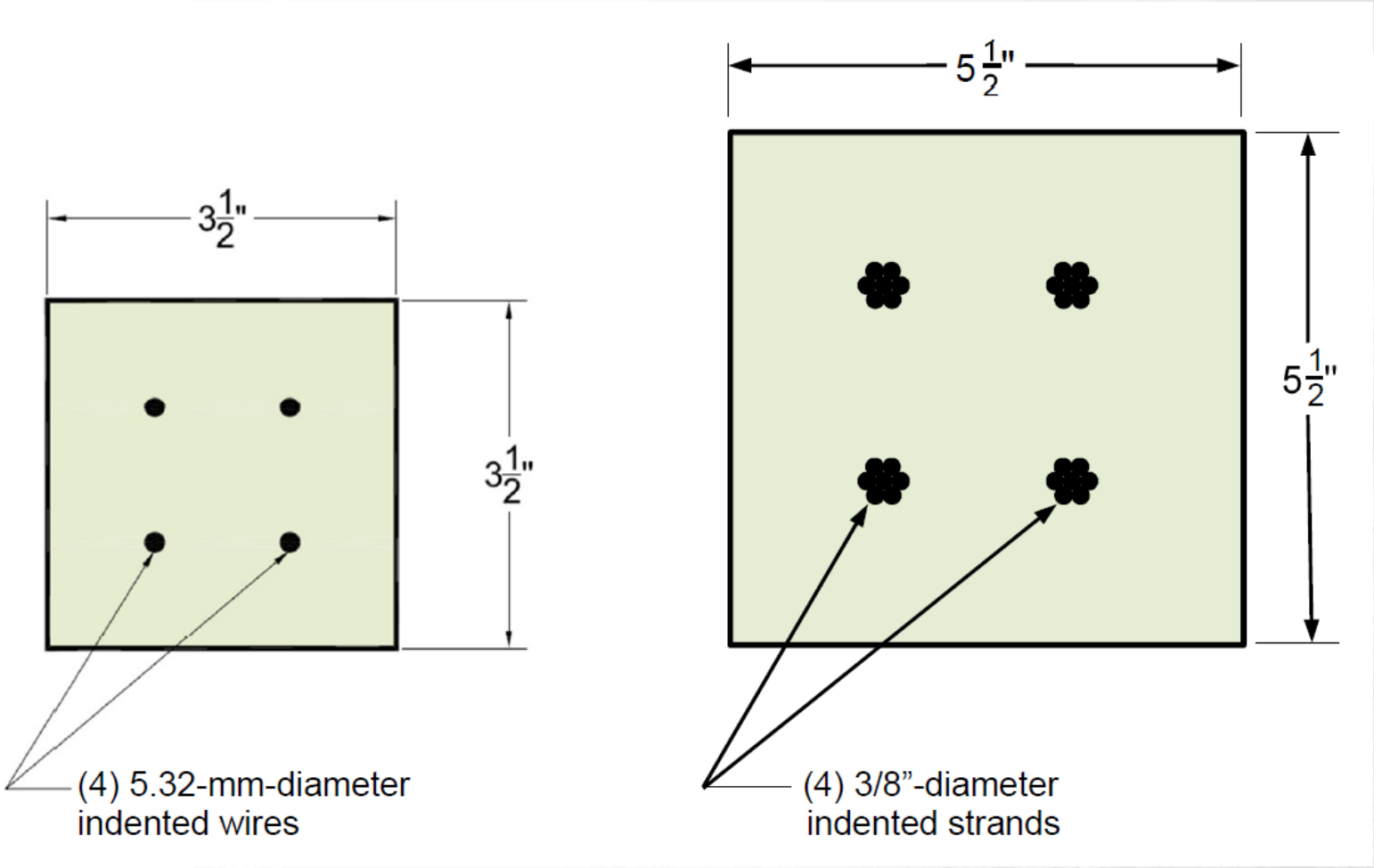




WJ (chevron)



Pre-tensioned Concrete Prisms



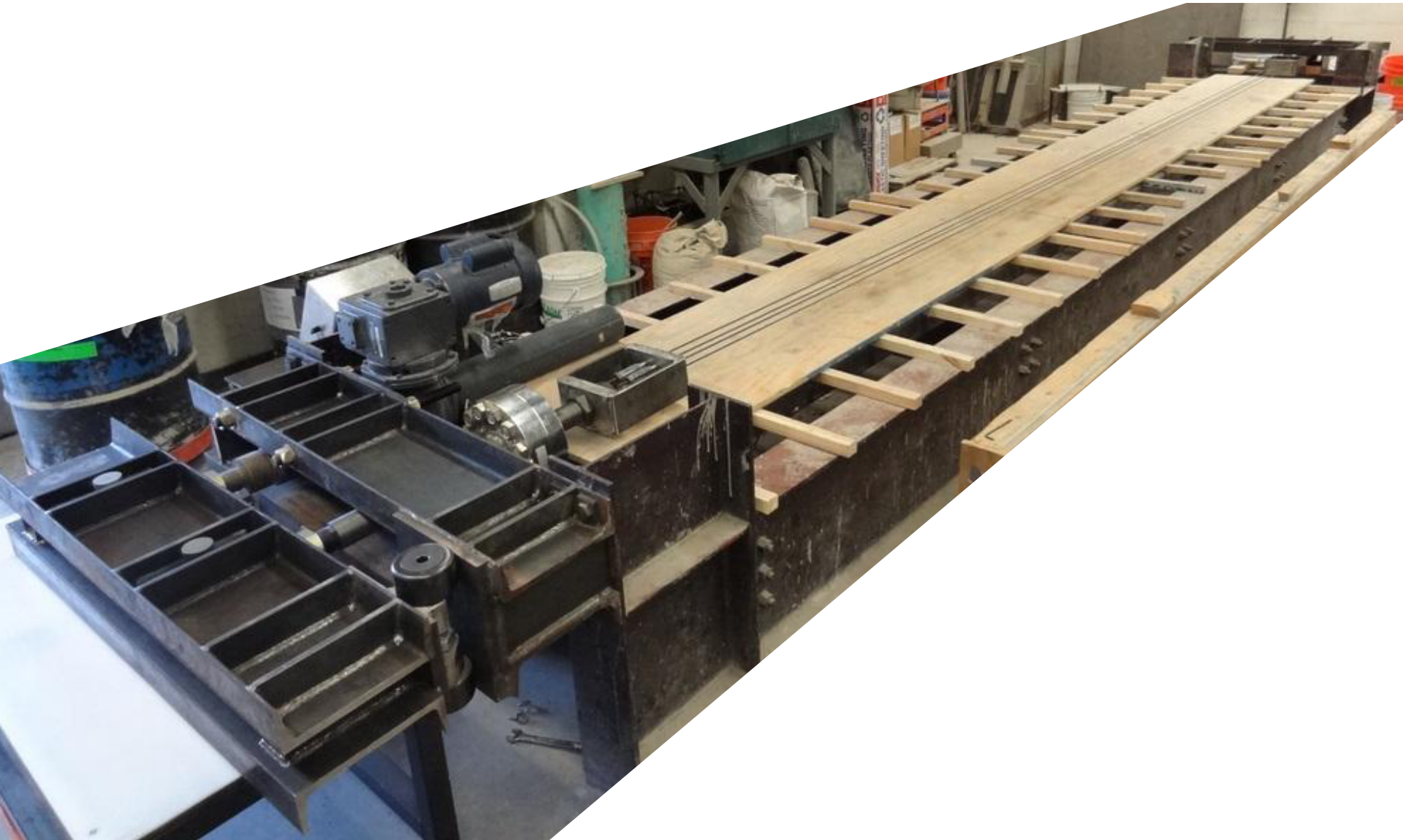
Parameters

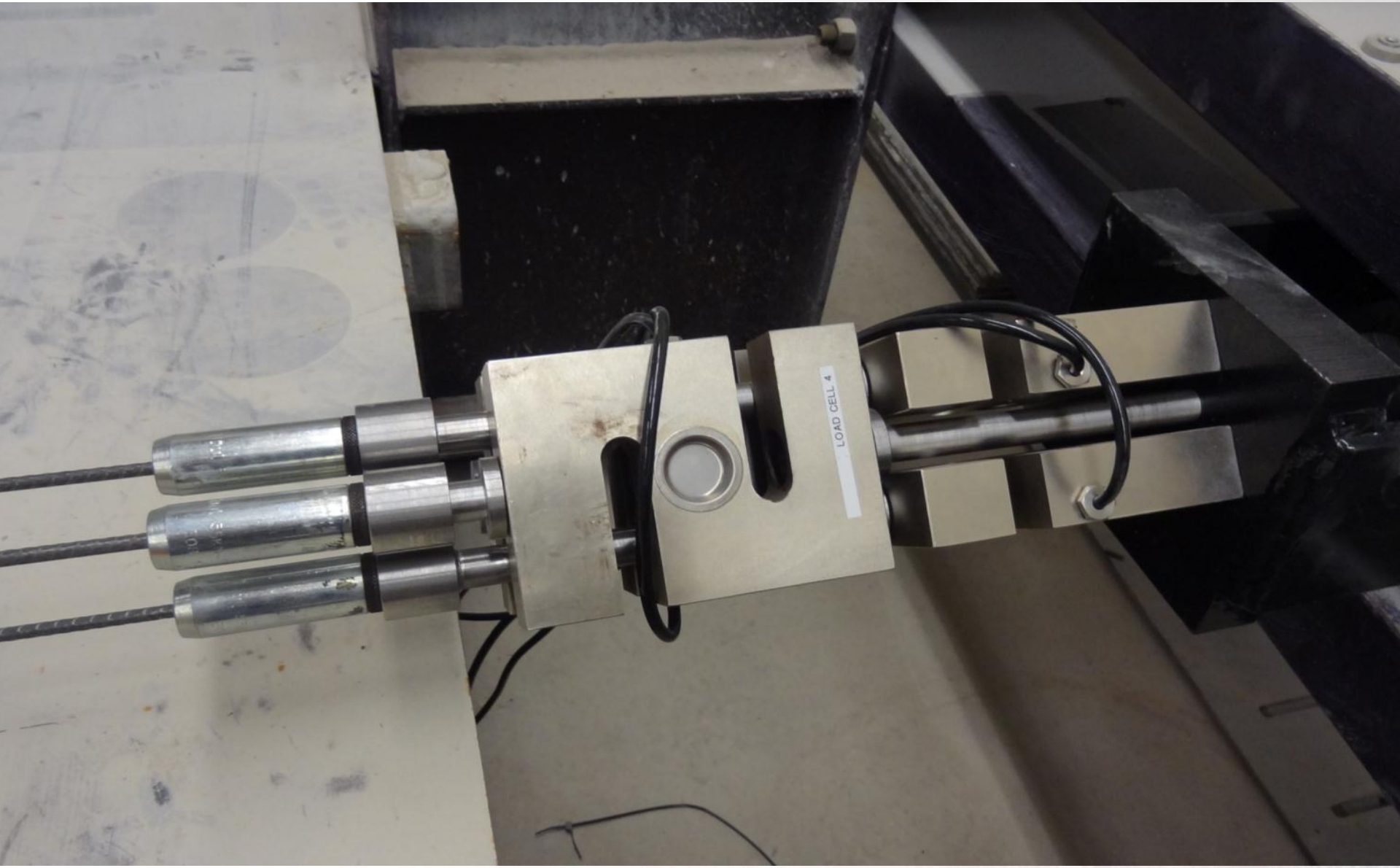
- The prisms are 60” Long
- Concrete cylinders are match cured to ensure the compression strength at the time of release.
- Prestressing reinforcement is tensioned to 0.75 f_{pu}
- Compressive stress at release ≈ 2100 psi
- A gradual release is be ensured
- Wire end-slip and surface strains are measured.

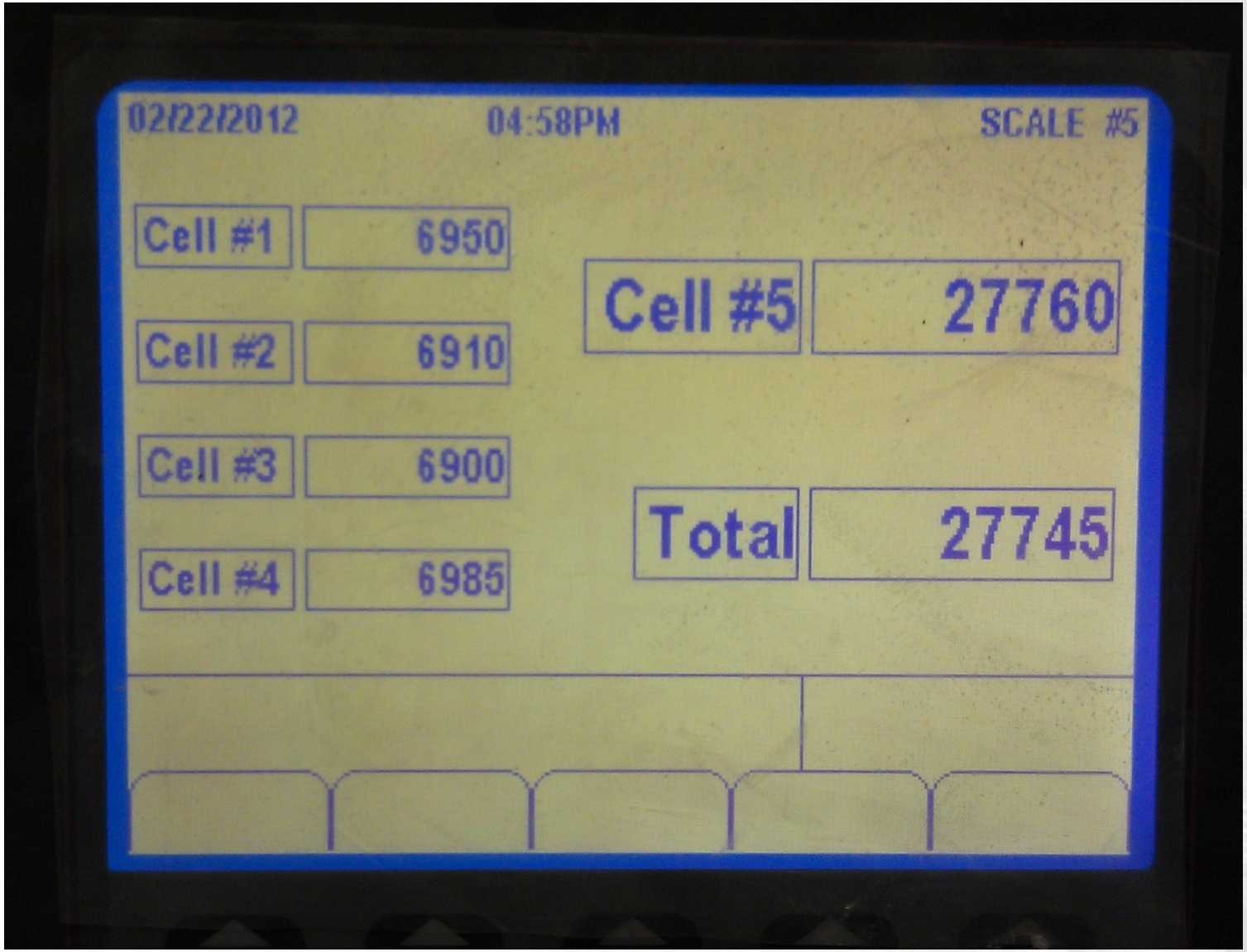
Pre-tensioned prism parameters

Part	Reinforcement Samples	Slump (Inches)	Release Strength (psi)	# of Prisms per group	Total # of Prisms
1	Tests on 18 reinforcements	6	4500	3	54
2	Additional 10 groups	3	4500	3	30
	Additional 10 groups	9	4500	3	30
	Additional 10 groups	6	3500	3	30
	Additional 10 groups	6	6000	3	30
	2 groups combined	9	3500	3	6
				Total =	180

Prestressing Frame

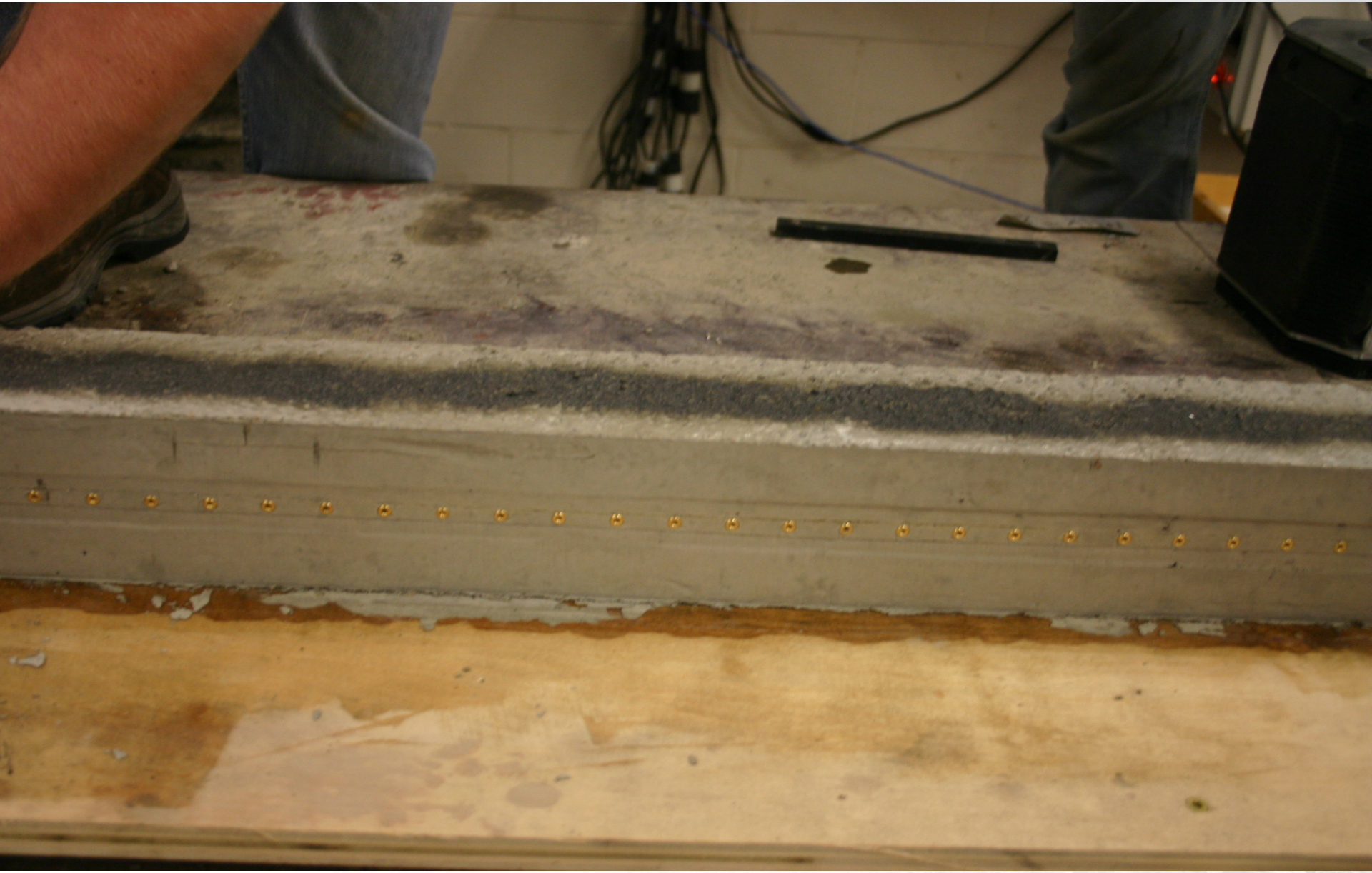



LOAD CELL 4


02/22/2012
04:58PM
SCALE #5
Cell #1
6950
Cell #2
6910
Cell #3
6900
Cell #4
6985
Cell #5
27760
Total
27745

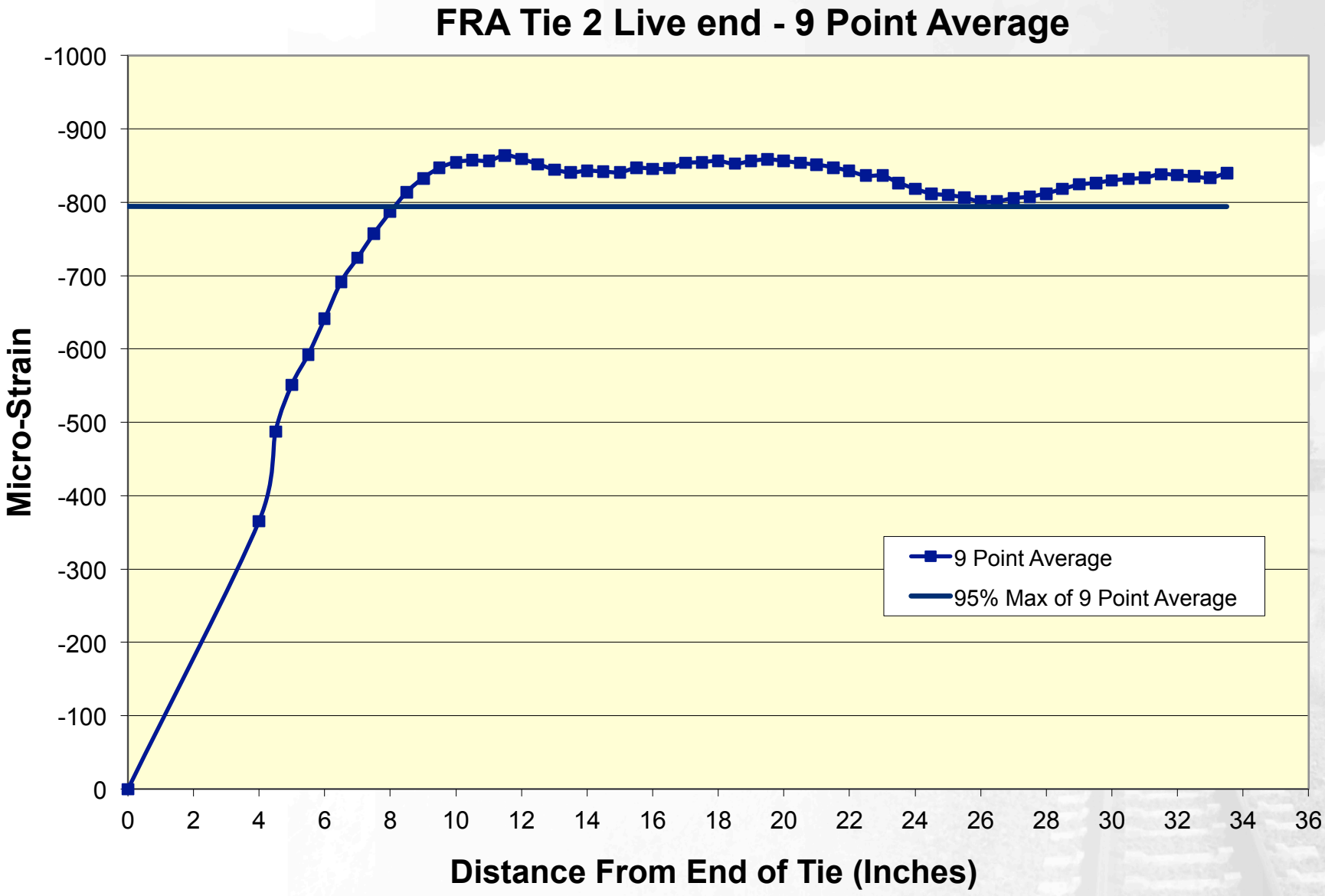
3 Prisms are cast at a time

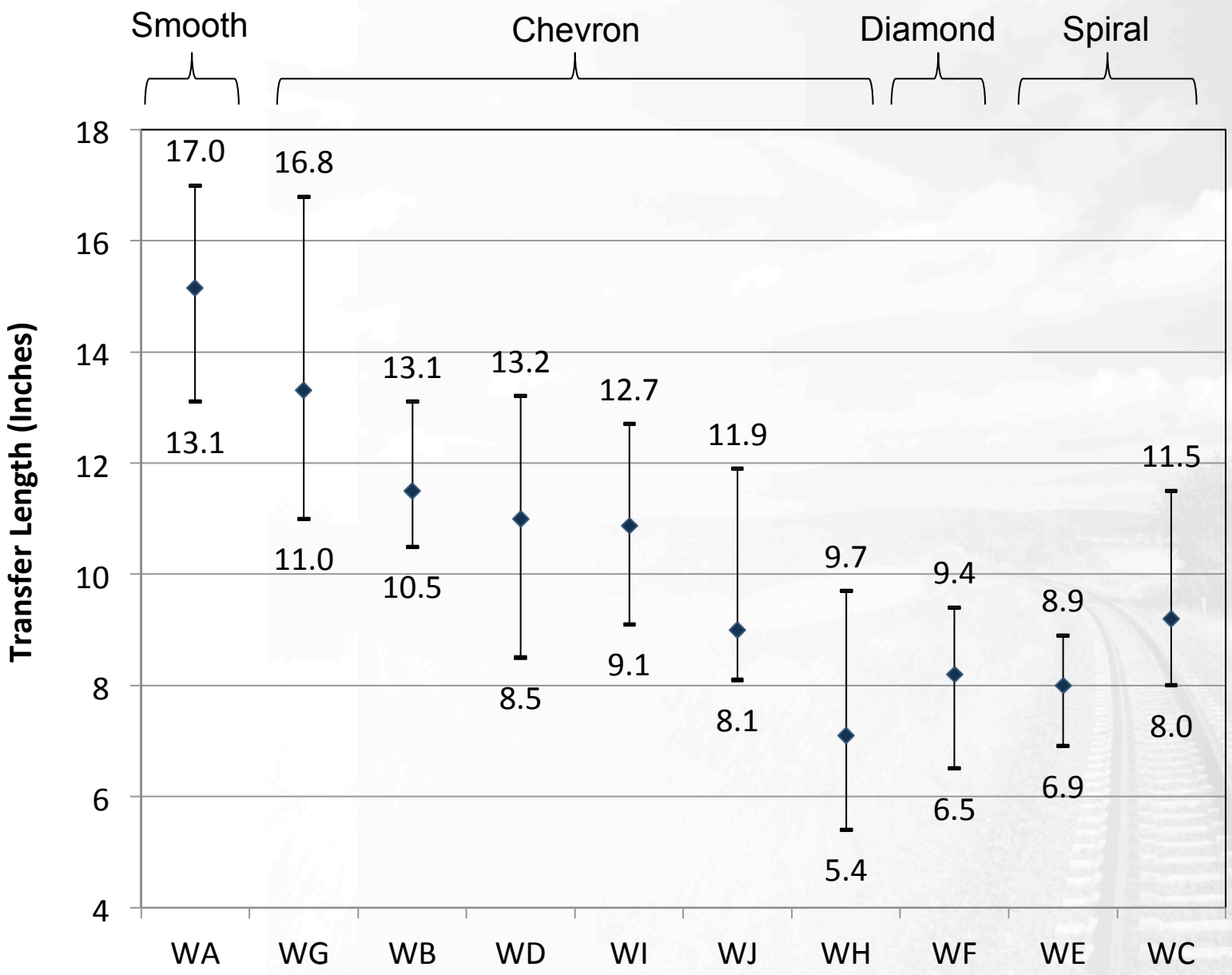
Brass Inserts



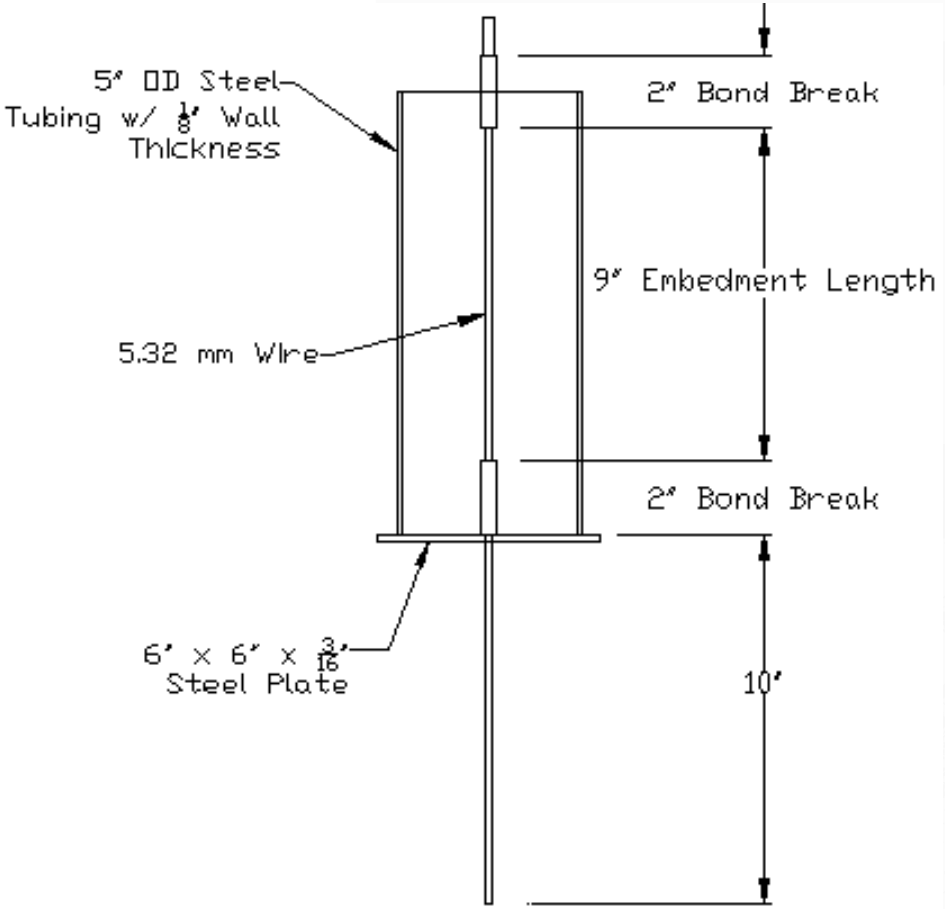
Whittemore Gage

Whittemore Gage Readings


FRA Tie 2 Live end - 9 Point Average
Micro-Strain
-1000
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
Distance From End of Tie (Inches)
9 Point Average
95% Max of 9 Point Average


Smooth
Chevron
Diamond
Spiral
Transfer Length (Inches)
18
16
14
12
10
8
6
4
17.0
13.1
16.8
11.0
13.1
10.5
13.2
8.5
12.7
9.1
11.9
8.1
9.7
5.4
9.4
6.5
8.9
6.9
11.5
8.0
WA
WG
WB
WD
WI
WJ
WH
WF
WE
WC

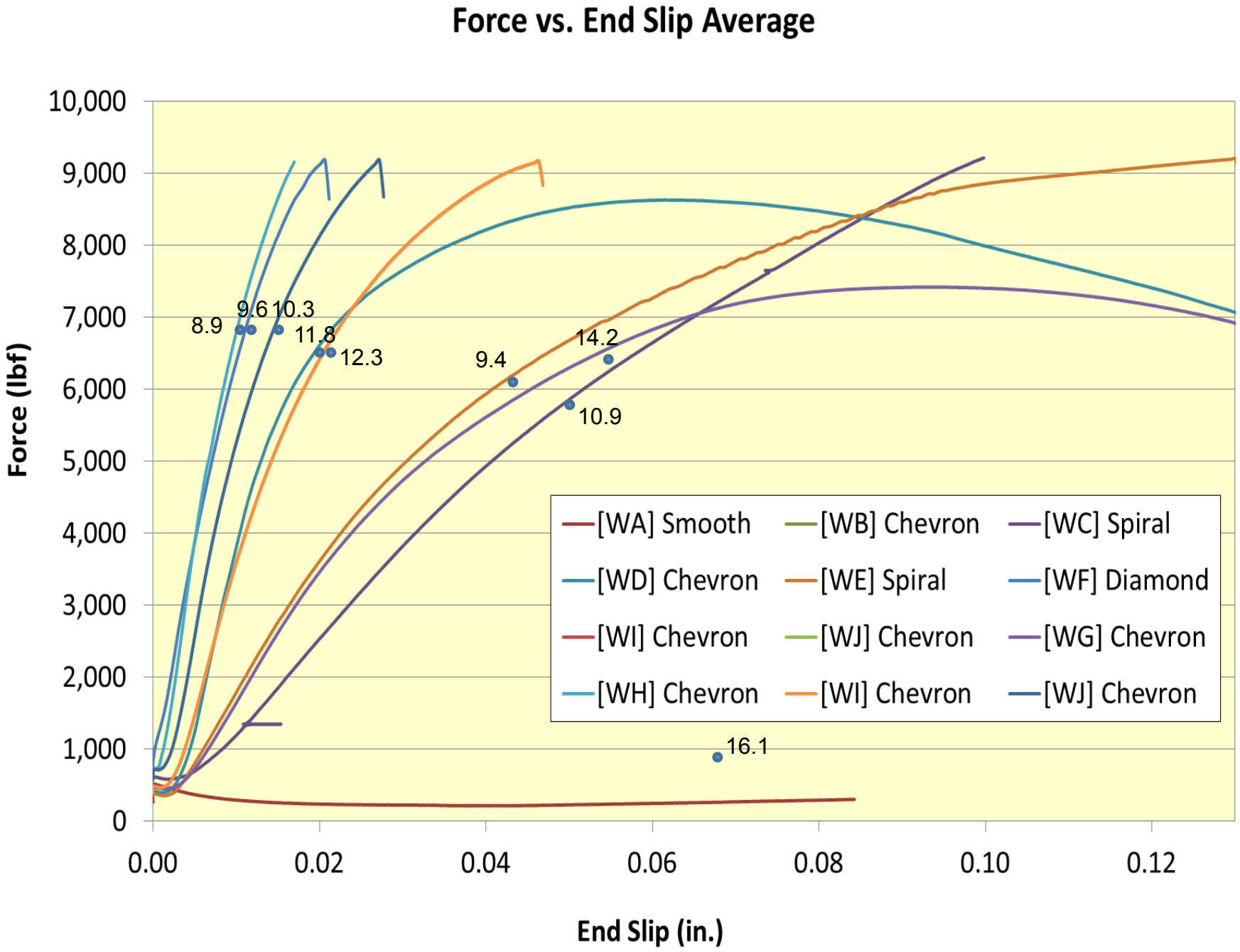
Un-Tensioned Pullout Tests with Mortar




AFTER
BEFORE
After concrete has been poured, specimens covered with moist rag and shower cap
Before concrete has been poured, wires tied in to "can toppers"

Pullout Frame at KSU

Ottowa Sand

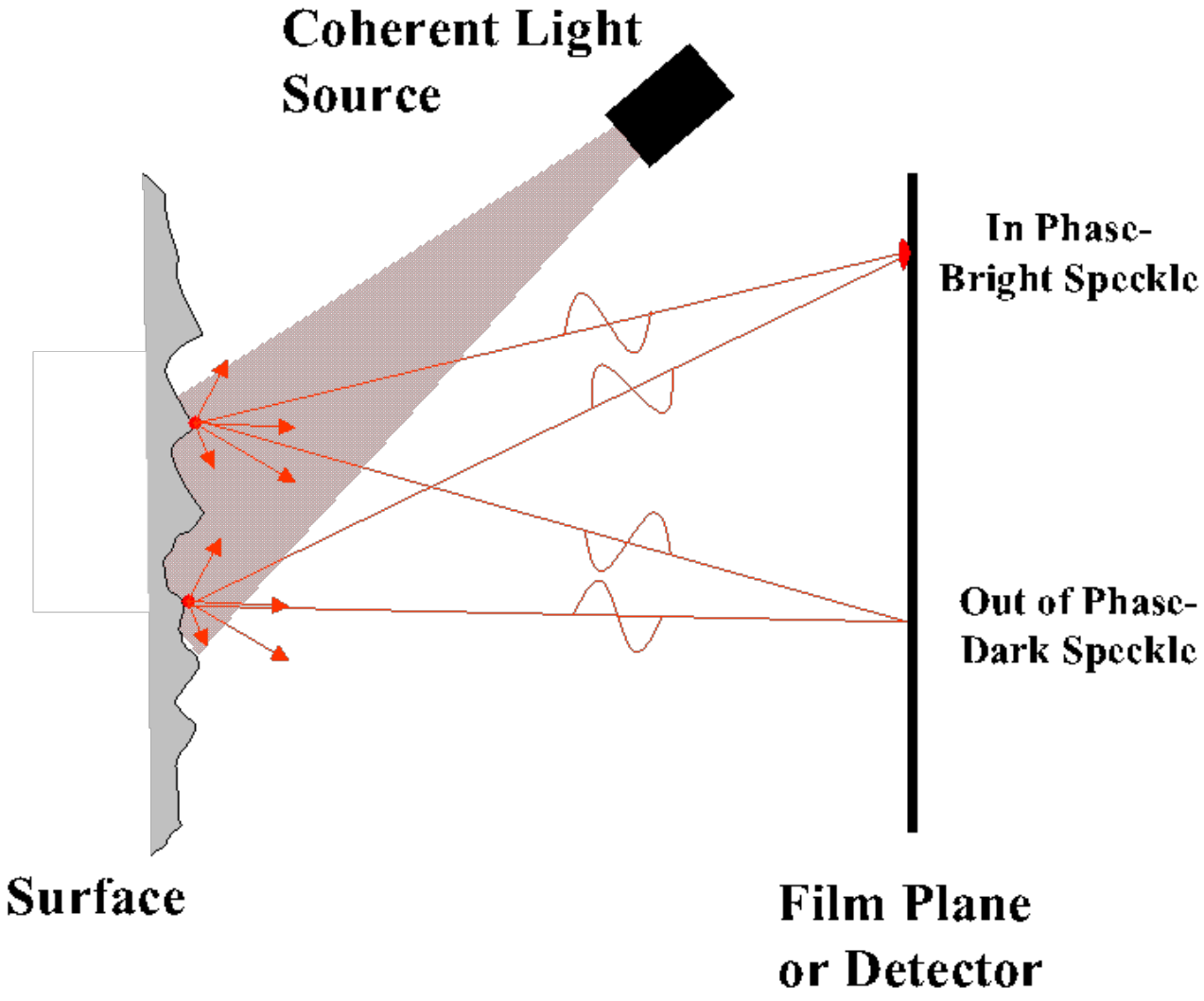

Force vs. End Slip Average
Force (lbf)
End Slip (in.)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
8.9
9.6
10.3
11.8
12.3
9.4
14.2
10.9
16.1
[WA] Smooth
[WB] Chevron
[WC] Spiral
[WD] Chevron
[WE] Spiral
[WF] Diamond
[WI] Chevron
[WJ] Chevron
[WG] Chevron
[WH] Chevron
[WI] Chevron
[WJ] Chevron

Plant Phase

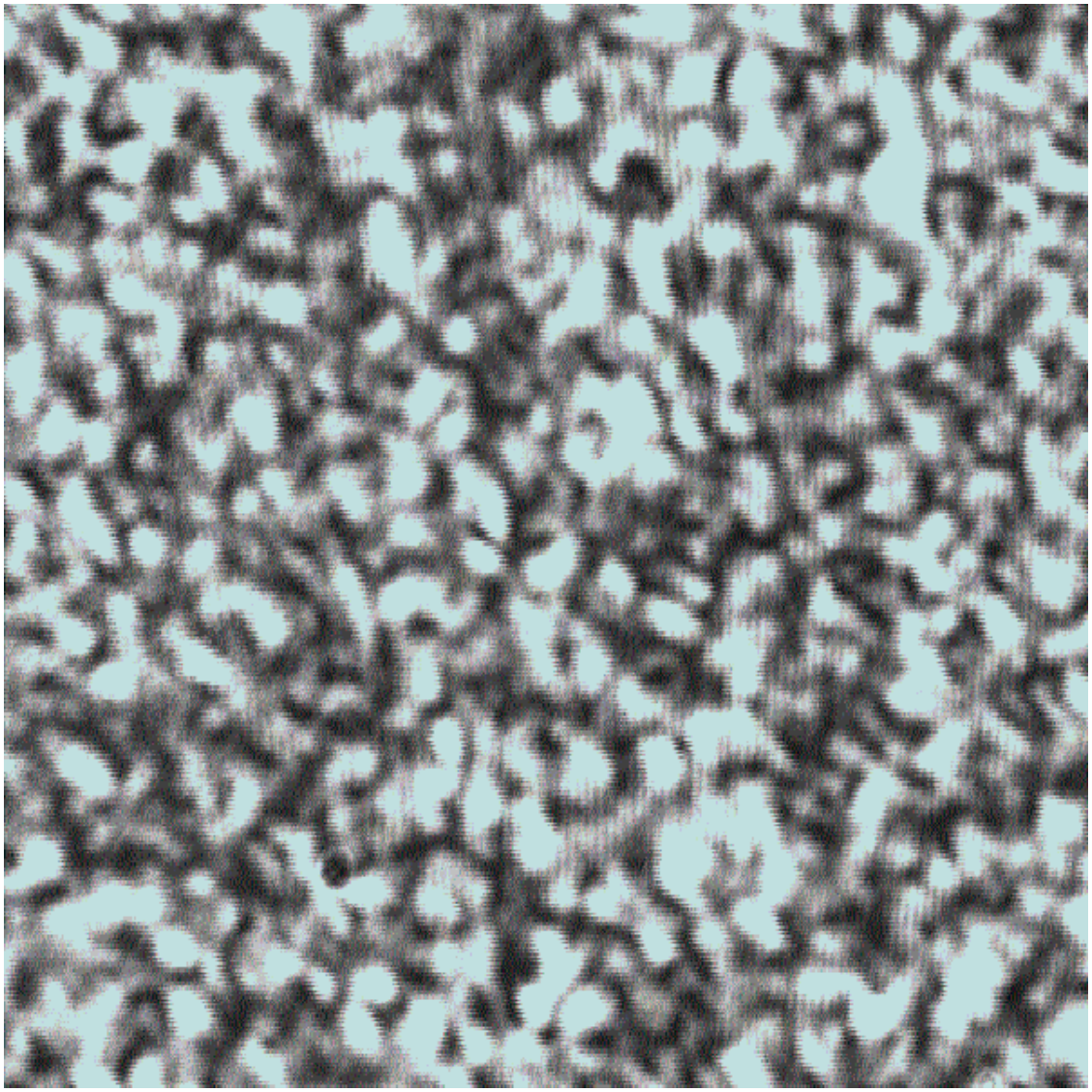
- 15 Reinforcements will be used to fabricate concrete railroad ties at the CXT pant.
- Would like at least 30 transfer lengths with each reinforcement type to be statistically relevant.
- This cannot be accomplished using current methods
- Need for Automated Transfer-Length Measuring Device

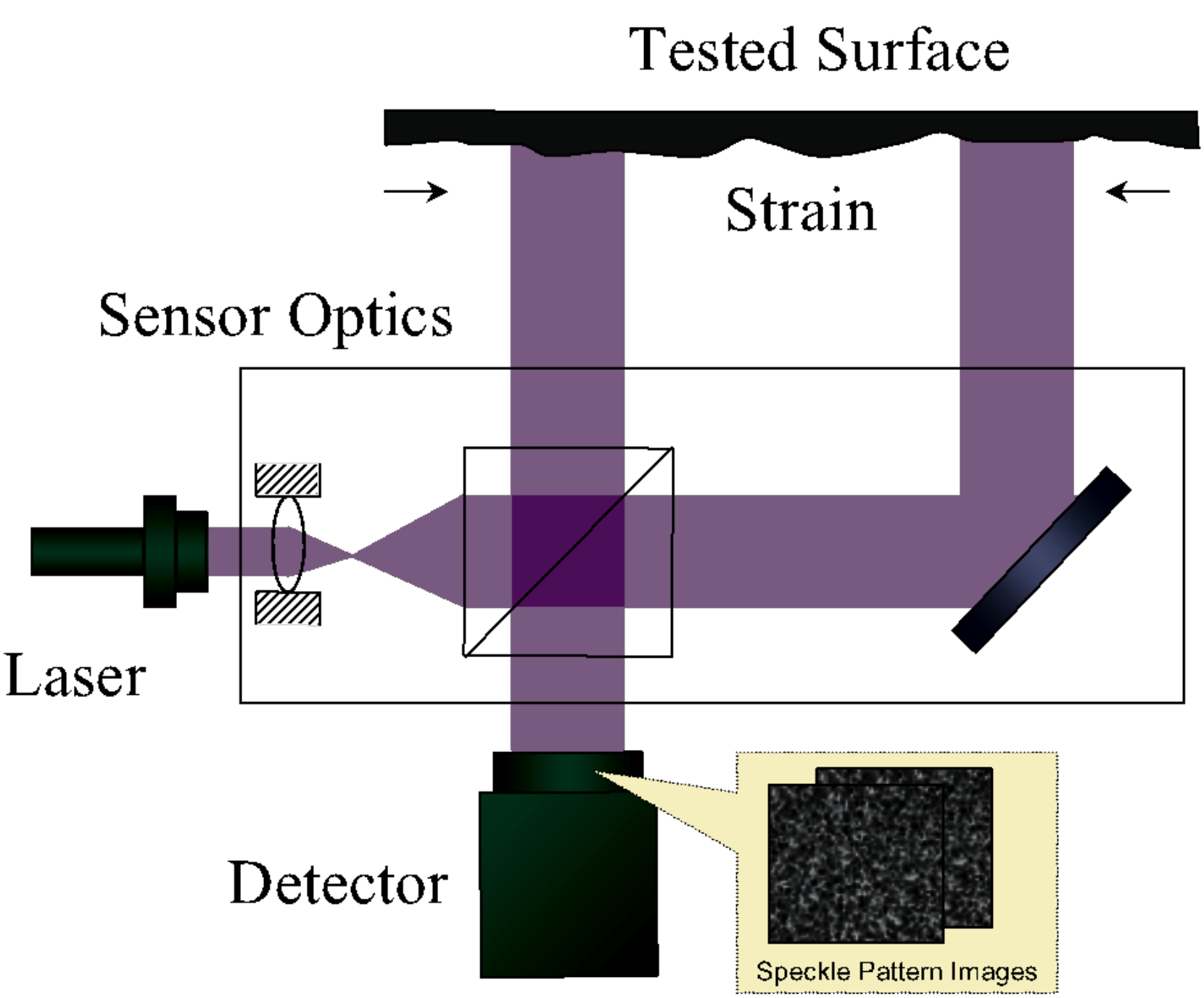
Use of Laser-Speckle Imaging Device to Measure Transfer Lengths in Pretensioned Concrete Crossties

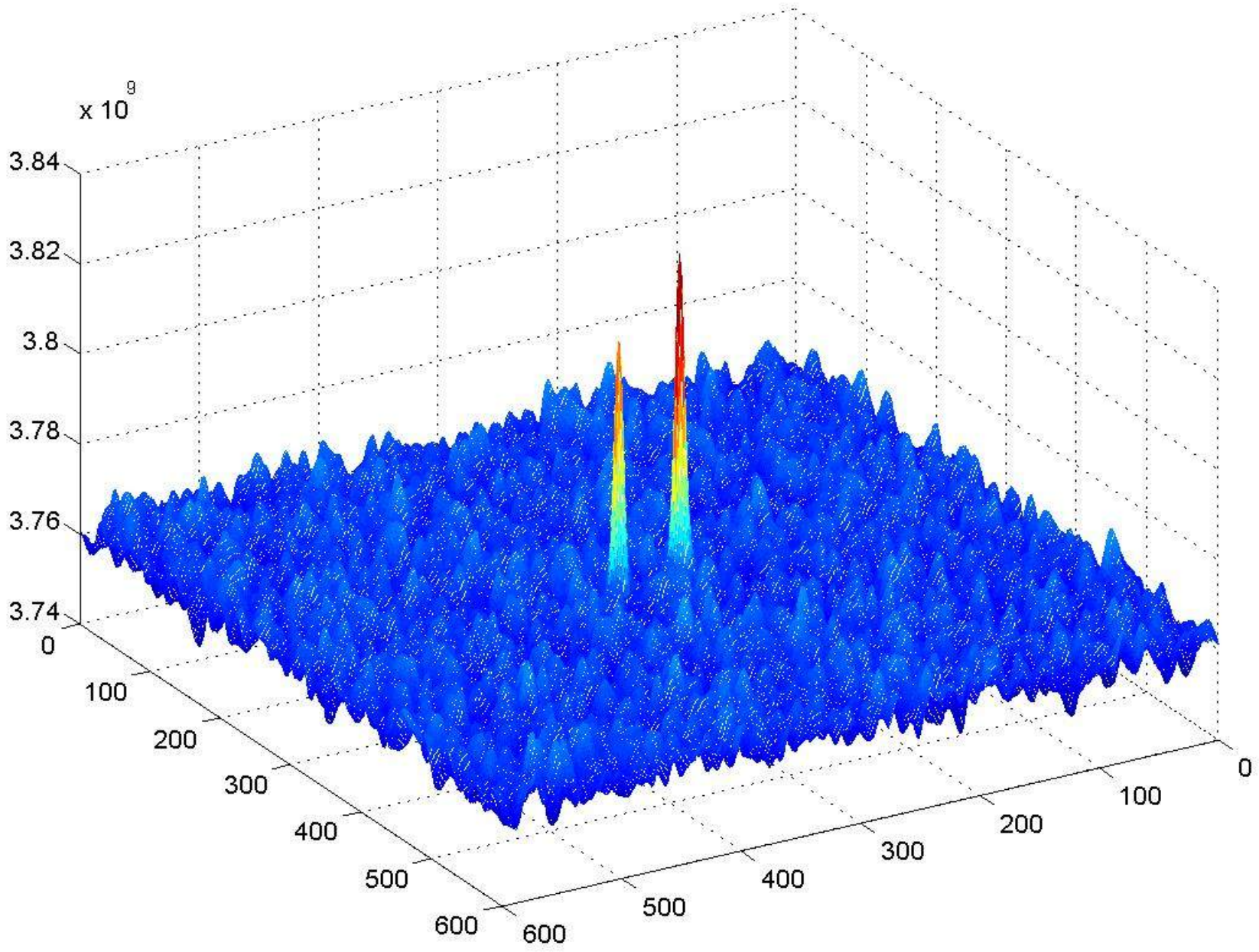
Concept of Laser Speckle

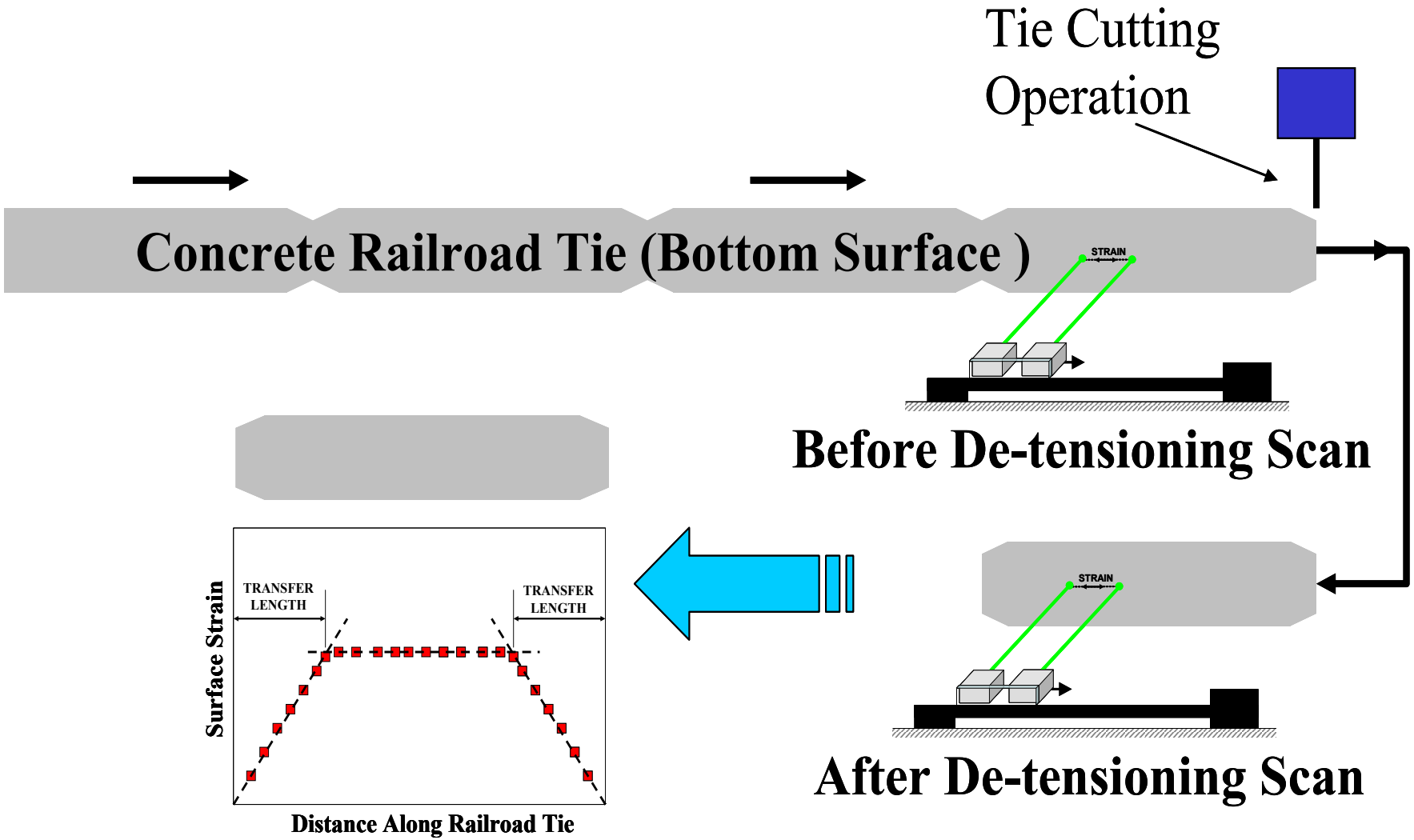


Photograph of Laser Speckle on Concrete

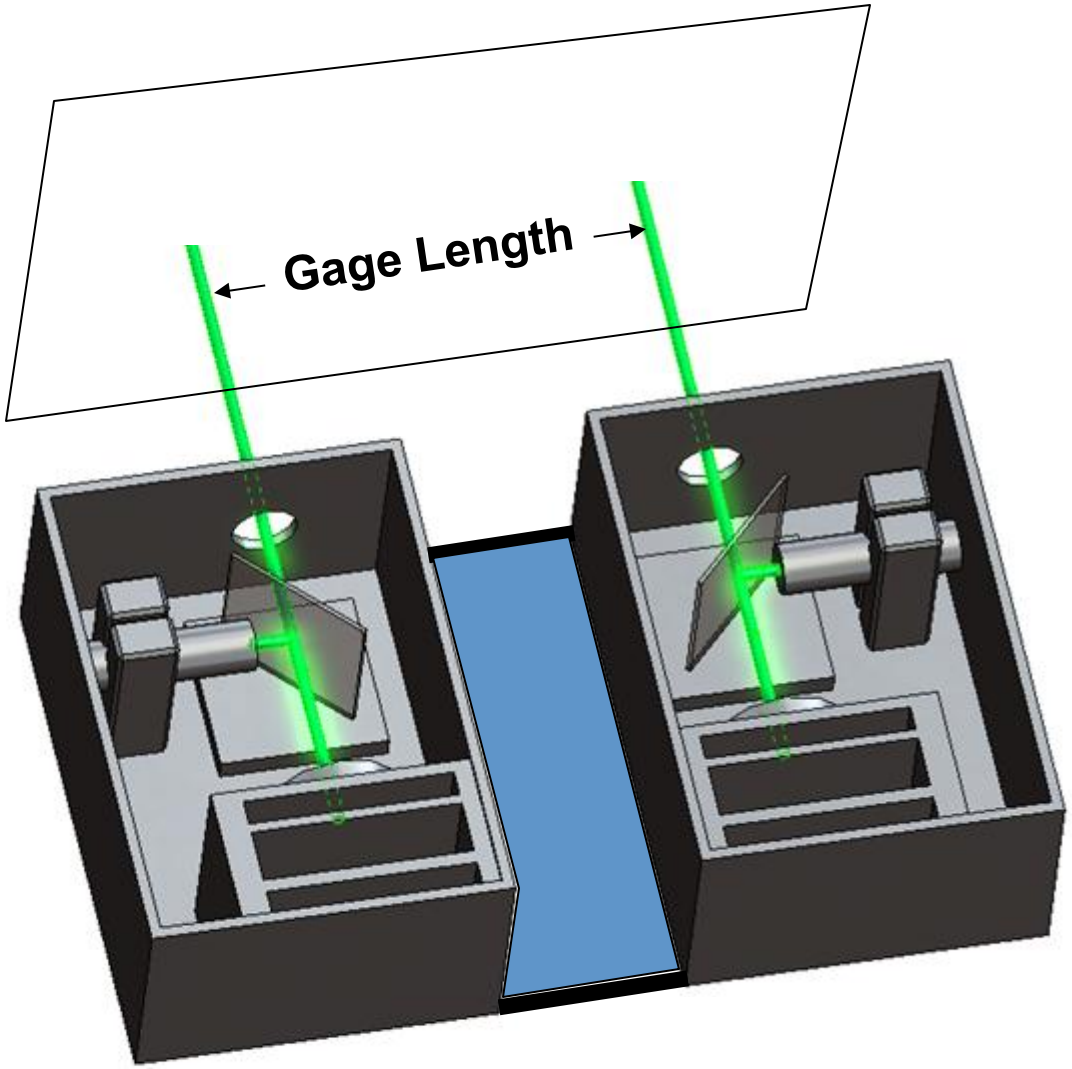



Tested Surface
Strain
Sensor Optics
Laser
Detector
Speckle Pattern Images

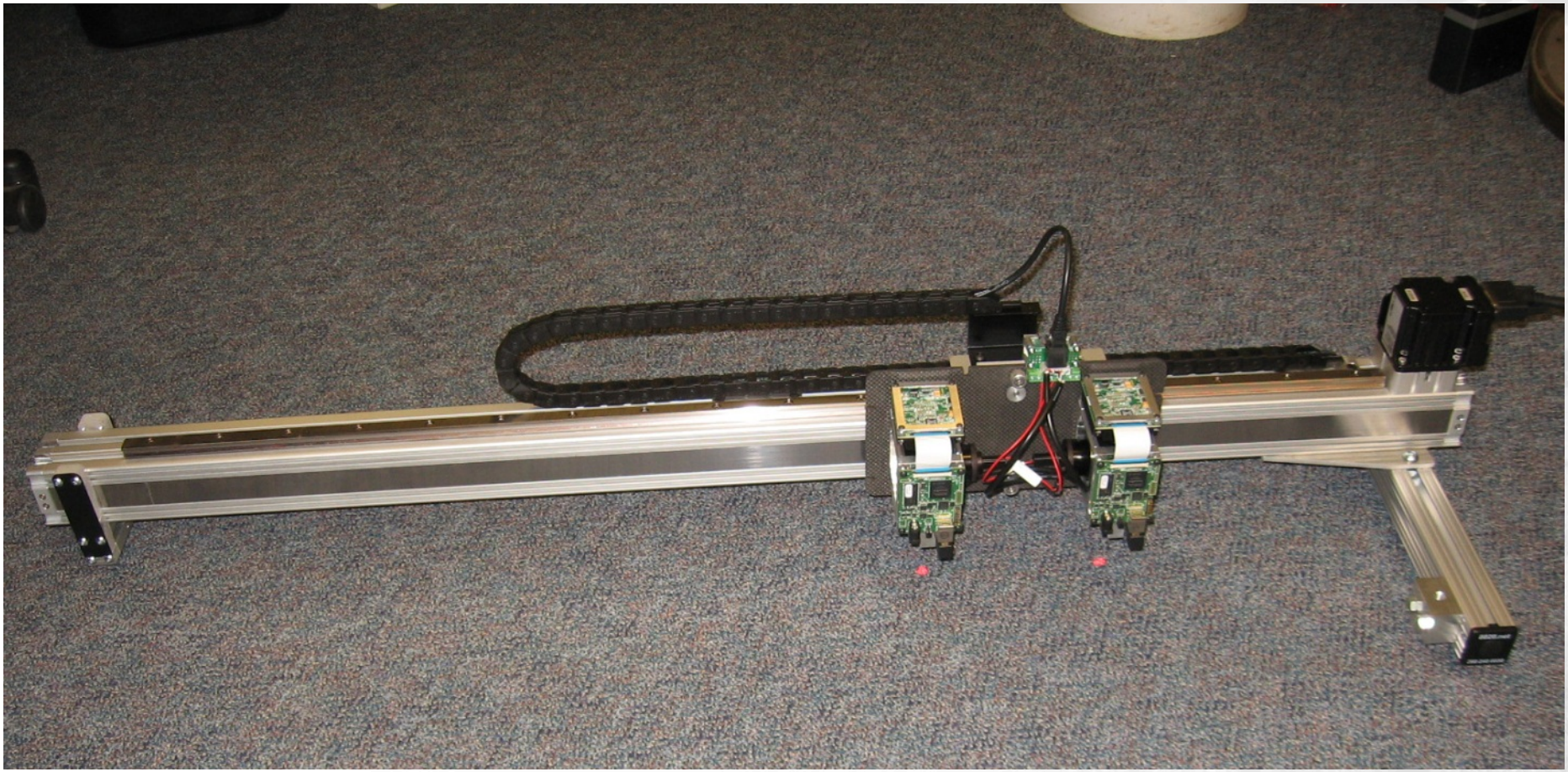

x 10^9
3.84
3.82
3.8
3.78
3.76
3.74
0
100
200
300
400
500
600
600
500
400
300
200
100
0

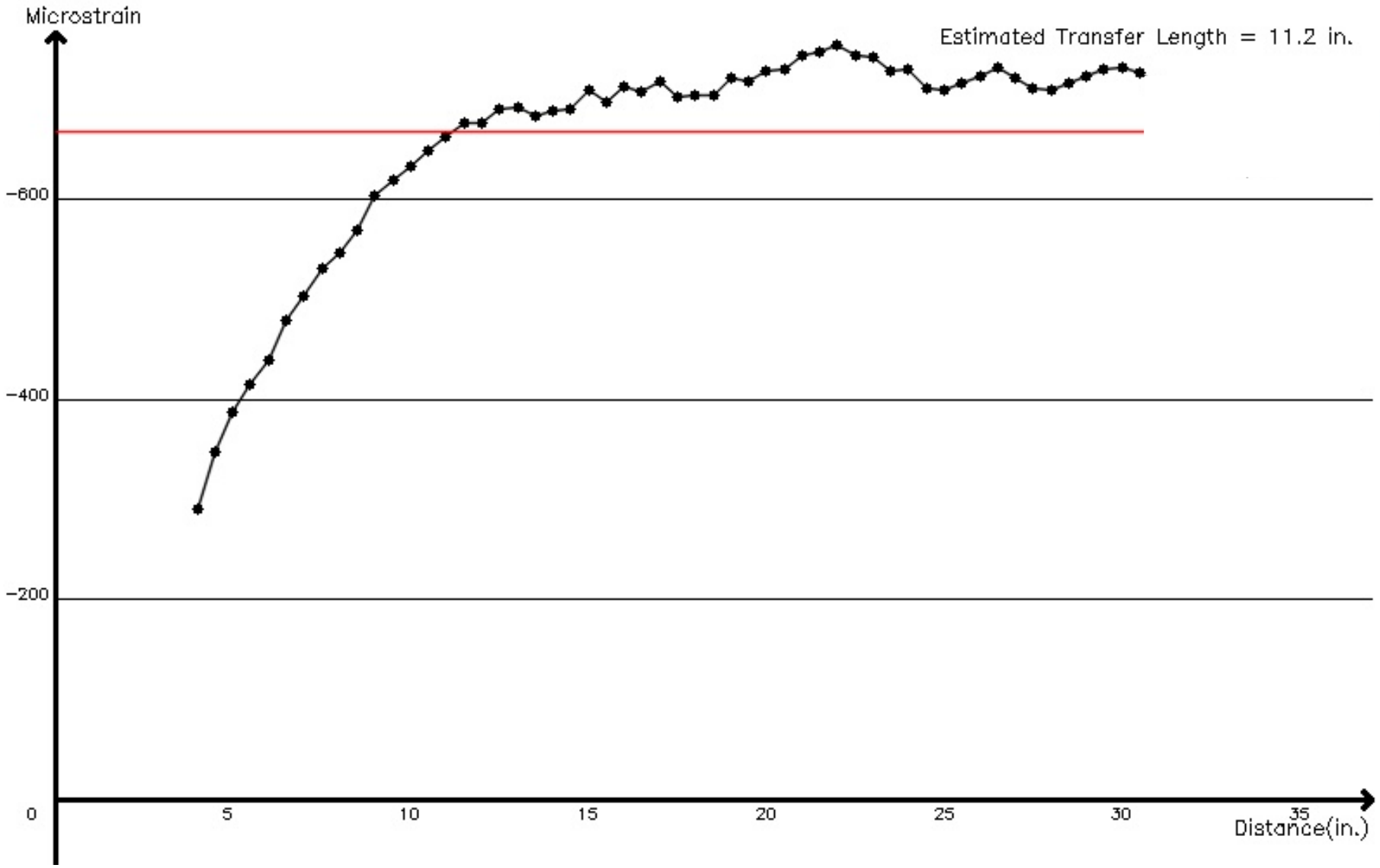

Tie Cutting Operation
Concrete Railroad Tie (Bottom Surface)
STRAIN
Before De-tensioning Scan
STRAIN
After De-tensioning Scan
TRANSFER LENGTH
TRANSFER LENGTH
Surface Strain
Distance Along Railroad Tie

Modular LSI Design With 2 Cameras



Automated LSI Device




Microstrain
Estimated Transfer Length = 11.2 in.
-600
-400
-200
0
5
10
15
20
25
30
35
Distance(in.)