Systematic Evaluation of Concrete Ties Removed From Track After Many Years of Service

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Work is part of a larger project funded by FRA titled “Developing Qualification Tests to Ensure Proper Selection and Interaction of Pretensioned Concrete Railroad Tie Materials”

Investigators

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Dr. Kyle Riding	KSU Dept. of Civil Engineering
Dr. Terry Beck	KSU Dept. of Mechanical Engineering
Dr. John Wu	KSU Dept. of Industrial Engineering

Industry Partners

Railroads	Concrete Tie Producers	Prestressing Steel Suppliers	Other
• Amtrak • BNSF • CSX • KCS	• GIC • Koppers KSA • LBFoster CXT • voestalpine Nortrak • Rail.One • Rocla	• DW Davis Wire • HSM • Insteel • Nucor-LMP • WMC	• PCI

Outline

- Obtaining Ties
- Non-Destructive Testing
- Destructive Testing
- Feedback

Identify and Obtain Existing In-Service Crossties:

- Ties in service and performed well for 25 Years
- Ties that have failed in track
- Ties that have signs of distress in service.
- Compare with current tie designs

Obtaining Old Ties

- In May 2015, KSU team members Bob Peterman and Kyle Riding, along with project partners Steve Mattson (Nortrak) and Rusty Croley (Rocla) selected over 100 ties from the TTCI tie boneyard in Pueblo Colorado to be shipped to Manhattan, KS for detailed analysis.

Ties Selected

- Six (6) matching ties representing major design types that were commonly used by Class 1 railroads since the 1970's were selected and marked for shipment

Shipment to KSU

- Two semi-trailer loads of ties were shipped to the USDA ARS Lab in Manhattan Kansas in July 2015 where the initial visual inspection and 3D scanning is being conducted.


BENSON

Other Ties

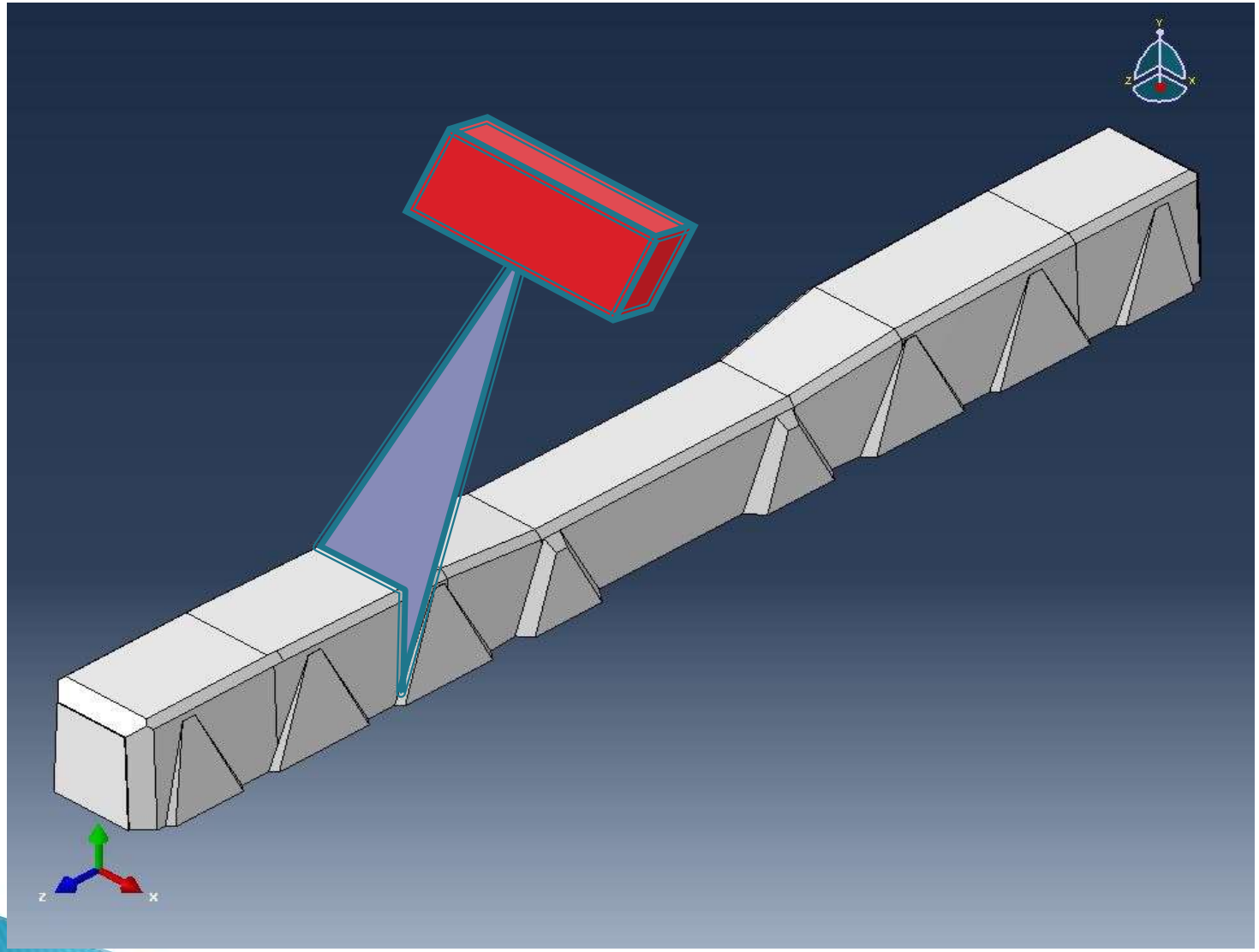
- In addition to the ties from TTCI, KSU is receiving old ties from our railroad partners (Amtrak, BNSF, CSX, and Kansas City Southern) as well as new ties from our tie producer partners.
- If any of you are aware of additional ties that we should include in this study please contact us.

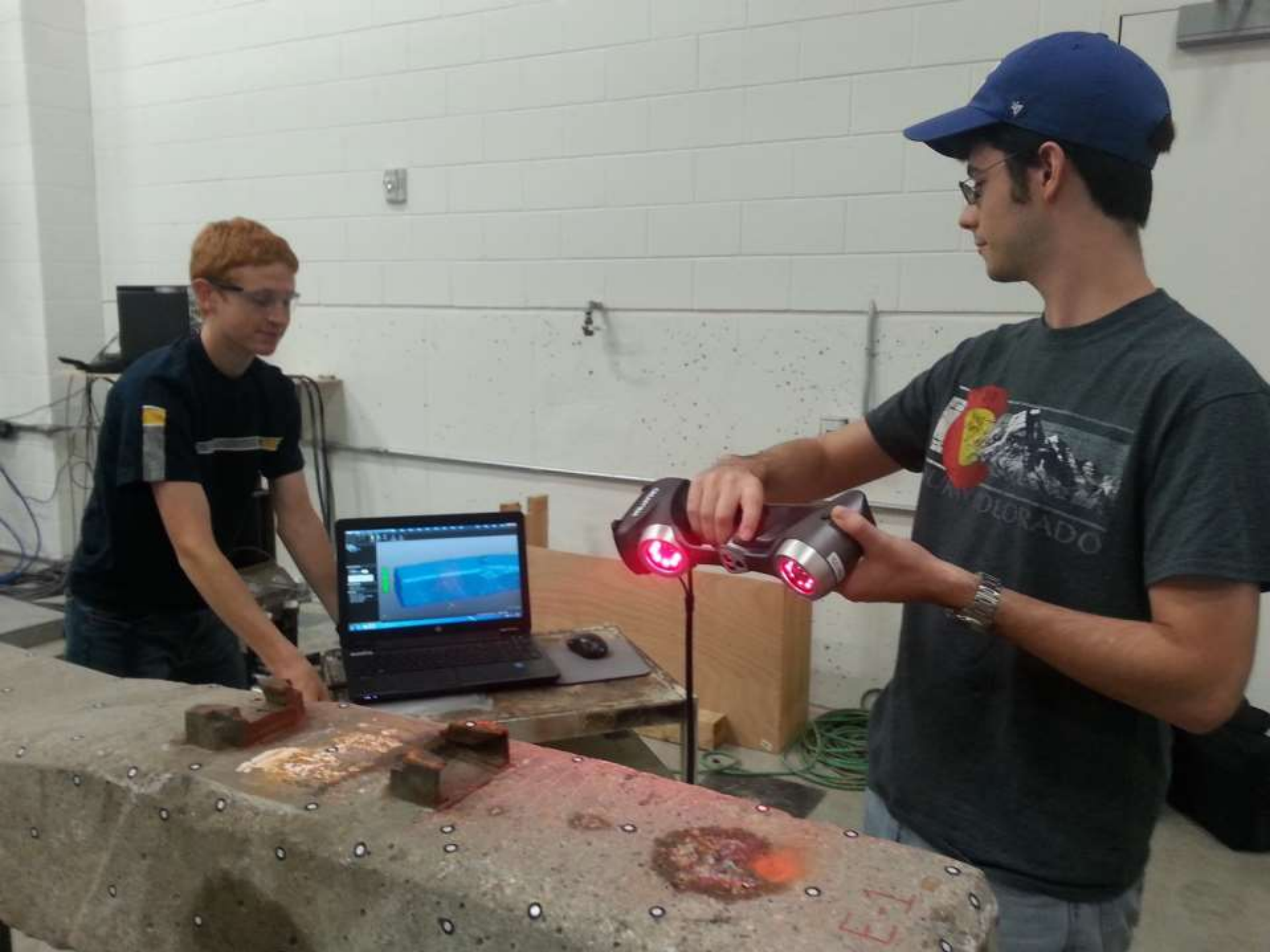
Non-Destructive Evaluation of Ties:

- Systematic Photographic Documentation
- Measurement of End-Slippage when possible
- Visual Inspection and Damage or Wear Assessment (Mapping of Cracks, etc.)
- Non-Contact 3-Dimensional Scanning

Camera Positions for Crosstie Photo Captures

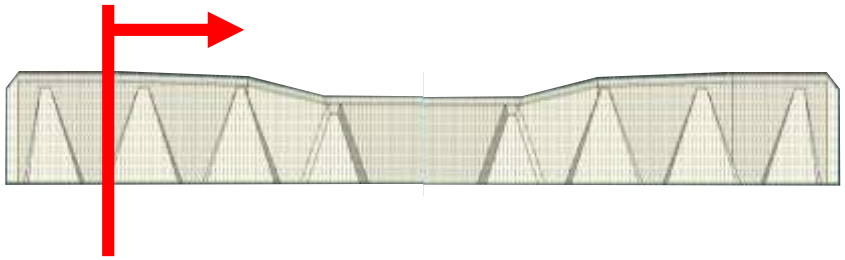
3D Optical Scanning of Ties





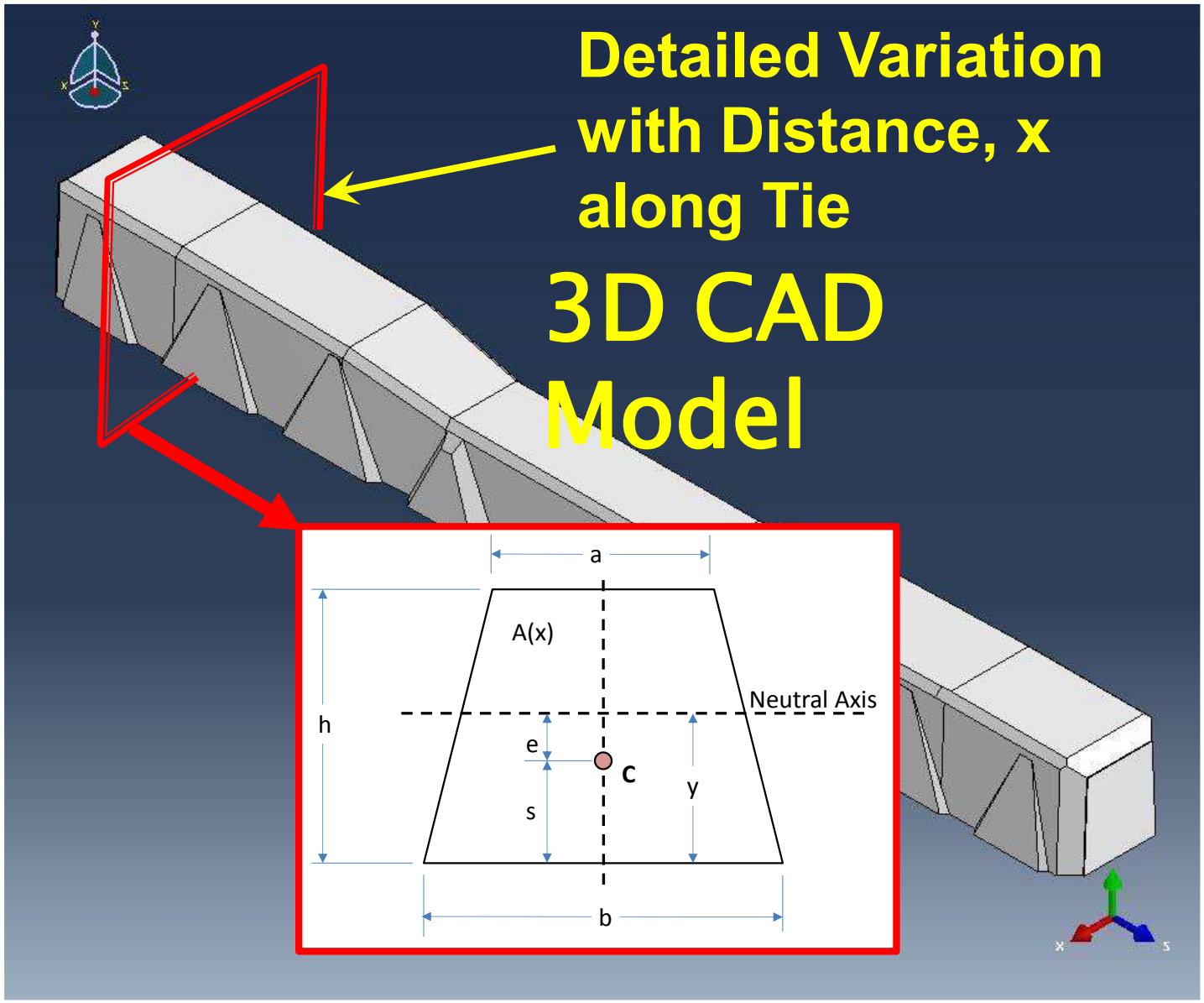
3D Scanning of Existing Crossties

Determine Section Properties along the Length of Tie:

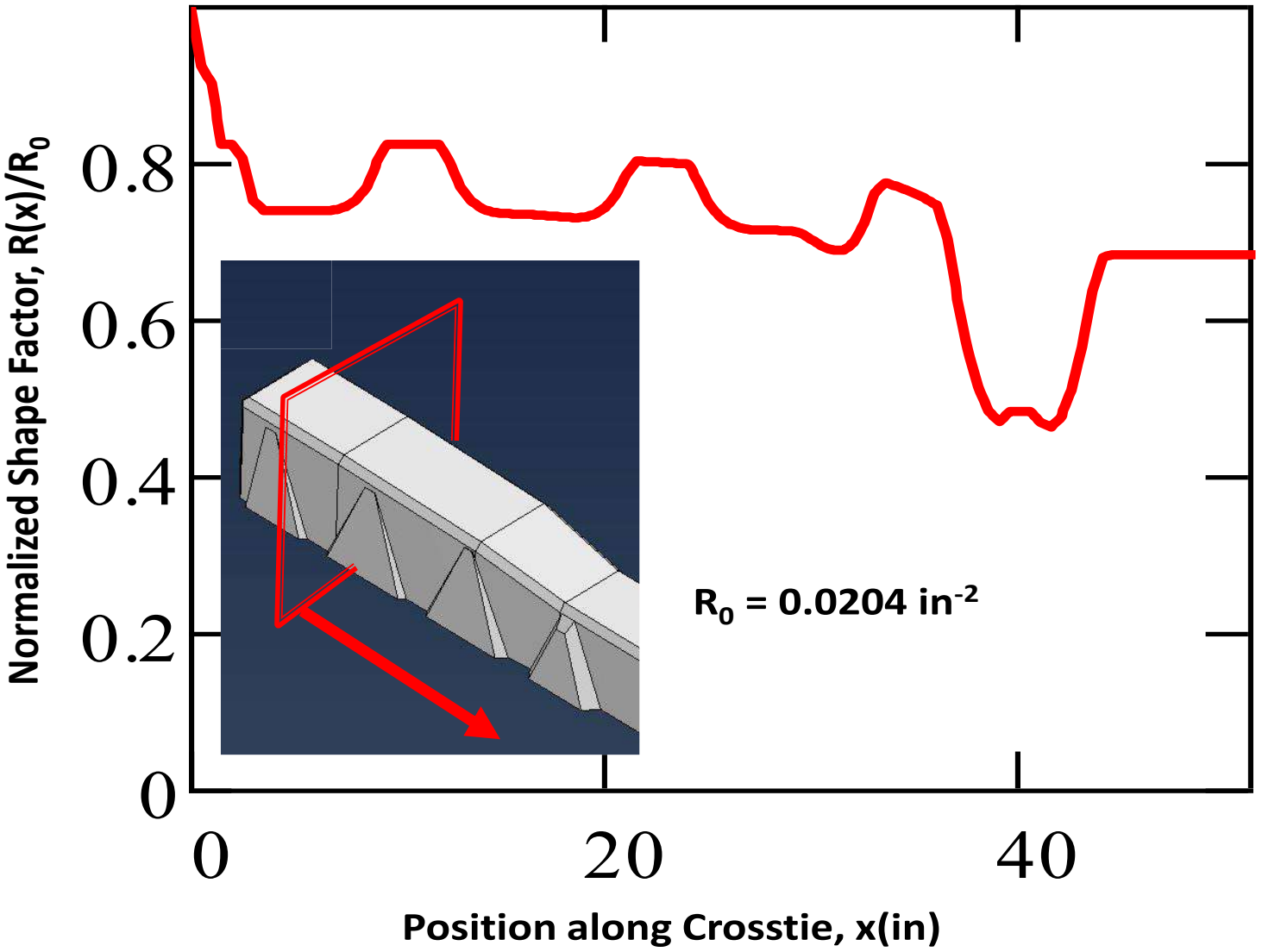


- Determine Section Properties along Length of Tie
- Cross-Section Parameter Evaluation (Area, Neutral Axis, Area Moment of Inertia, Eccentricity, etc.

Extraction of Crosstie Geometrical Parameters



Normalized Shape Factor for Crosstie



A 4-Page report is generated for each tie based on visual inspection and 3-D Scanning

PROCESSING REPORT: A1

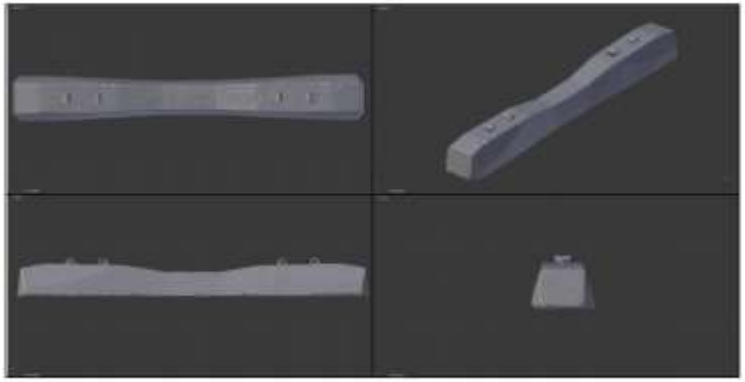


Figure 1: Scanned Tie Profiles

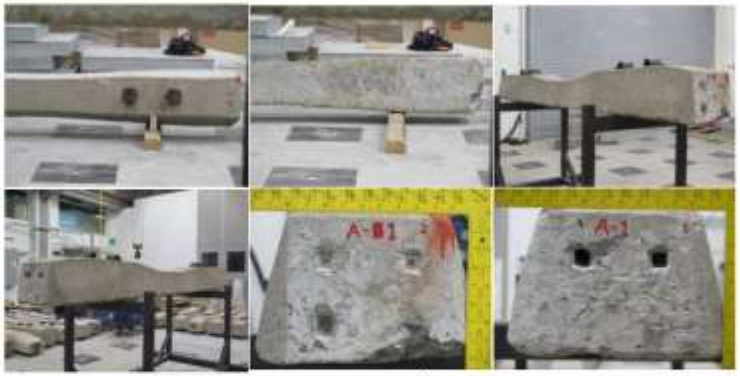


Figure 2: Tie Profiles

GENERAL INFORMATION

TIE INFORMATION

Tie ID	: A1	Estimated GT :	Unknown
Wire Centroid	: 3.4256"	Date Received :	06/07/16
Place in Track :	Unknown	Date Scanned :	06/08/16
Origin	: TTCI	Date Released :	---

WIRE INFORMATION

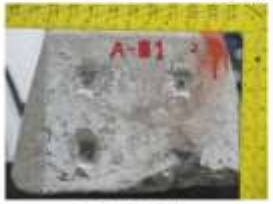


Figure 2: End 1

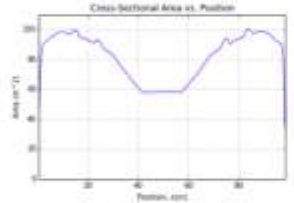
Figure 3: End 2

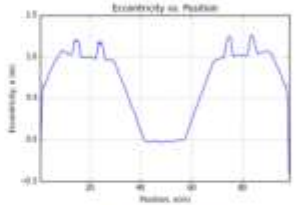
Calculated Wire Centroid
End 1: 3.426 in
End 2: Unknown
Avg : 3.426 in

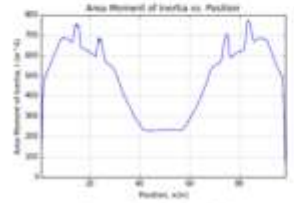
Prestressing Wire Specifics
# of Tendons : 4
Wire Type : Indented
Wire Size : Unknown

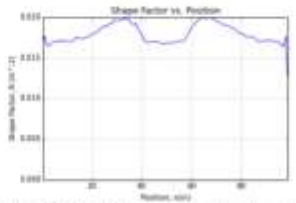
PROCESSED INFORMATION

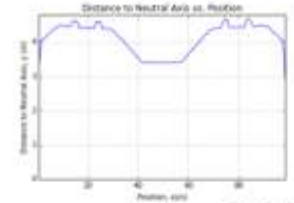
SHAPE PARAMETERS







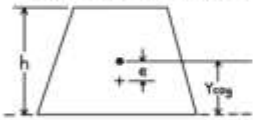




Note: Rail shoulders remained on the model during processing.

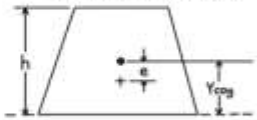
CRITICAL PROFILES

Average Rail Seat



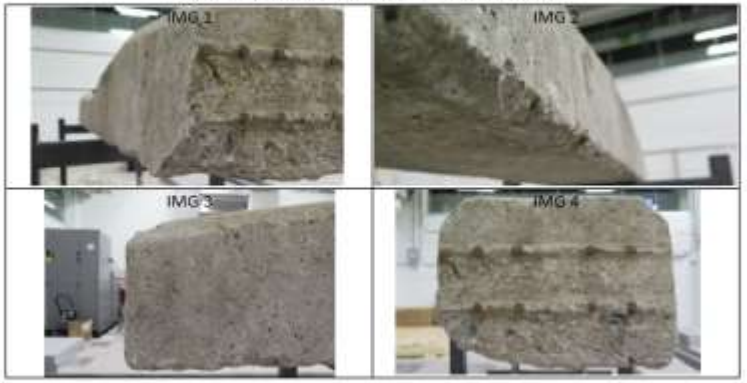
h = 9.225 in
Area = 93.012 in^2
Y_cog = 4.418 in
I = 615.185 in^4
e = 0.993 in

Middle Section



h = 7.135 in
Area = 58.581 in^2
Y_cog = 3.401 in
I = 233.527 in^4
e = -0.025 in

AS-RECEIVED DAMAGE



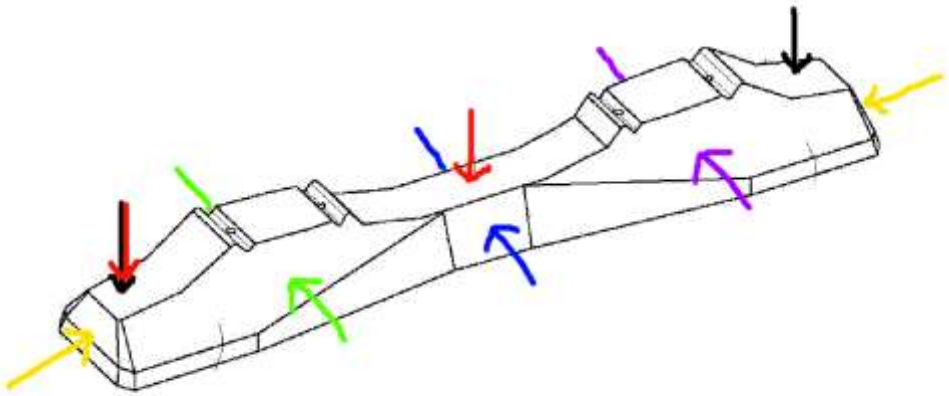
ANOMOLIES

Notes: ----------

Additional Non-Destructive Testing and Concrete Evaluation

Non-Destructive Testing of Tie Condition

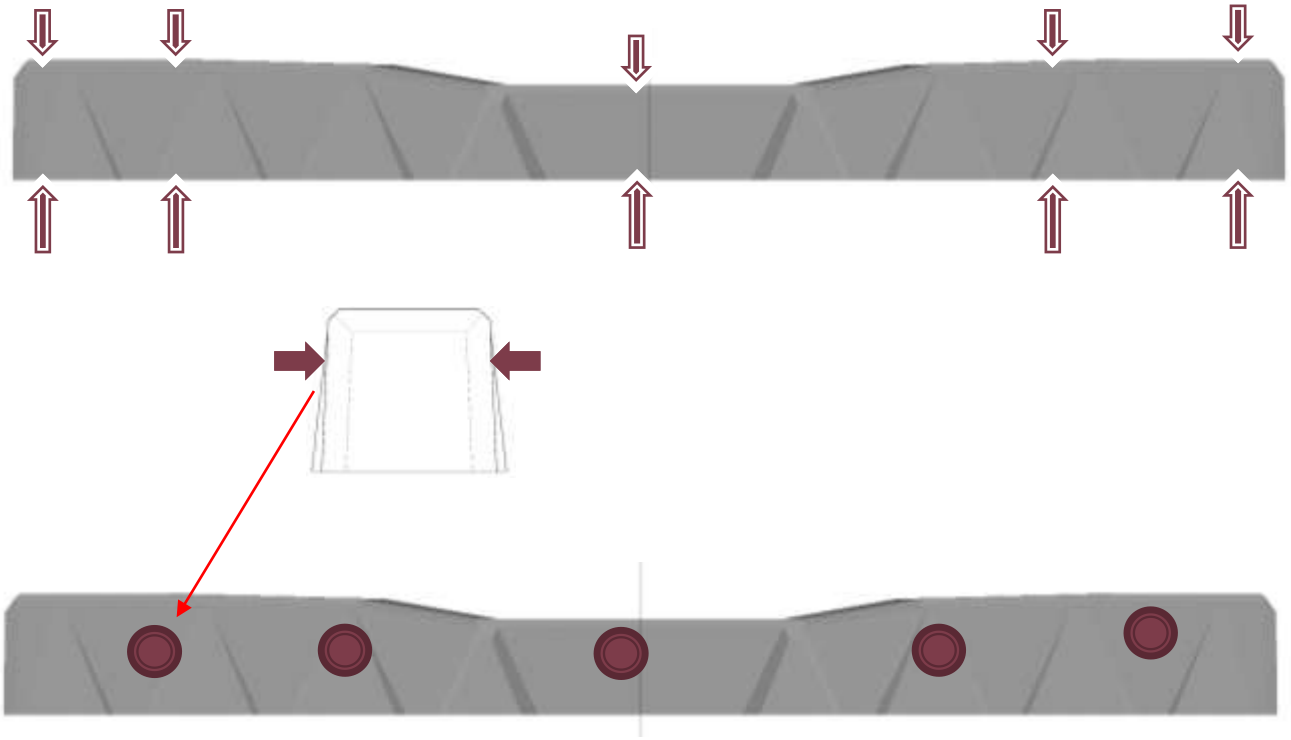
- Impact Echo
- Ultrasonic Pulse Velocity



Damage Detection

- Ultrasonic pulse velocity
  - Micro-cracking slows wave propagation in concrete
  - Measurements taken at different locations in the ties to measure deterioration at different locations

Pulse Velocity Measurements

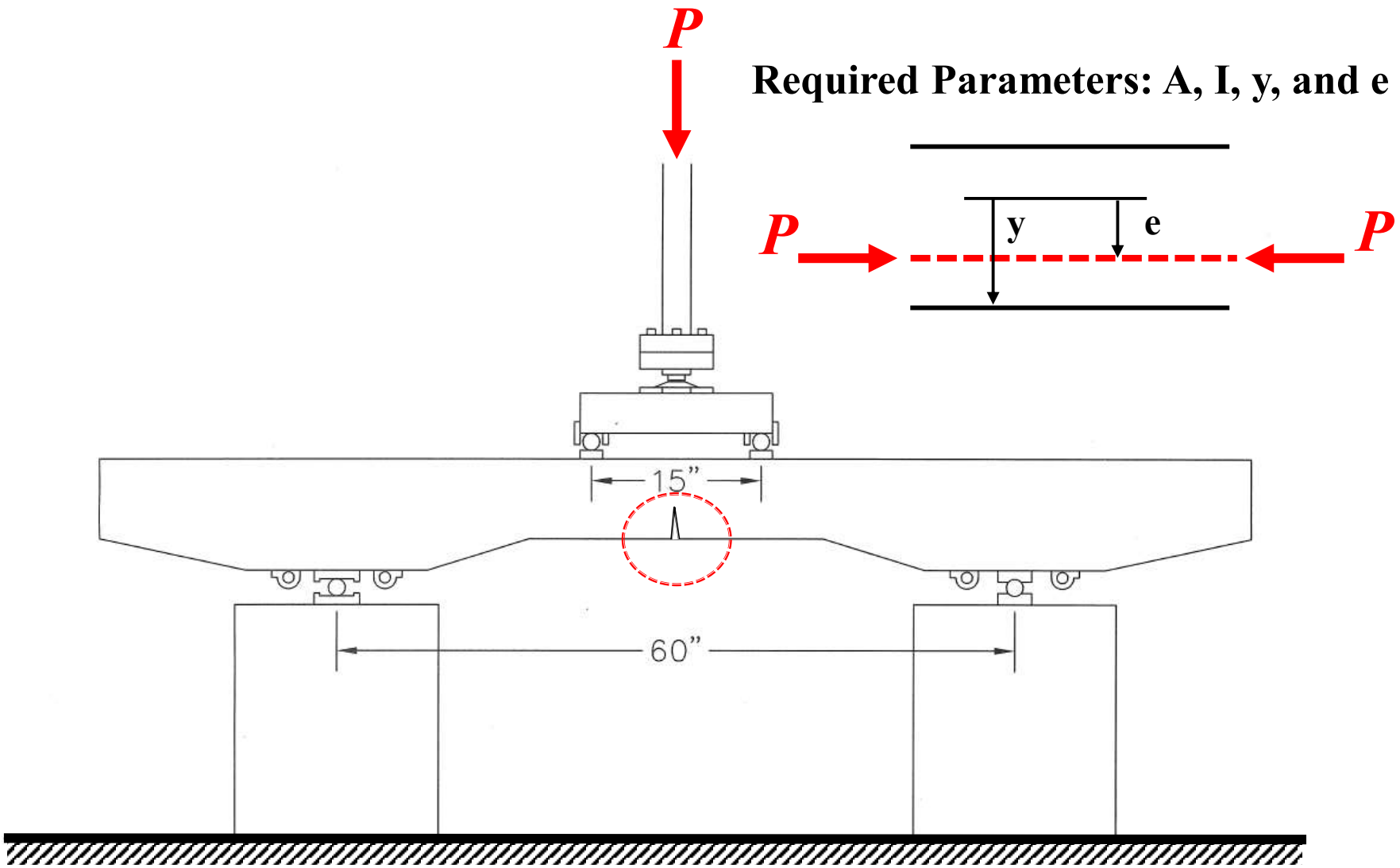


Destructive Evaluation

Determine Remaining Prestress Force

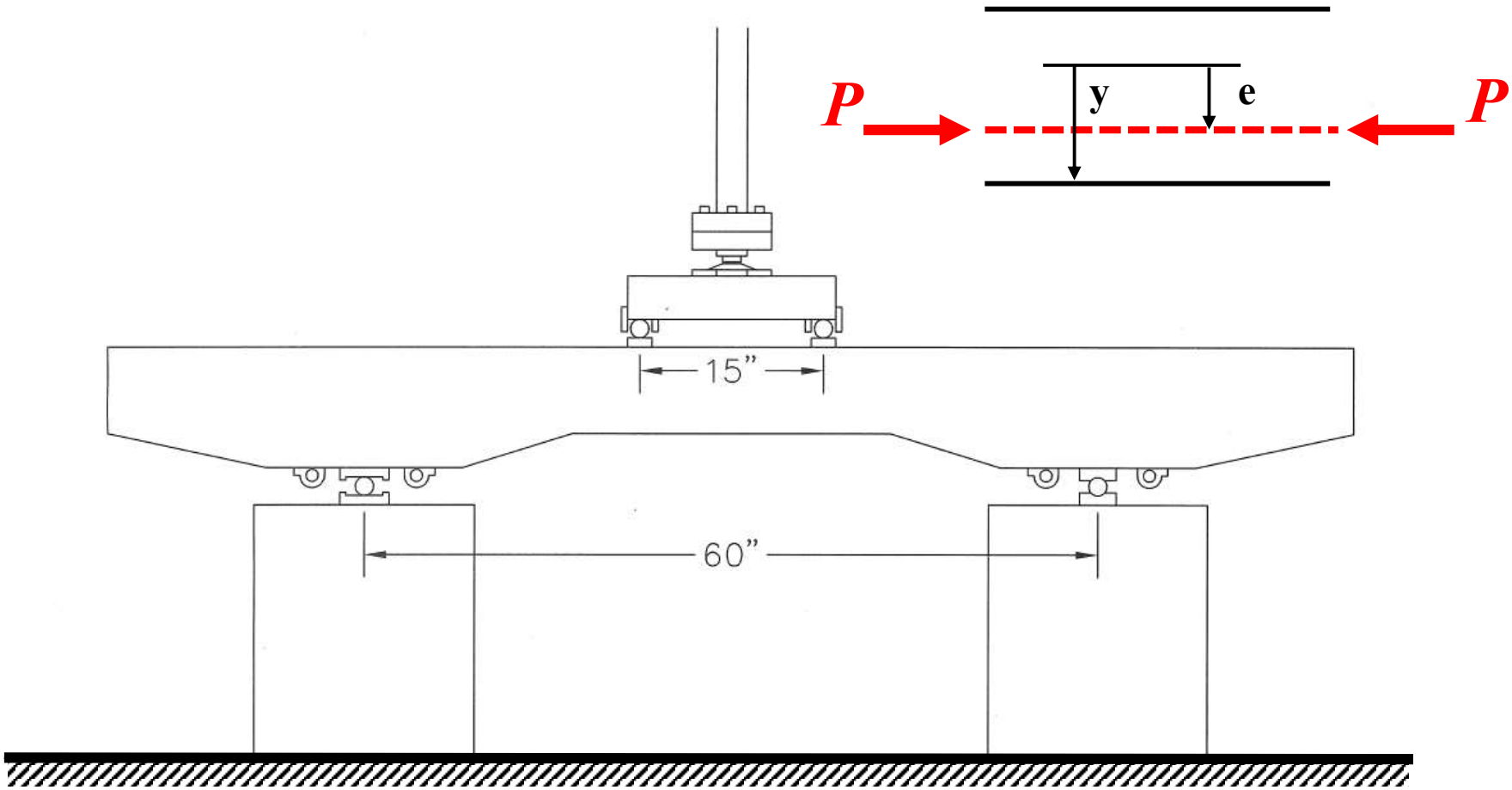
- Support tie upside-at rail seat and load at center until cracking.
- Unload tie and apply instrumentation across crack.
- Re-load and establish the crack-opening load
- Calculate the prestress force from statics (knowing the detailed geometry and cross-section)

Modified Center Negative Loading Test



Modified Center Negative Loading Test

Required Parameters: A, I, y, and e



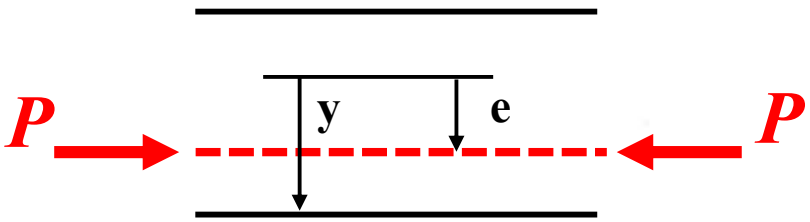
Modified Center Negative Loading Test

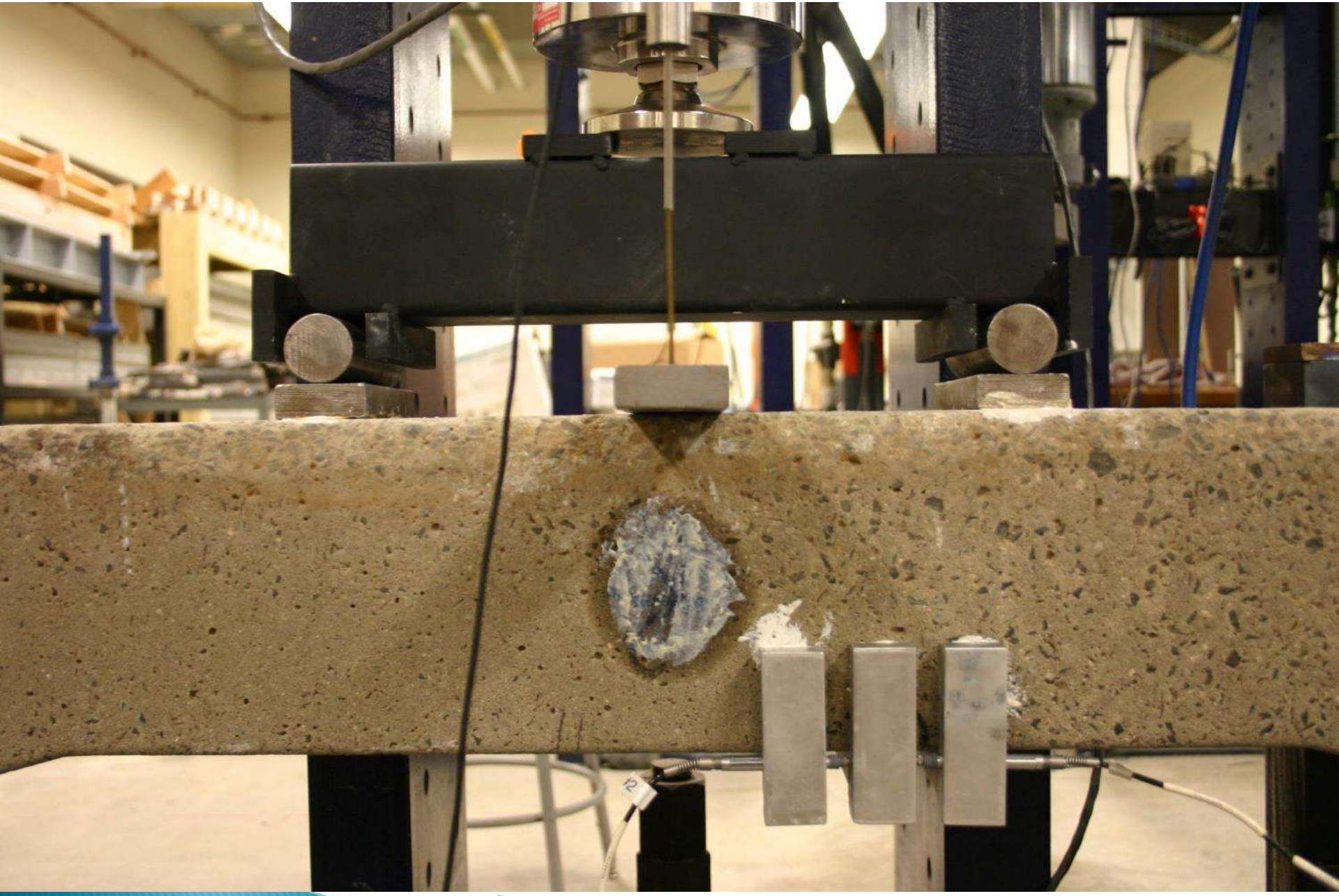
At Crack Initiation:

$$-\frac{P}{A}-\frac{Pey}{I}+\frac{My}{I}=0$$

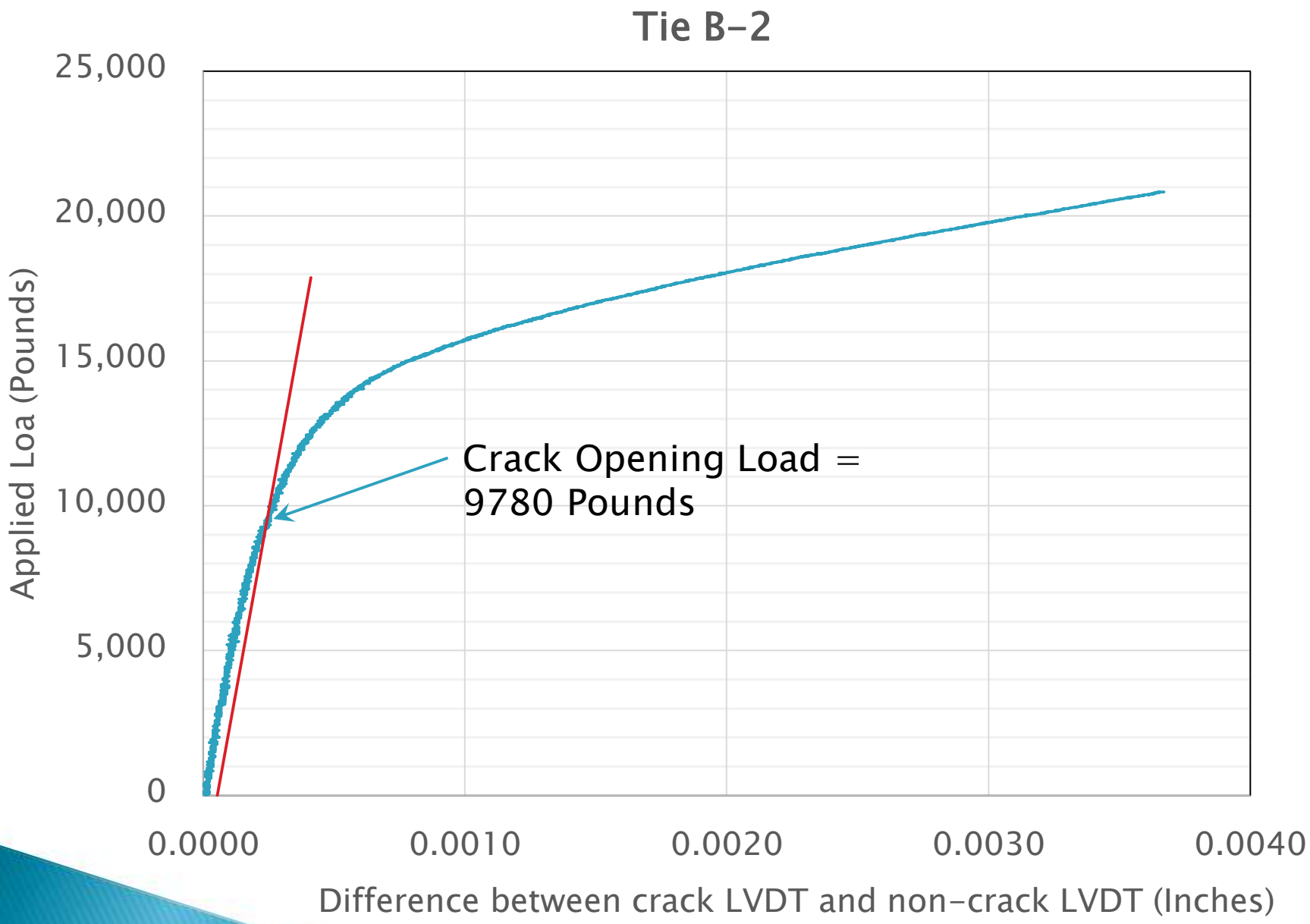
$$P=\frac{MyA}{I+Aey}$$

Required Parameters: A, I, y, and e

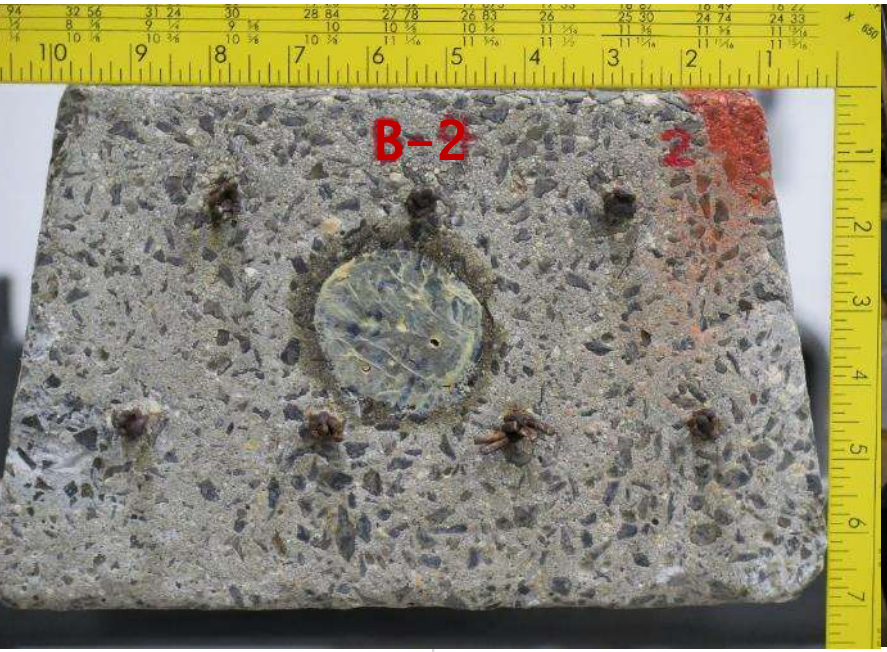





MTS
MODEL
032 02F-20

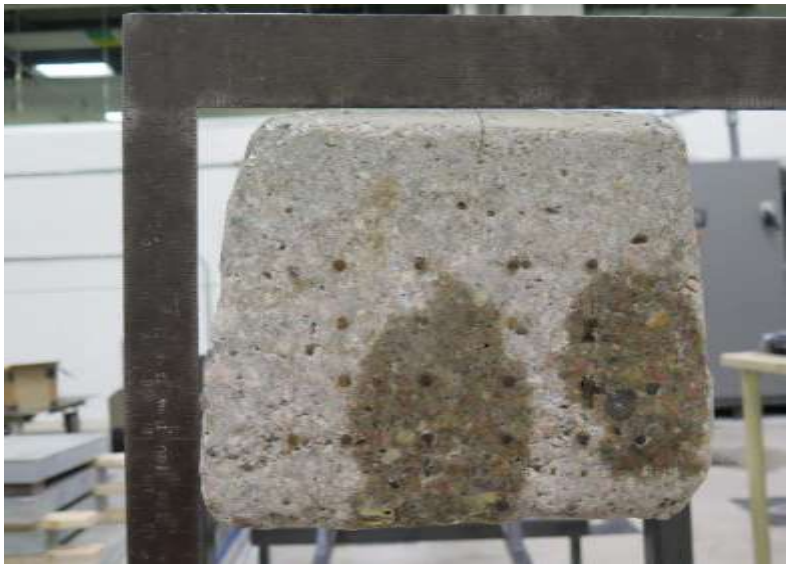

Tie B-2
25,000
20,000
15,000
10,000
5,000
0
Applied Loa (Pounds)
Crack Opening Load =
9780 Pounds
0.0000
0.0010
0.0020
0.0030
0.0040
Difference between crack LVDT and non-crack LVDT (Inches)

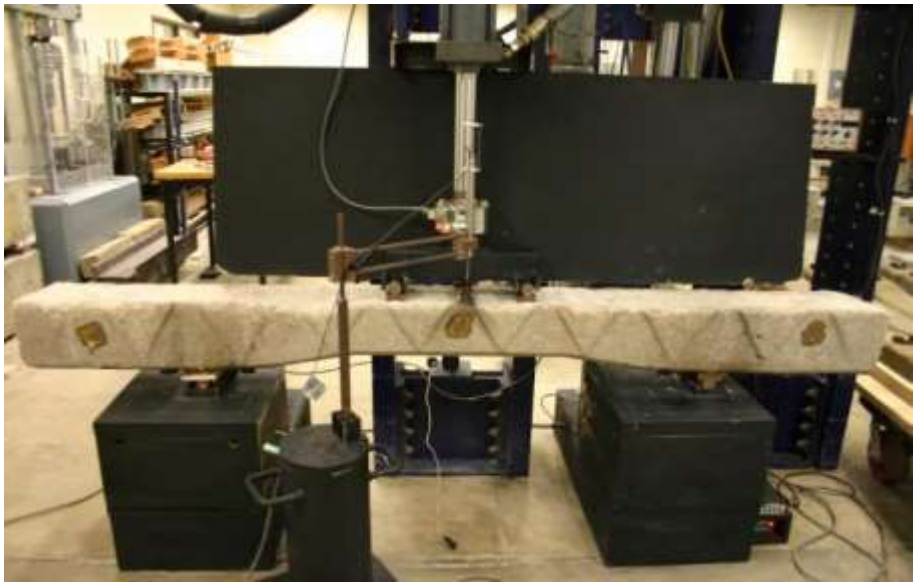
Determination of Remaining Prestress Force in Tie B-2



Crack Load =	9780	lbs
M =	110025	lb-in
y =	3.62	in
A =	69.06	in^2
I =	275.3	in^4
e =	0.457	in
P =	70610	lb
P =	70.6	kip

Determination of Remaining Prestress Force in Tie E-4





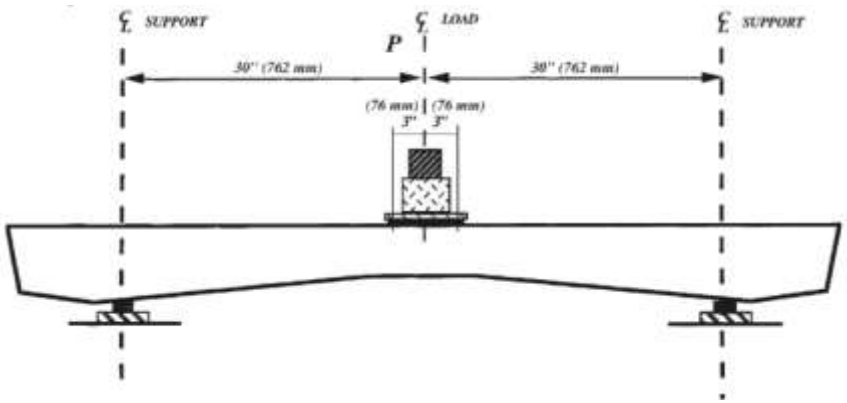
$$P = \frac{MyA}{I + Aey}$$

Crack Load =	12630	lbs
M =	142087.5	lb-in
y =	3.4	in
A =	62	in^2
I =	225	in^4
e =	0.21	in

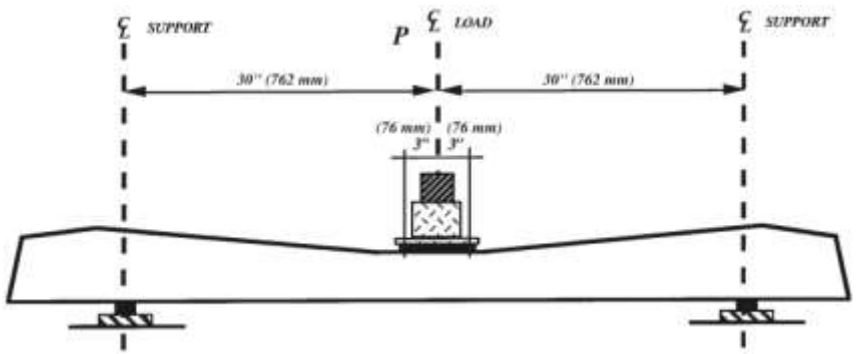
P =	111235	lb
P =	111.2	kip

Crosstie Loading Tests

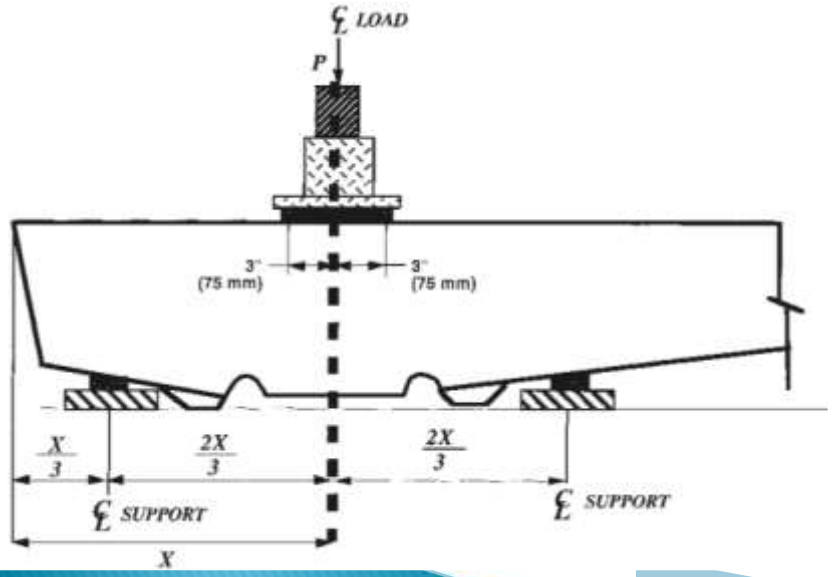
Center Negative Test (C–)



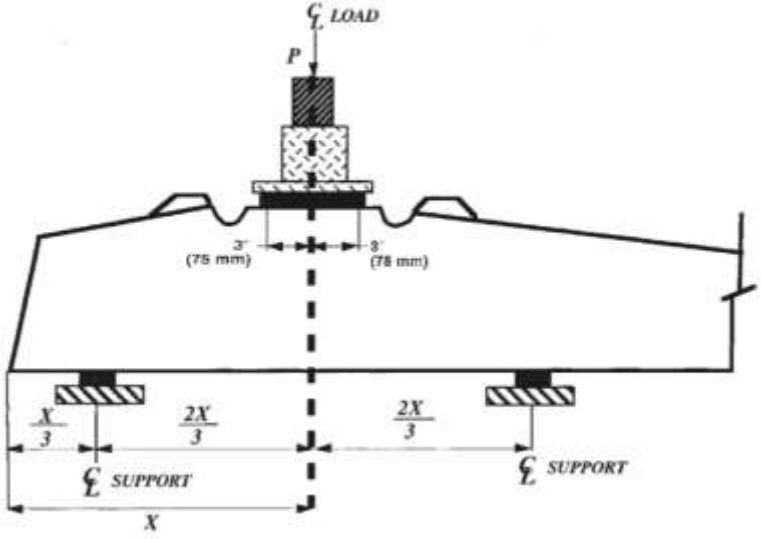
Center Positive Test (C+)



Rail Seat Negative Test (RS–)



Rail Seat Positive Test (RS+)

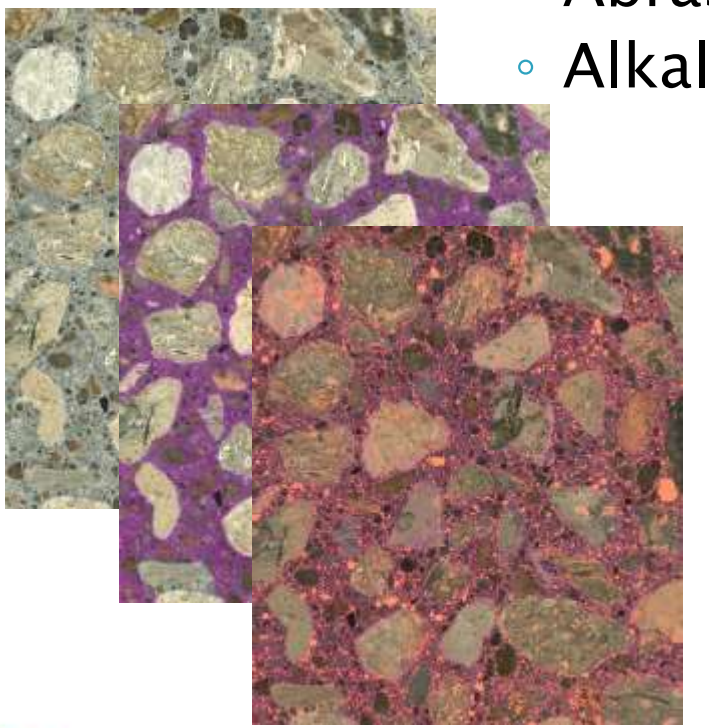


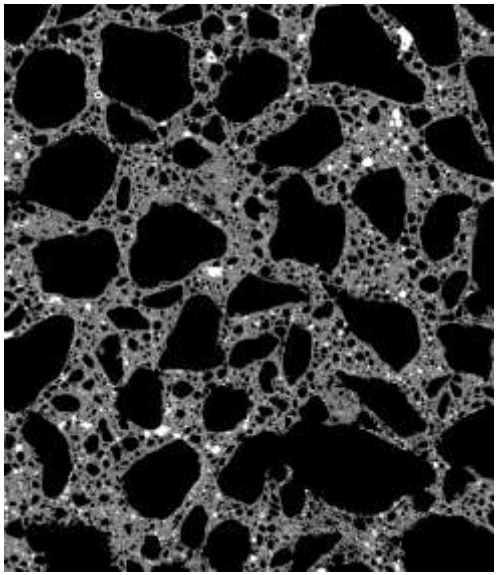
Concrete Properties

- Unit weight
- Concrete compressive strength
- Concrete tensile strength
- Abrasion testing – correlate to aggregate hardness
- Aggregate hardness (Moh's)
- Characterize aggregate mineralogy
- Determination of Presence of alkali-silica reaction
- Fracture Toughness

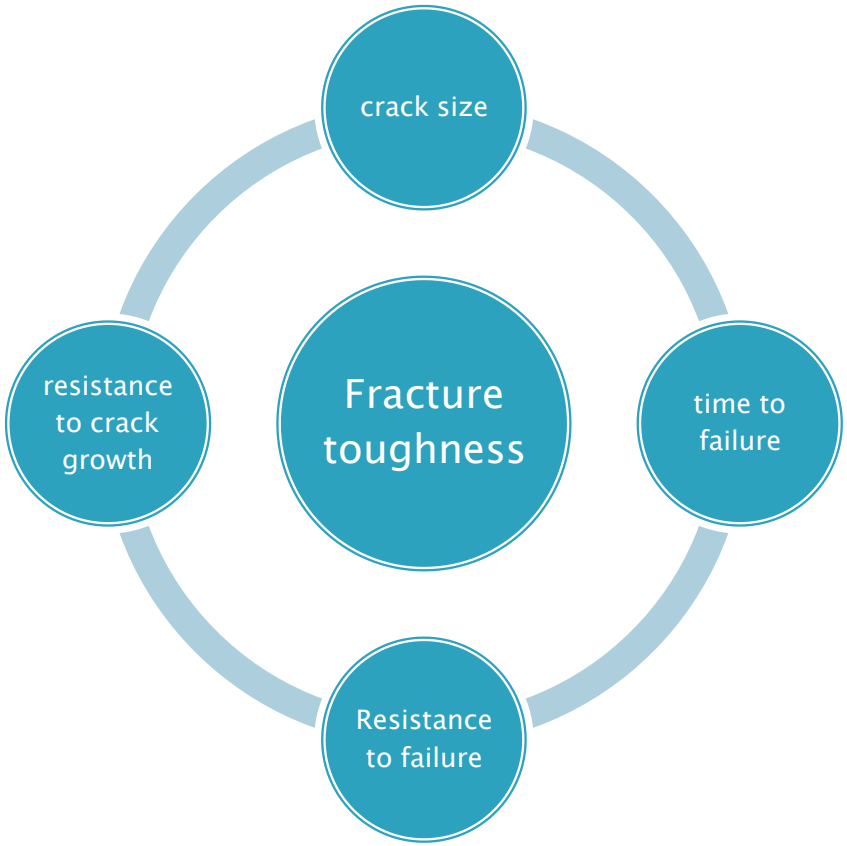
Tie Destructive Testing

- Hardened air void analysis
- Abrasion testing
- Alkali-silica reaction examination

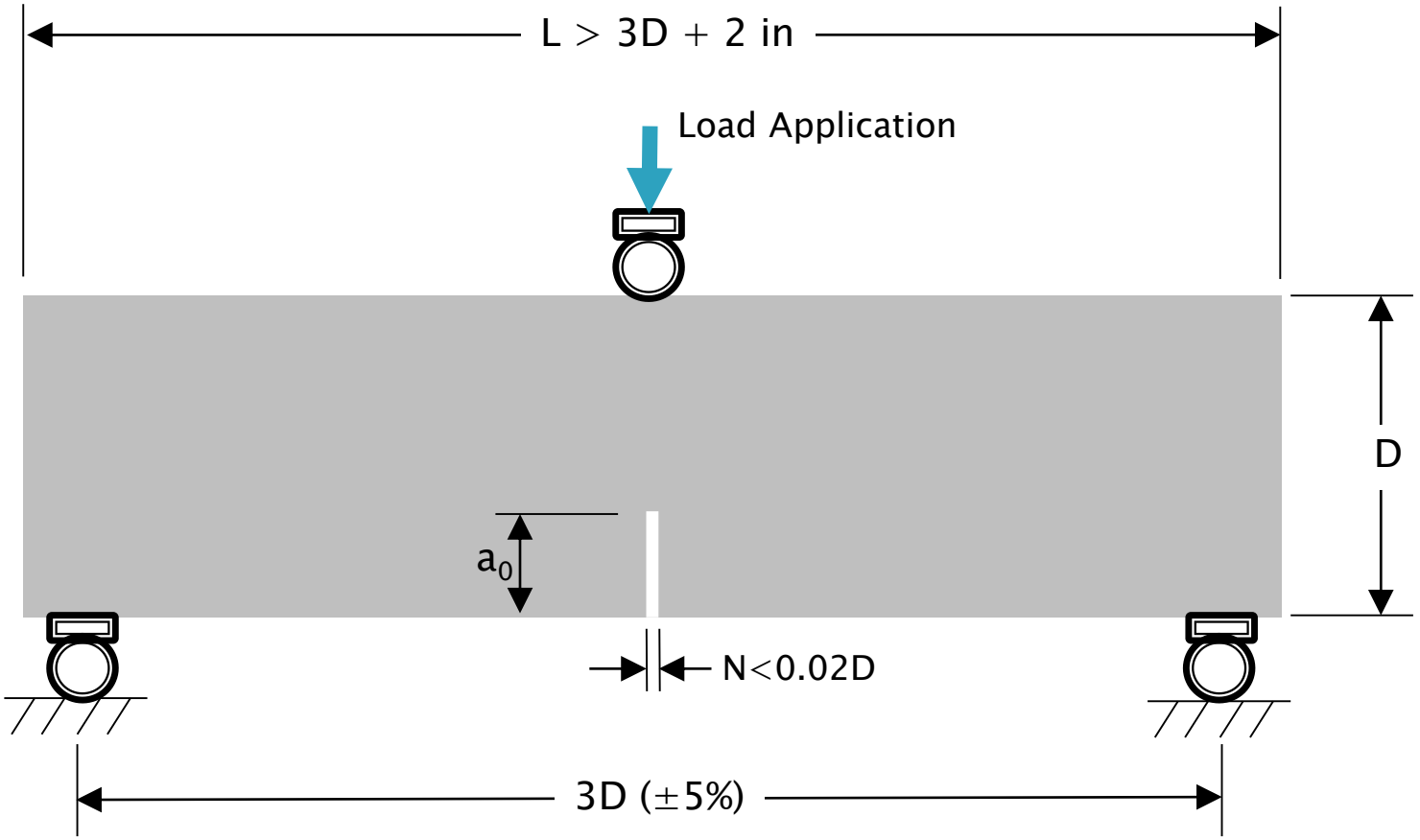




Concerns:


crack size
resistance to crack growth
Fracture toughness
time to failure
Resistance to failure

Fracture Toughness Based on Aggregate and Concrete Composition



Prestressing Steel Evaluation

Prestressing Tendon Properties

- Acid cleaning of the different reinforcement types using the methodology developed in the current FRA project
- Close-up photo documentation of reinforcement types and indents
- Physical measurements according to ASTM A881 and automated scanner
- Conduct un-tensioned pullout tests according to ASTM A1096 (on wires only)

Questions/Feedback?