CONCRETE PILE SPLICES

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ACKNOWLEDGMENTS

"*Investigation and Development of an Effective, Economical and Efficient Concrete Pile Splice – Final Report.*" University of South Florida – Gray Mullins, et. al., 2015.

Pile Driving Contractors Associates (PDCA)

GRL – Mohammad Hussein, P.E., BC.GE

LaDOTD – Jesse Rauser, P.E.

OUTLINE

Renewed Interest / Background?

Categories of Concrete Pile Splices

Design Specifications (FDOT)

Case Study: LA 1 Relocated

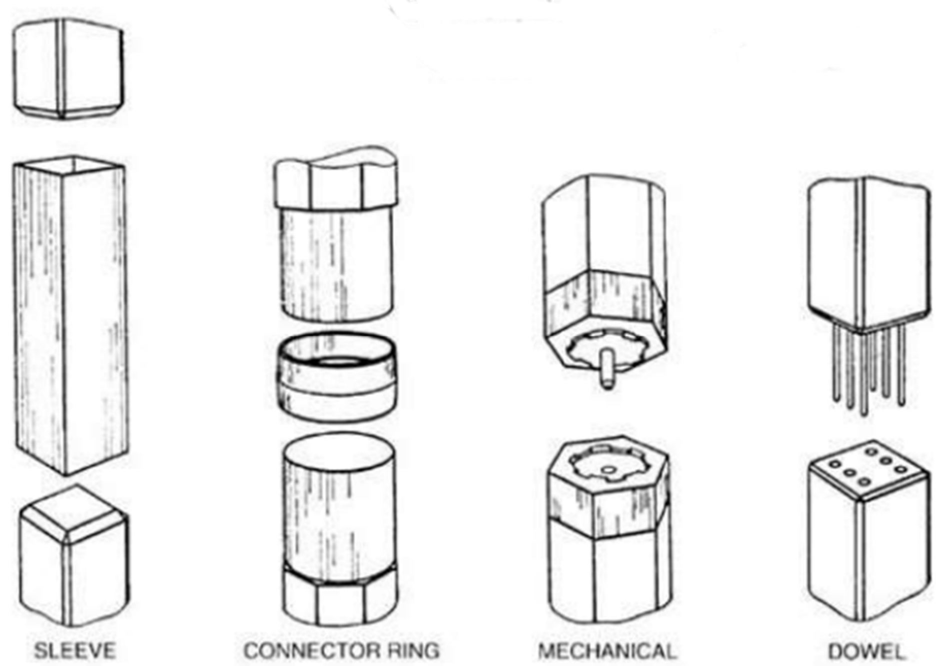
RENEWED INTEREST / BACKGROUND

- Costs increasing with longer piles
- Construction processes
- PDCA Technical Committee
- Auburn University – Initiated research by ALDOT

CATEGORIES OF PILE SPLICES

Based on Bruce and Herbert (1974) –(see Mullins, 2015 for additional information)

- Welded
- Sleeved
- Mechanical
- Connector Ring
- Doweled
- Post-tensioned



DESIGN SPECIFICATIONS (FDOT)

- Pile splice should be located a minimum of 15 ft below the mudline.
- Ideally for Preplanned Splices place the splice at the midpoint between the estimated pile tip and ground surface considering scour.
- Stagger the splice location between adjacent piles a minimum of 10ft
- One pile splice on the APL: Kie-Lock (18”/24”/30”)
- Mechanical Splices must develop the following capacities:

Pile Size (inches)	Bending Strength (kip-feet)
18	245
20	325
24	600
30	950

RENEWED INTEREST / BACKGROUND

DOT	Allow Concrete Splices	Comments
Hawaii	Typically do not use concrete piles	
KYTC	No	Doesn't use concrete piles
ALDOT	No	Have inquired about research with Auburn
TDOT	follow up	
LaDOTD	Yes	
SCDOT	No	
MnDOT	Typically No	
GDOT	Yes	Have details but most likely follow FDOT (need to look at details)
FDOT	Yes	Developed specifications
Nebraska	Yes	

DESIGN SPECIFICATIONS (FDOT)

Driving Stresses FDOT Specifications 455

$$(1)\quad s_{apc} = 0.7f'_c - 0.75f_{pe}$$

$$(2)\quad s_{apt} = 6.5\left(f'_c\right)^{0.5} + 1.05f_{pe}$$

$$(3)\quad s_{apt} = 3.25\left(f'_c\right)0.5 + 1.05f_{pe}$$

$$(4)\quad s_{apt} = 500psi$$

Item 4 is for mechanical splices

* Dowel splices the initial prestress is 0 psi (250 psi to 500 psi driving tension stress)

WHAT ABOUT IF WE CAN GET HIGHER DRIVING STRESSES WITHOUT DAMAGE????

LA-1 RELOCATED

Case Study
(Work in progress!)

PROJECT OVERVIEW

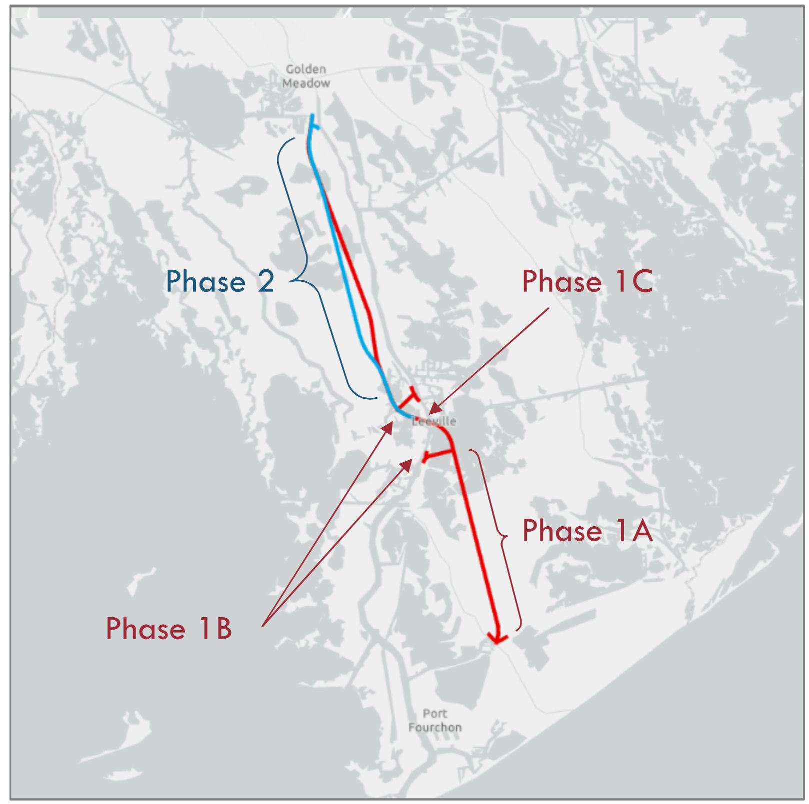
18-mile corridor in Lafourche Parish, LA

Connects LOOP facility to Golden Meadow, LA (inside protection levee)

Phase 1 (2005-2011, $360mm)
- 1B: North & South Connectors
- 1C: High-level bridge over Bayou Lafourche
- 1A: 5.5mi elevated highway

Phase 2 (2022-present, $464mm)
- 2A: Connection to North Connector
- 2B: ~8mi elevated, end-on construction
- 2C: Levee crossing

Project Location: Lafourche Parish



PILE SPLICES: PHASE 1A

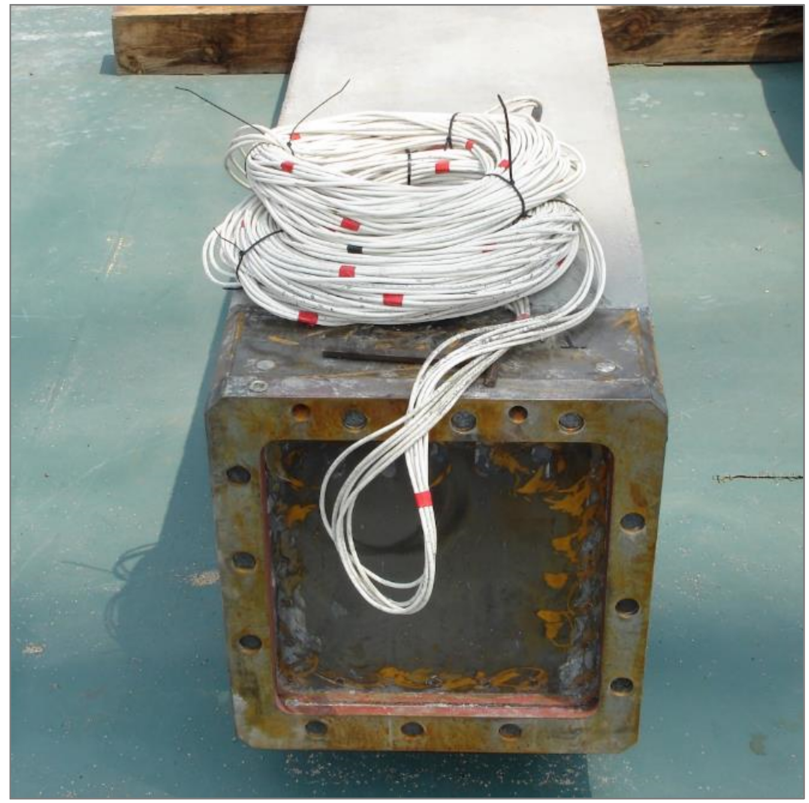
Phase 1 piles used Kie-Lock splices

- Square-shaped male & female ends
- Connection finished with driven steel dowels

Phase 1A:

- 436 bents, 3 to 4 piles per bent (Alt 2)
- Dynamic monitoring on 1 pile per bent (>20%)
- 24" sq PPC piles
- Designed using ASD, FS=2.0
- Required resistances 207 tons to 470 tons
- Pile lengths: 81' to 170'

Kie-Lock Male & Female Ends



PH-1A: SPLICE DAMAGE

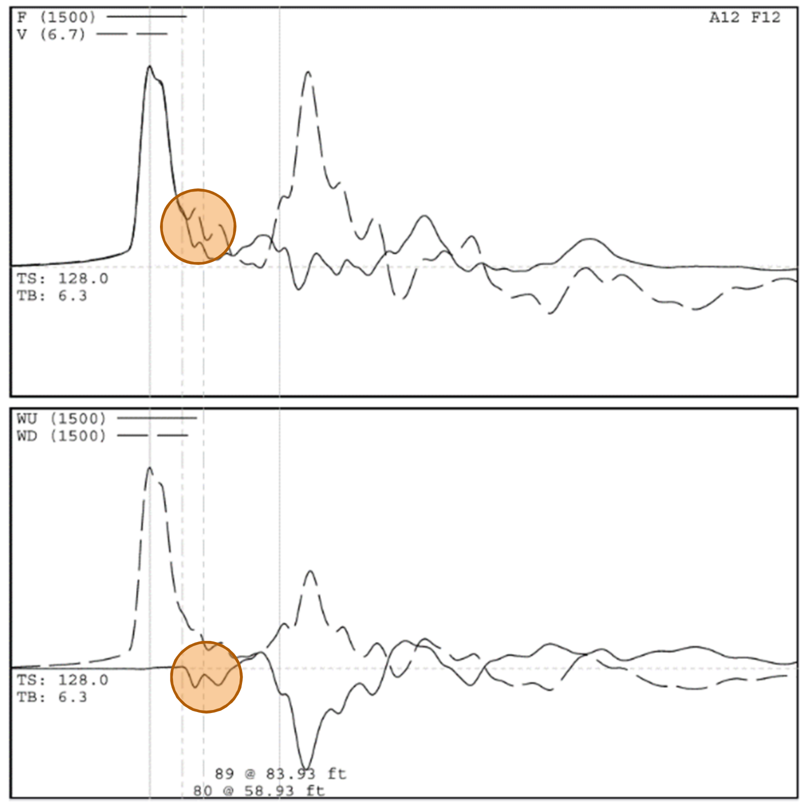
Typical splice pile data

- BTA = 81%

Damaged pile

- BTA = 73% (blow 229)
- BTA = 83% (blow 755)
  - Apparent movement: 28'
  - Different shape
  - BTA inconsistent
- BTA = 80% & 90% (blow 796)
  - Two distinct impedance changes
  - Inconsistent with other Monitor Piles
  - Pile was rejected – only time contingency cap was used

PDA Data from Kie-Lock Splices



PILE SPLICES: PHASE 2

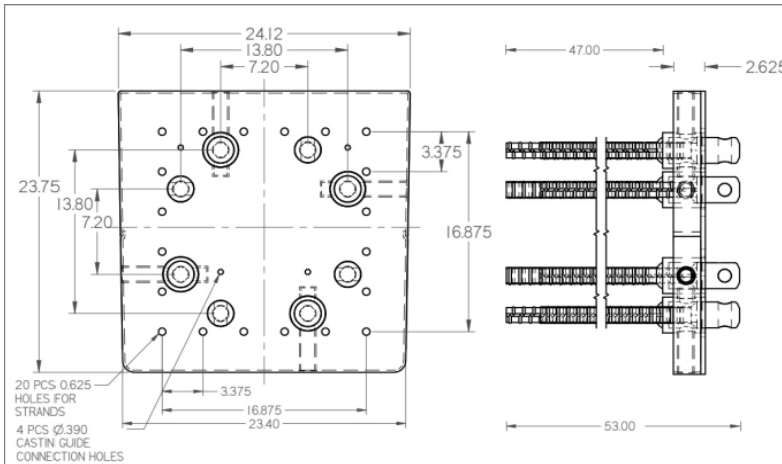
Phase 2 piles use Emeca splices

- Socket & stud connection
- Connection finished with driven steel dowels

Phase 2B:

- 351 bents, 4 to 8 piles per bent
- Dynamic monitoring on 1 pile per bent (~20%)
- 30” sq PPC piles
- Designed using LRFD, ϕ=0.80
- Required resistances 319 tons to 544 tons
- Pile lengths: 144’ to 203’

Emeca 24” Splice Stress Limits



Parameter	Allowable Limit
Rated Tensile Capacity for Full Splice (8 bars)	701 kips
Shear Capacity of the Splice Joint	1033 kips
Bending Moment Capacity of the Splice Joint	603 k-ft (at 0 Axial load)
Allowable Driving tensile stress limit	1290 psi
Recommended Driving Tensile Stress Limit	<1200 psi
* Calculations based on 6000 psi concrete	

PLAN NOTES

Splice Location

- > 3D away from maximum moment location
- > 5D below mudline

Structural

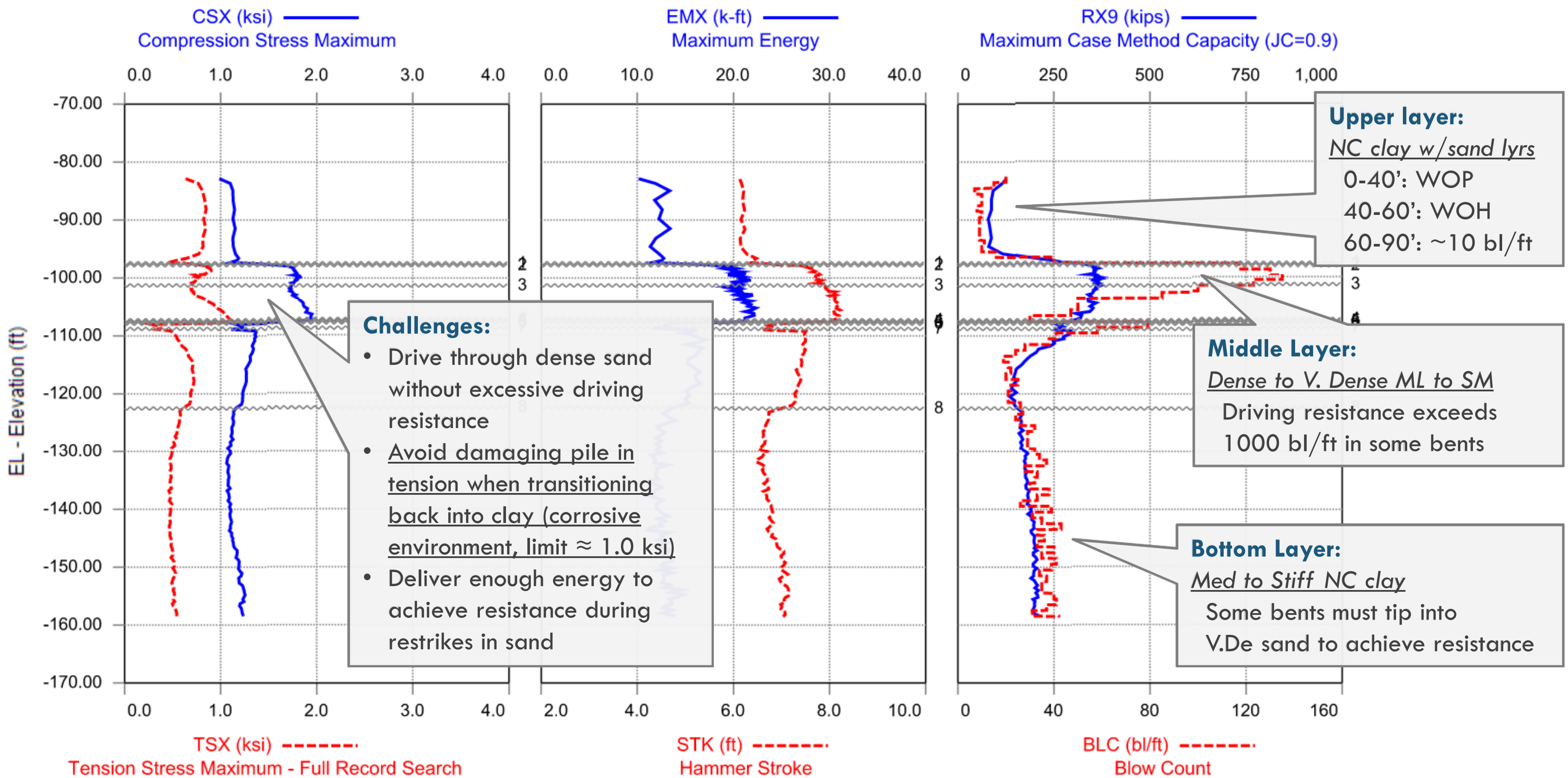
- Splice capacity should be ≥ pile capacity in axial, lateral, and bending
- Splice steel shall extend beyond where prestress is fully developed, 50% must extend 1D beyond that
- Pile void > 2D beyond longest splice steel

Splice components shall be installed at casting yard during fabrication

Splice shall not preclude use of dynamic monitoring

Splice shall not be used to splice different pile sizes

Cost shall be included in the cost of the pile



1 - swapped to 12" cushion block
2 - fs2
3 - fs3
4 - fs2
5 - fs1
6 - swapped to 18" cushion block
7 - fs2
8 - WC = 15,020.0 f/s

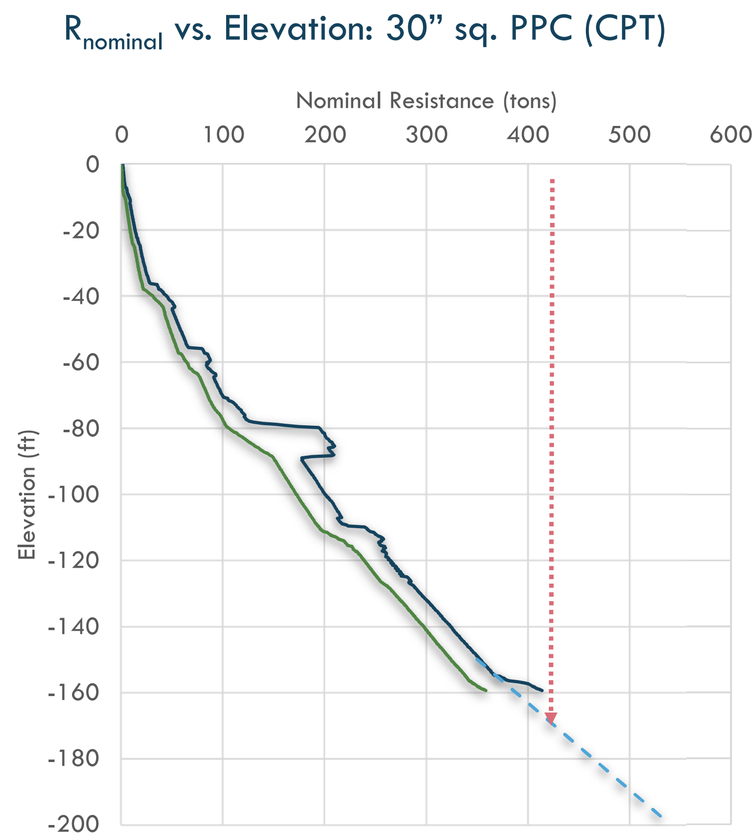
PHASE 2 DATA ANALYSIS

Initiated to explore hammer performance

- "Refusal" type driving resistances in sand
- Not enough resistance in sand layer
- Low stroke/low ETR

Decided to look at splice data based on PDCA committee discussion

- Still a work in progress!
- Need to look at LA-1 Phase 1 data (Kie-Lock)



PHASE 2 DATA ANALYSIS

Exported SQFile data from PDA files

Filtered based on data quality

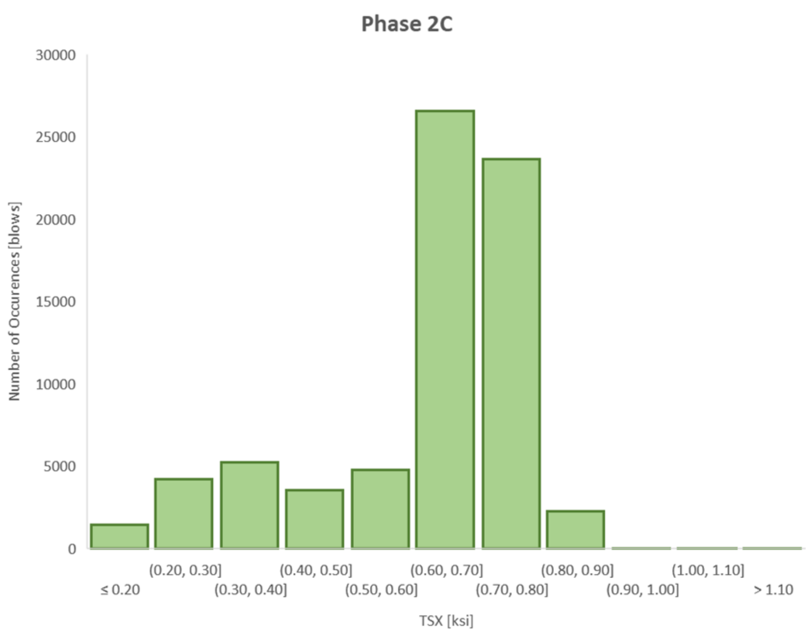
- Anything with multiple flags was omitted
- Impossible stroke values were omitted

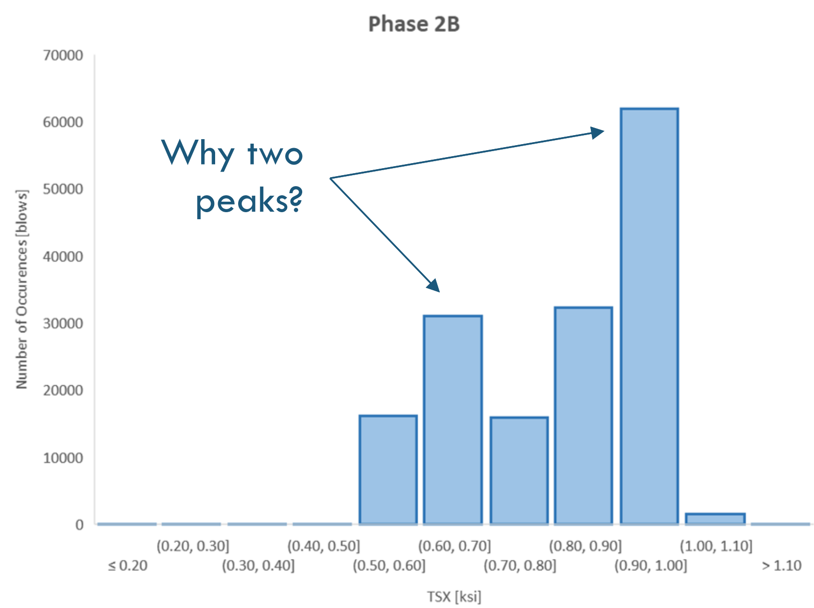
Analyzed every blow for occurrence of

- CSX: average compression stress
- TSX: average tension stress
- TLS: average tension stress @ splice
- ETR: energy transfer ratio
- STK: stroke
- BTA: beta/aka cross-section reduction

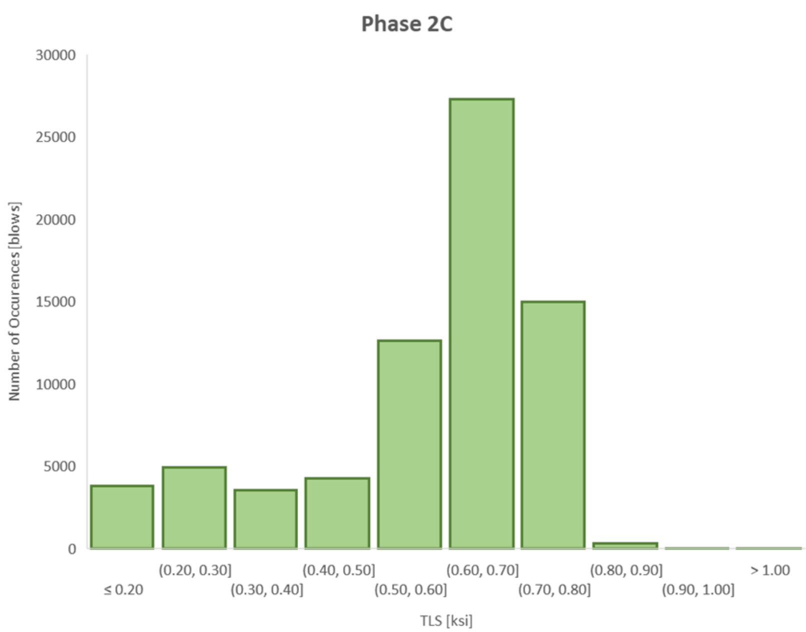
Phase 2C Levee Crossing (JGC Drone Image)

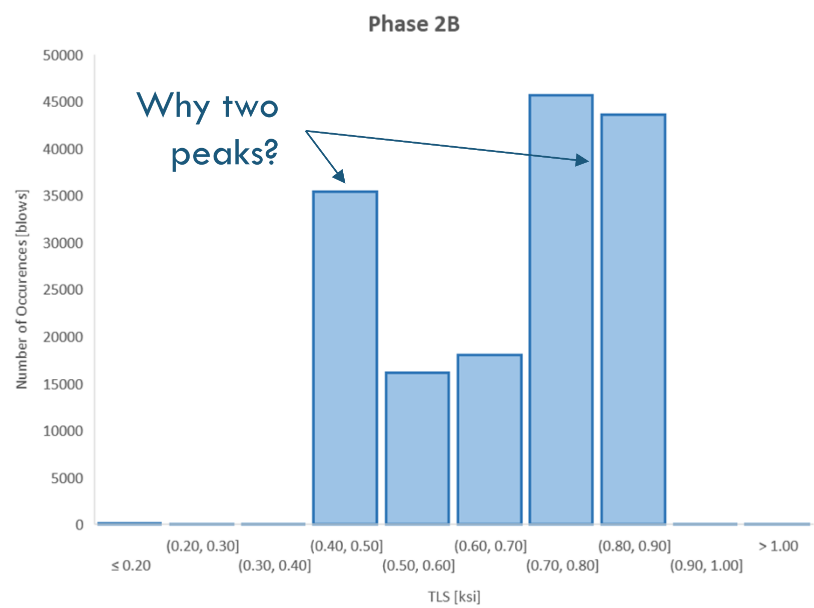
PHASE 2C VS. 2B: TENSION STRESSES



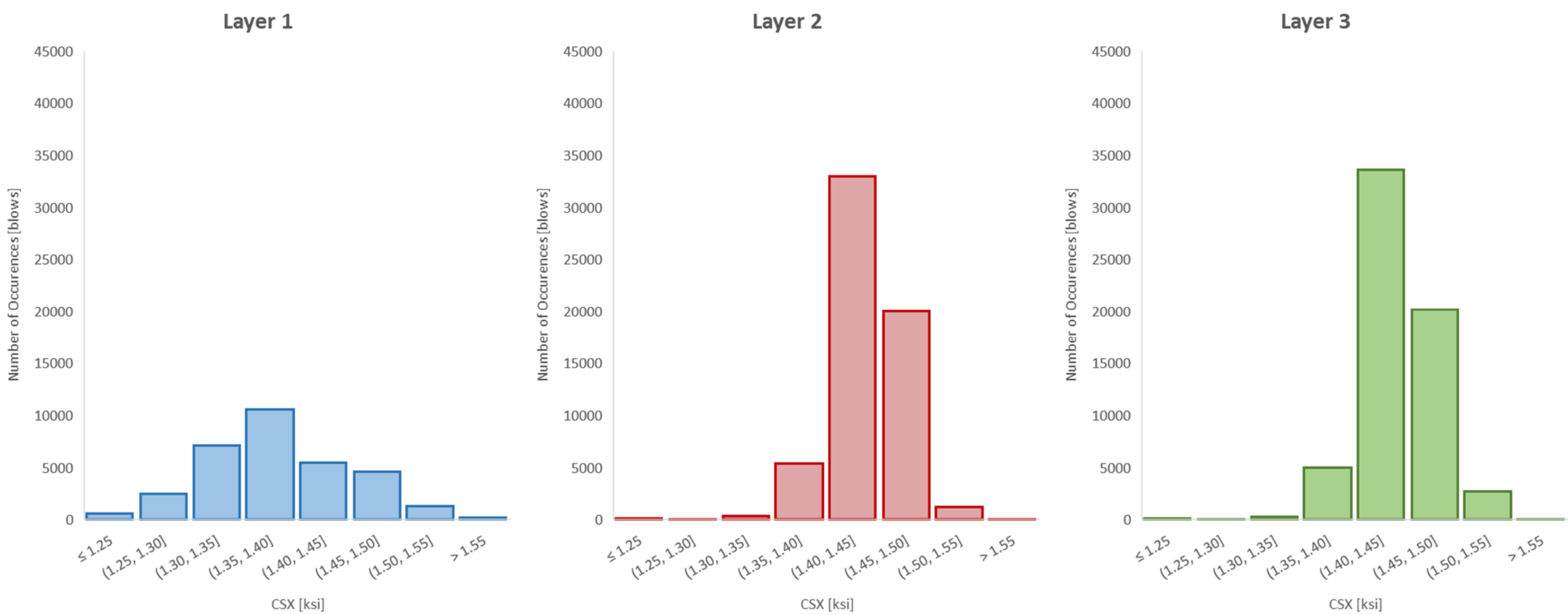


PHASE 2C VS. 2B: TENSION AT SPLICE

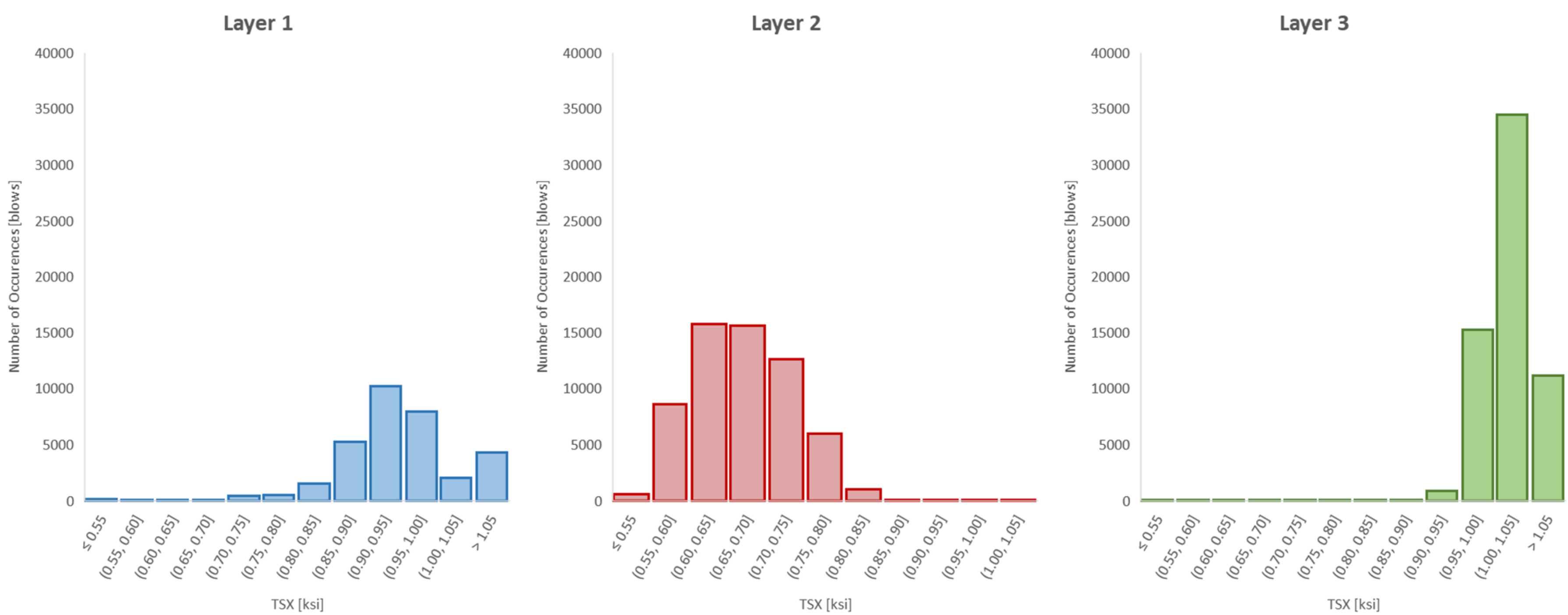




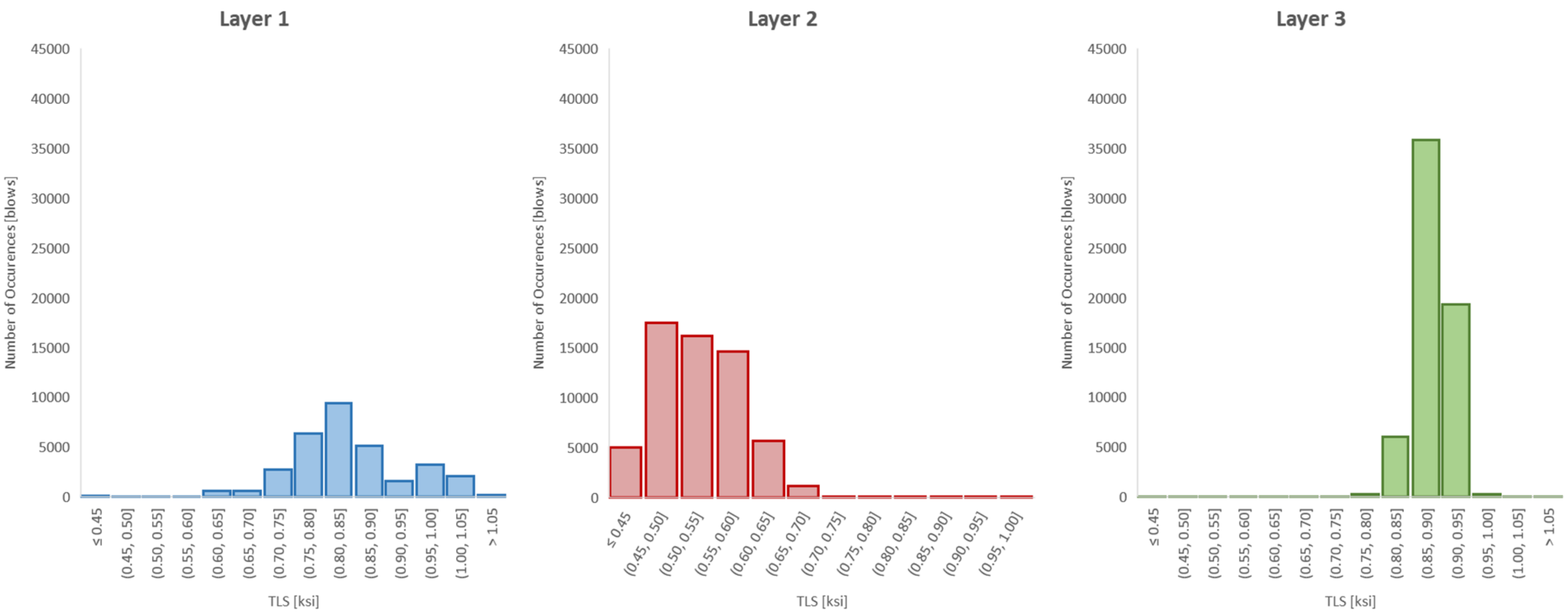
PHASE 2B BY LAYER: COMPRESSIVE STRESS



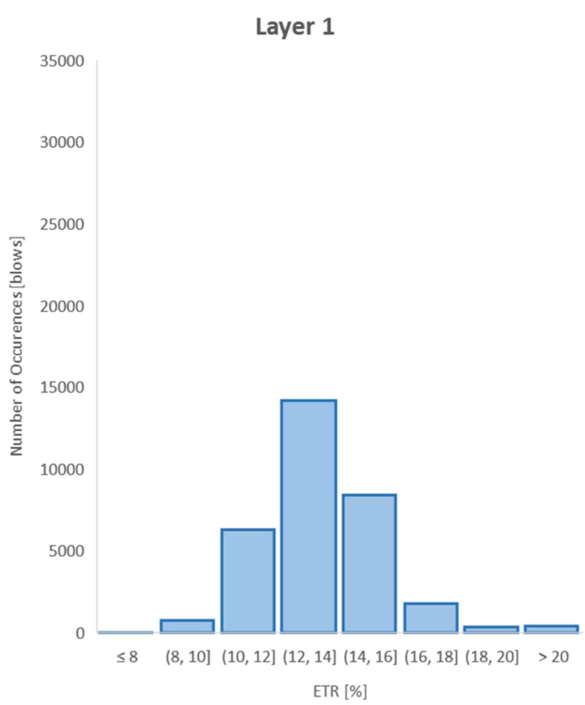
PHASE 2B BY LAYER: TENSION STRESS

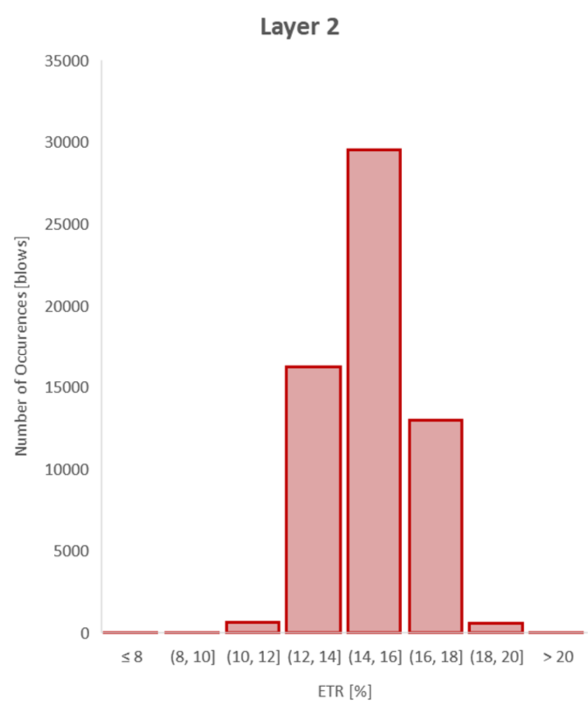


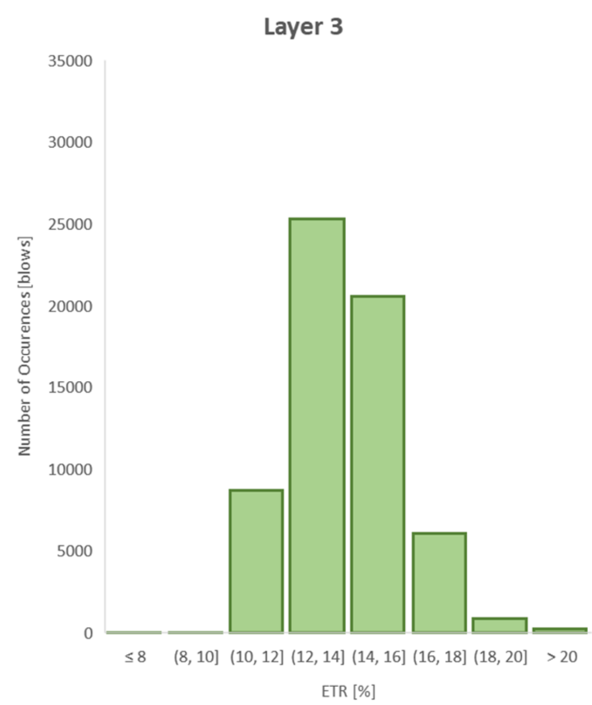
PHASE 2B BY LAYER: TENSION AT SPLICE



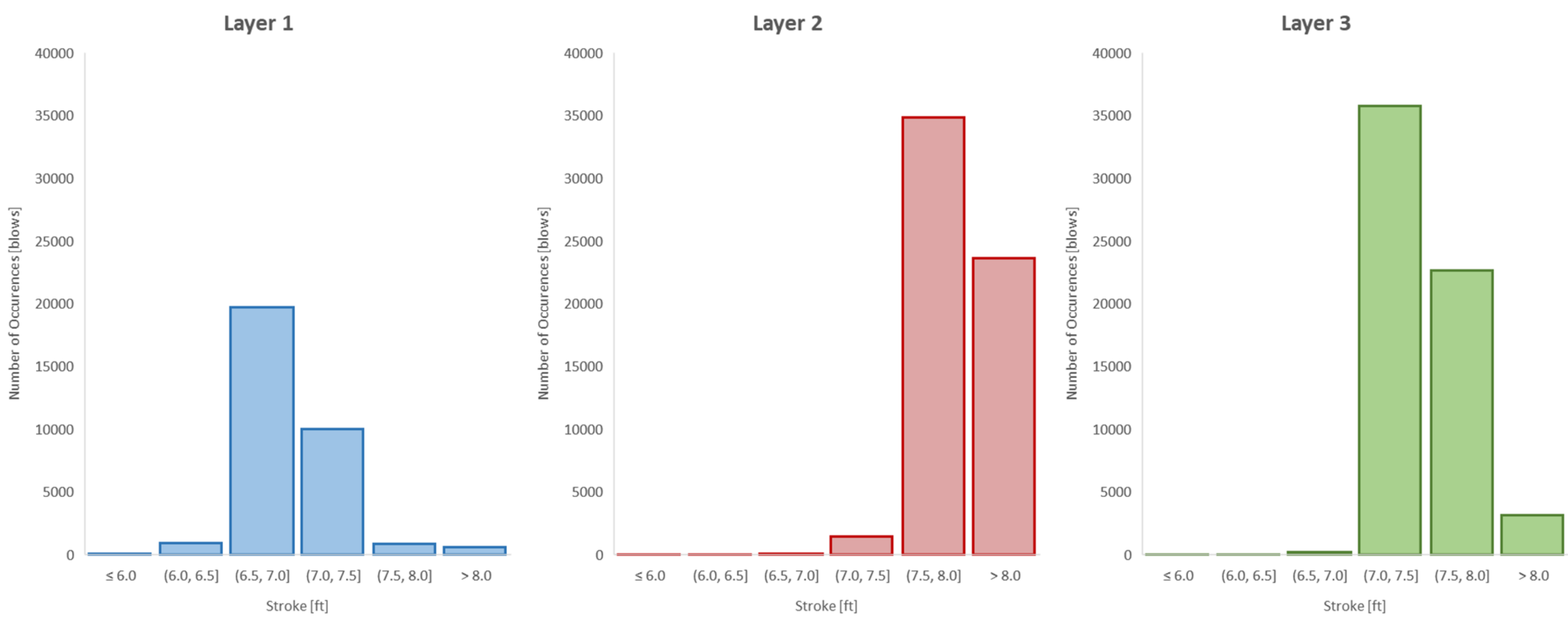
PHASE 2B BY LAYER: ENERGY TRANSFER RATIO







PHASE 2B BY LAYER: HAMMER STROKE



DATA OBSERVATIONS

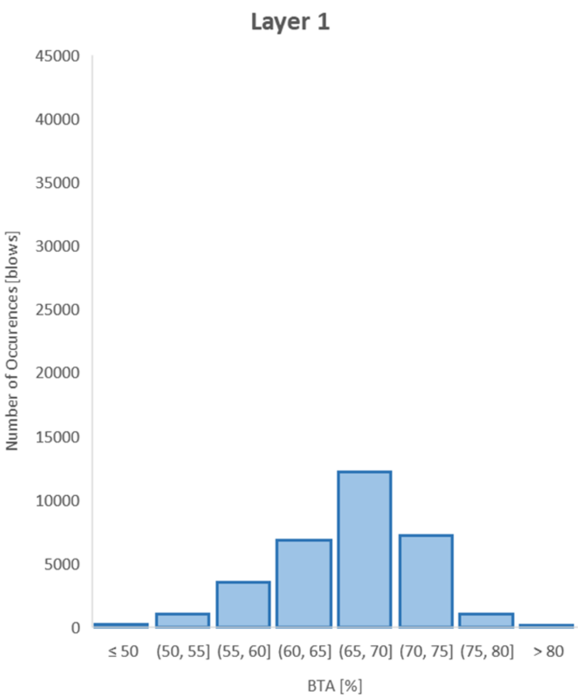
Stresses:

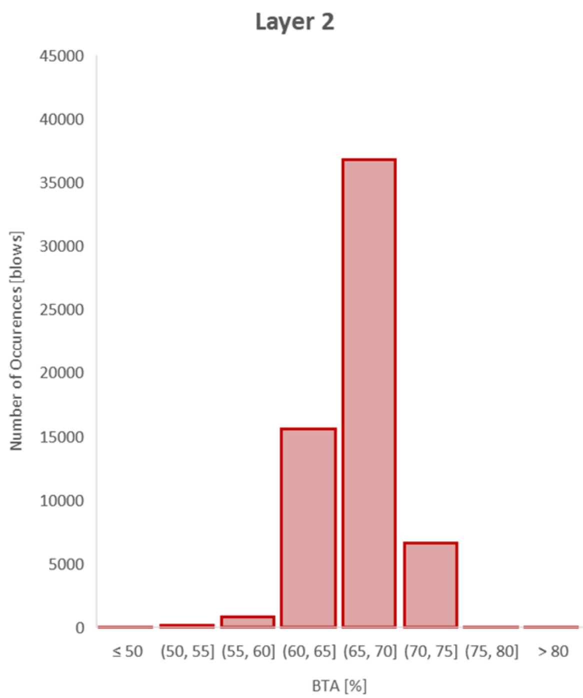
- Compressive stresses consistently OK
- Tension high in softer soils, as expected
- Tension approaches limit after penetrating into Layer 3, PDA is critical to inform fuel settings & cushion changes

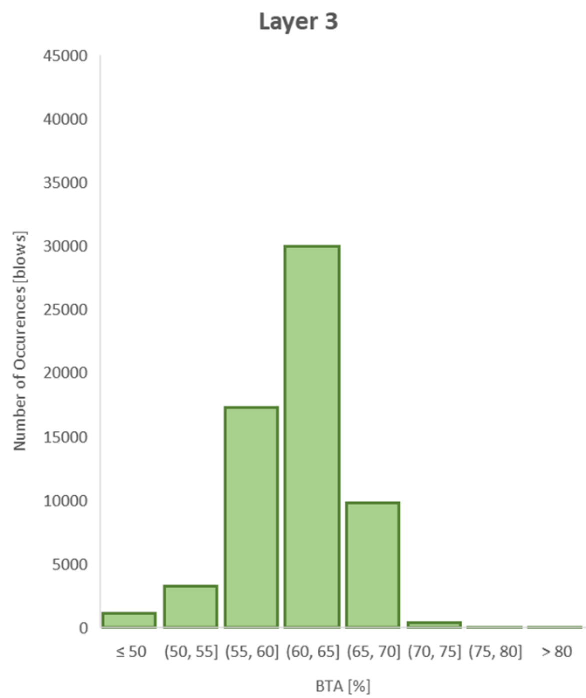
Hammer:

- Stroke & ETR are quite low, even in hard driving
- Hammer issues have been discussed with the Contractor
- Could eventually impact restrike testing but results so far are good

PHASE 2B BY LAYER: BTA/PILE INTEGRITY







BTA: OBSERVATIONS

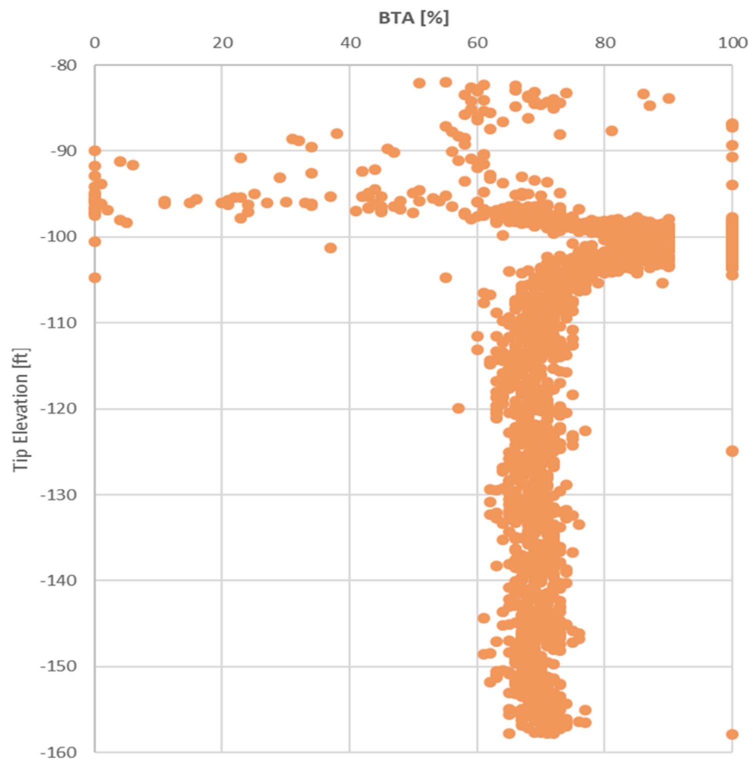
BTA:

- Lower than average* on Phase 1A
- These are larger piles
- This is a different type of splice

Can't look at BTA in a vacuum:

- Need to understand the splice's "signature"
- Is splice deteriorating throughout drive?
  - No
- Tension seems to impact BTA in this example:
  - Inconsistent in easy driving (high set per blow)
  - Increases (better) in sand layer
  - Decreases after penetrating sand, but approaches a consistent value for remainder of drive

BTA vs. Pile Tip Elevation Example Record



CONCLUSIONS

LADOTD has achieved good performance with tension stresses > 500 psi

- Monitor Piles: large sample size (400+ piles on Phase 1A, ~100 on Phase 2)
- Sites: small sample size

Still need to do analysis on Phase 1A data to quantify comparison

Continue analyzing 200+ remaining bents on Phase 2B

Other groupings would be valuable:

- Layers based on driving resistance instead of tip elevation
- Fuel settings
- Cushion thicknesses
- Other PDA operator notes such as gage problems, stoppages, etc.