



advanced awareness technology that enables our clients to optimize the design, construction and operation of the nation's infrastructure.

Agenda

Introduction (Speakers)

- Sastry Putcha, FDOT (Retired)
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- Kurt Hecht, Chief Engineer, Smart Structures
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- Richard Hecht, Vice President, Smart Structures
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EDC Background

System Components (Hardware and Software)

EDC Benefits

Roadmap (new Applications)

Cost and EDC Smart Start

Q&A

Introduction

- EDC technology was designed as a dynamic test system with results comparable to the accuracy of static load test, with repeatability, at a lower cost.
- Provide the industry with tools and methods to perform 100% testing while accelerating construction productivity.
- Enable designers and engineers to utilize higher resistance factors to reduce cost while enhancing confidence and quality assurance.
- Enable economies of volume to enable large deployments of low cost wireless sensors in the transportation infrastructure.

EDC Background

- Based on FDOT / University of Florida Research
- Commercialization focused on creating a system with simple, repeatable, and standardized
 - installation
 - data collection
 - reporting
- Established DOT Processes/Specifications
- Organize / Share data through the Internet
- Create the foundation of a wireless sensor system that can be deployed in all concrete structures

3rd Generation Product

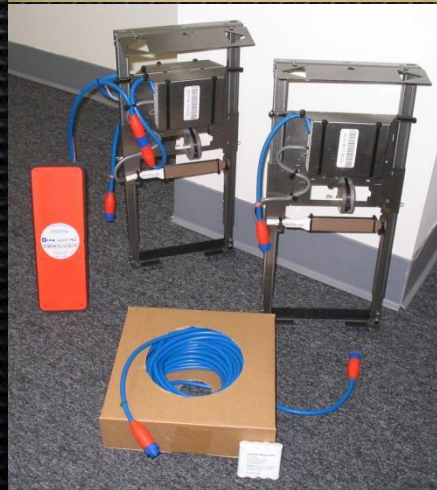
Smaller, Lower Cost, More Integrated, Improved Moisture Resistance, Easier to Install ...

SP-400



First Generation

SP-401



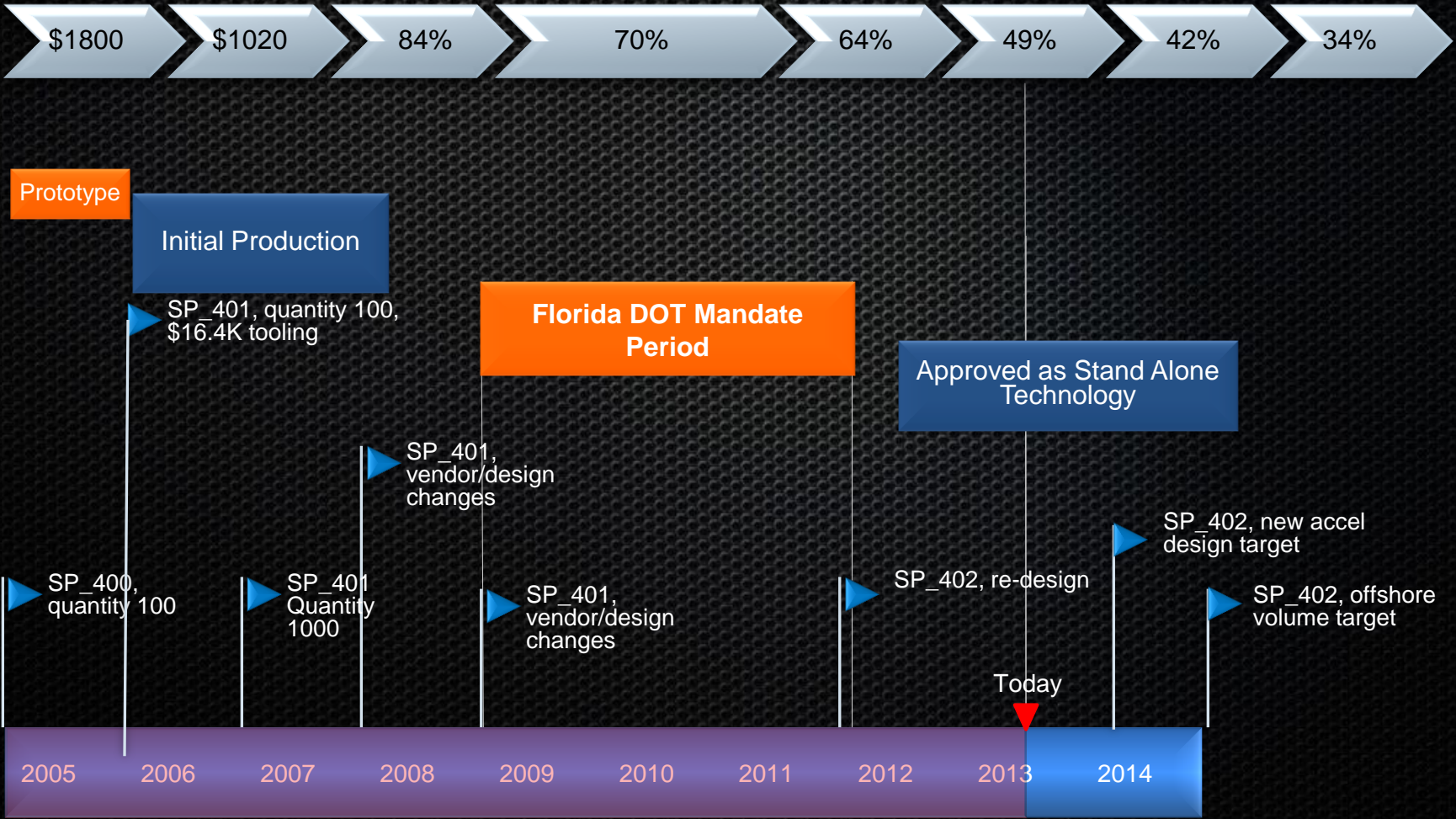
Smaller, lower profile DataPort for less intrusion into pile core, better sealing connectors, faster and more sensitive electronics, hardware diagnostics, StateStamp Batteries (against corrosion)

SP-402



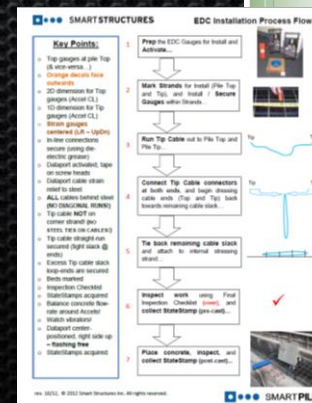
Combined radio and sensor electronics resulting in fewer connectors, higher reliability and simplified installation, Smaller DataPort with further sealing improvement (against corrosion, moisture), Improved hardware diagnostics, calibration at sensor level to support Field Swaps, More sensor configurations (ie. Dual Strain, Corrosion, etc.)

Lower the cost of Testing (Hardware)



A Complete Ecosystem

- Volume Manufacturing
- Casting Yard / Installation Partners
 - Training and Tools
- Testing Partners
 - Training and Tools
 - Certifications
- Performance Driving Specifications



System Components

- Embedded Electronics: Embedded Data Collector
- Acquisition Hardware: COTS, Rugged, Wireless-enabled Laptop
- Acquisition Software: SmartPile® Acquisition
- Processing/ Reporting Software: SmartPile® Review, Match, and Simulate
- Internet Portal: Data, Configuration

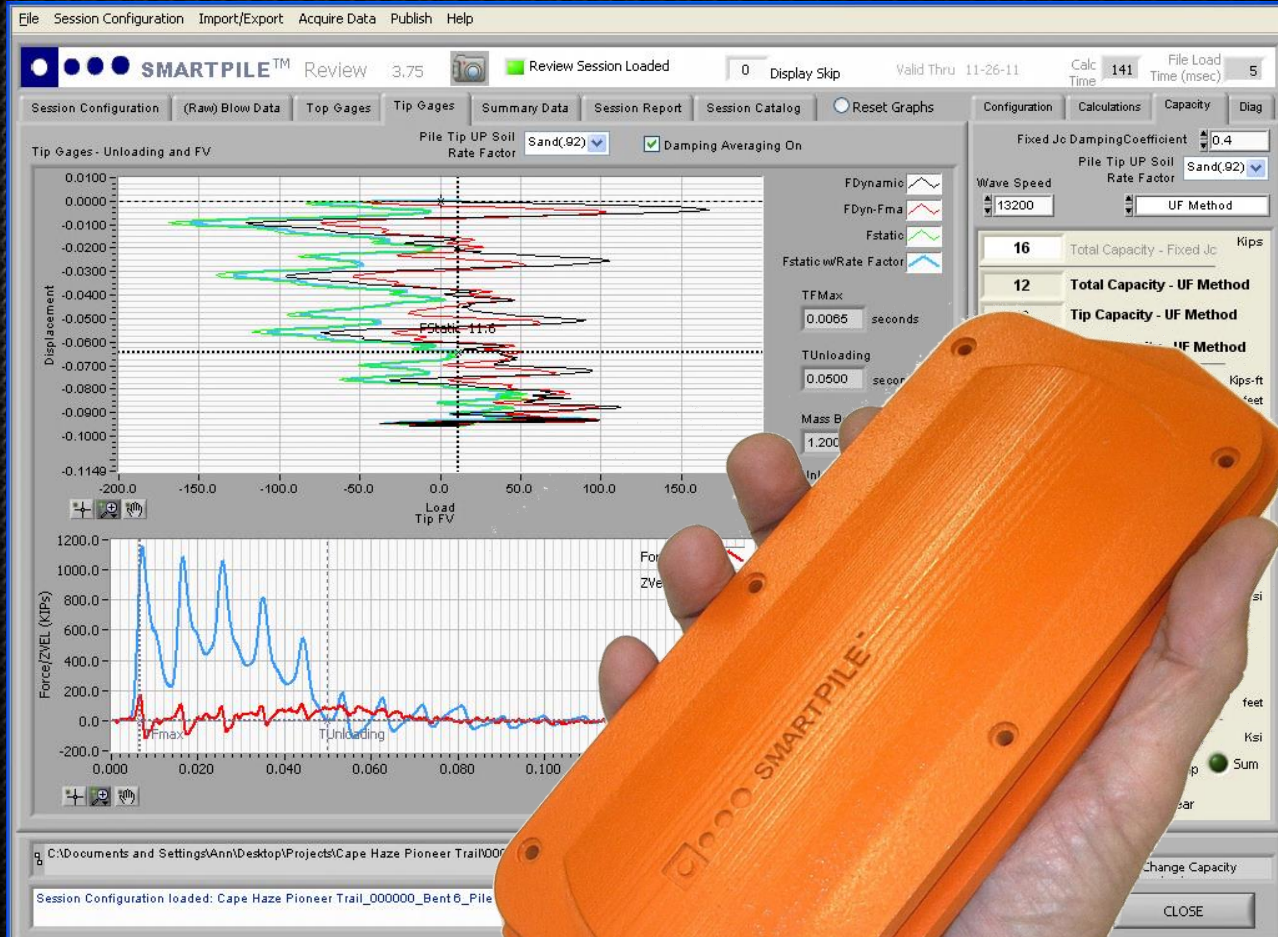
Embedded Data Collector

100% wireless

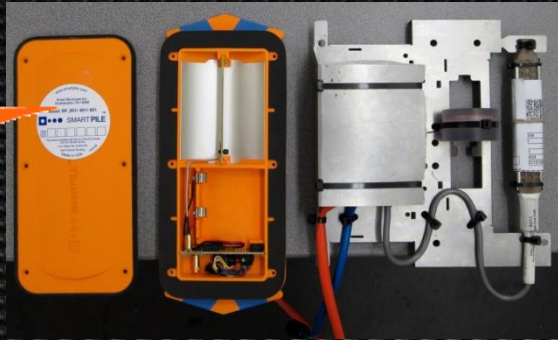
Embedded within concrete

Tip & Top sensing

Internet Information System



Embedded Sensor System



Datalogger & wireless transceiver

*Replaceable Battery Pack
Temperature sensor
Network port*



Strain/Accel Sensor

Strain/Accel Sensor

Strain/Accel Sensor

Temperature Sensor

Typical EDC Use Model



- Wireless communication and data transmission from the pile
- Ruggedized Workstation to collect sensor data in *Real Time*
- Software to Analyze, Present, and Report (at the completion of driving)
- Internet information system to organize and share data



Engineered Installation Process



Real-Time Analysis

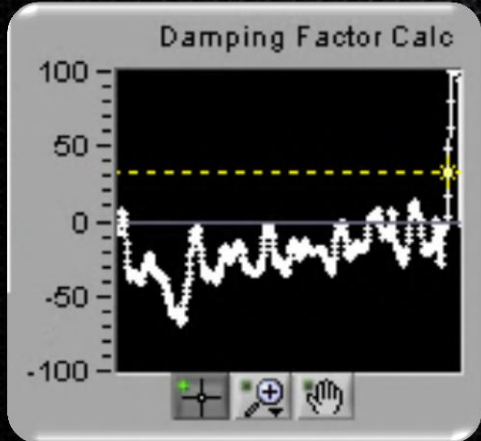
Configuration Calculations Capacity Diag

Fixed Jc Damping Coefficient 0.4

Pile Tip UP Soil Rate Factor Sand(92)

Wave Speed 13200 UF Method

16	Total Capacity - Fixed Jc	Kips
12	Total Capacity - UF Method	
12	Tip Capacity - UF Method	
0	Skin Capacity - UF Method	
9.1	Energy	Kips-ft
6.12	Stroke	-45.00 DBRef
47	BPM	2 Blow Count



File Session Configuration Import/Export Acquire Data Publish Help

SMARTPILE™ Review 3.75 Review Session Loaded 0 Display Skip Valid Thru 11-26-11 Calc Time 141 File Load Time (msec) 5

Session Configuration (Raw) Blow Data Top Gages Tip Gages Summary Data Session Report Session Catalog Reset Graphs Configuration Calculations Capacity Diag

Tip Gages - Unloading and FV Pile Tip UP Soil Rate Factor Sand(92) Damping Averaging On

Displacement

Load Tip FV

Force(Z)VEL (KIPS) Force Tip ZVel Tip

TFMax 0.0065 seconds

TUnloading 0.0500 seconds

Mass Below Gages 1.2000 Slugs

Unloading Displacement 0.0926 feet

Median Damping Factor 23.9470

Damping Factor Calc

C:\Documents and Settings\Ann\Desktop\Projects\Cape Haze Pioneer Trail\00000001\Bent 6\Pile 1\00-A0-96-29-A3-1A_blow-00142.blf

Session Configuration loaded: Cape Haze Pioneer Trail_000000_Bent 6_Pile1.sen

Blow Number Load 142 of 529

Page Up Next Blow Page On Prev Blow Mode Change Capacity CLOSE

Configuration Calculations Capacity Diag

Fixed Jc Damping Coefficient 0.4

Wave Speed 13200 UF Method

16	Total Capacity - Fixed Jc	Kips
12	Total Capacity - UF Method	
12	Tip Capacity - UF Method	
0	Skin Capacity - UF Method	
9.1	Energy	Kips-ft
6.12	Stroke	-45.00 DBRef
47	BPM	2 Blow Count

Avg Capacity

56	DBRef+1	Kips
67	DBRef+2	
12546	Calculated Wave Speed	Ksi
1.25	Max Top Compressive Stress	
0.29	Max Tip Compressive Stress	
0.96	Max Tension Stress	
35.48	Length to Max Tension	feet
0.02	Residual Stresses Top	Ksi
-0.01	Residual Stresses Tip	Sum
98.00	MPI (%)	Clear

Internet Information System

Data Portal | **Data Administration**

- Remote Devices
- Project Administration
- Structure Administration
- Create/Delete Things
- Transfer Log

Device Name: aaRL_Laptop_Testing

Remote Devices | **Dov**

- Device Overview
- Device File Transfer
- Repository Management

User Administration

- User Group Management
- User Management
- Roles Management

CR 305 Over Bull Creek

- 734081
 - End Bent1
 - End Bent2
 - Pile1

SMARTSTRUCTURES

TChiarella | Show | Change Password | Log Out

Data Portal | Data Administration | License Management | User Administration | Remote Devices | Downloads | Support Blog

None of 4 Active Filter(s) | Add Filter

Project View

- 32nd Street Test
- 40 Testing Updates
- 42nd St Flyover
- 5th St Bascule Bridge
- 826836 Interchange
- ___No Project Defined___
- Aqui Esta Drive bridge over Venice canal
- BayouLacassine
- Bayshore Test1
- Beachline Expressway Widening
- Big John Monahan
- Bridge over C111 Canal
- Cape Haze Pioneer Trail
- Collins Rd at I295
- Collins Road Over I295
- CR 125
- CR 13 over Sixteen Mile Creek
- CR 305 Over Bull Creek**
 - 734081
 - End Bent1
 - End Bent2
 - Pile1
- CR720 Over Bee Branch
- CR 901 over Cocohatchee River
- Delware Port Authority
- Dixie Highway
- Dixie Highway Overpass
- Dominion BlvdRte17

Refresh

Map | Project Collaboration | Project Details

Map | Satellite

File(s) | Upload File(s)

Link	Related To	Name	Size
...	734081 End Bent1 Pile5	CR 305 Over Bull Creek_734081_End Be	
...	734081 End Bent2 Pile1	CR 305 Over Bull Creek_734081_End Be	

Download File

Sensor Information System

SMARTSTRUCTURES

Change Password RichH Show

Data Portal Data Administration License Management User Administration Remote Devices Downloads

None of 4 Active Filter(s) Add Filter

Project View

- Bridge 870311
 - Bridge A
 - Cast1
 - 140 Overpass
 - 170110

Map Satellite

Download File(s) Upload File(s)

Related To	Name	Link	Size	Last Modified
Cast1 Pile0	00.A0.96.29.A2.7E_09-12-2012_1043.tsp	...	39240.00	2012-09-12 10:44:00
Cast1 Pile1	00.A0.96.27.84.B3_09-12-2012_1045.tsp	...	37221.00	2012-09-12 10:45:33
Cast1 Pile3	00.A0.96.29.A2.7E_09-12-2012_1046.tsp	...	39240.00	2012-09-12 10:46:45
Cast1 Pile4	00.A0.96.27.84.B3_09-12-2012_1050.tsp	...	37221.00	2012-09-12 10:50:07

Refresh

Download File

SMARTSTRUCTURES

Session Configuration: Import/Export Analyze Data Publish Help

Session Configuration: (Sheet) Session Loaded

Pre-Load Data Tip: 3.9 Avg. Energy in Pile: 144.2
Pre-Load Data Tip: 3.5 Avg. Energy in Pile: 144.2

201 Total Capacity: Fixed In: Firm
209 Total Capacity: LP Method
209 Total Capacity: LP Method
38 Total Capacity: LP Method
18.5 Energy Current
8.77 Strain
45 BPA
2 Blade Count

16 Total Capacity: Fixed In: Firm
12 Total Capacity: LP Method
12 Total Capacity: LP Method
0.1 Energy Current
6.12 Strain
17 BPA
2 Blade Count

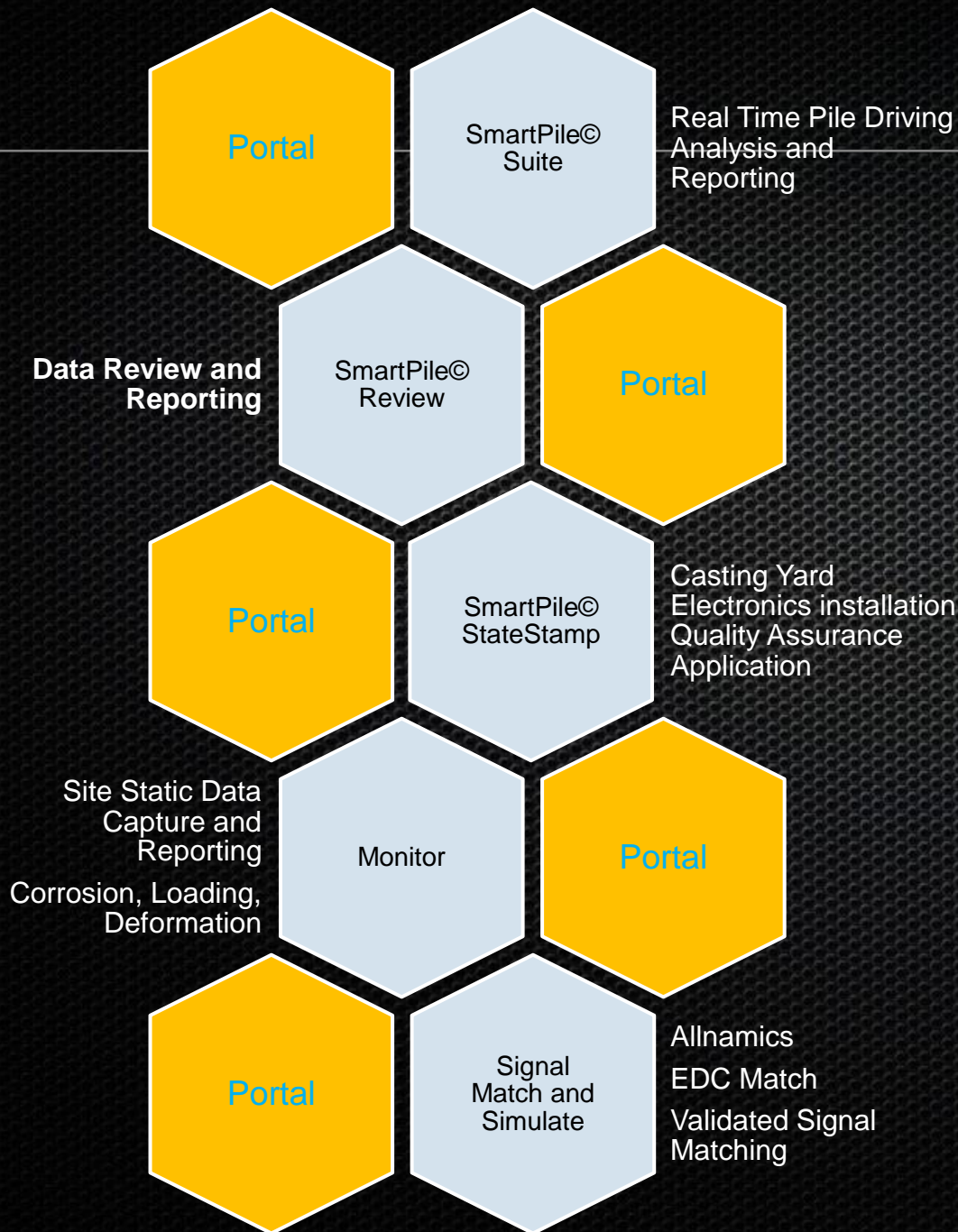
16 DBM#1-1 High
67 DBM#2-1 High
12546 Non-Resistance Achieved
Calculated Wave Speed

1.25 Max Tip Compressive Stress
6.29 Max Tip Compressive Stress
6.96 Max Tension Stress
35.48 Length to Max Tension
8.02 Residual Stress Tip
0.81 Residual Stress Top
99.00 BPI (%)

201 DBM#1-2 High
13180 Non-Resistance Achieved
Calculated Wave Speed
1.50 Max Tip Compressive Stress
0.52 Max Tension Stress
42.15 Length to Max Tension
6.05 Residual Stress Tip
3.03 Residual Stress Top
130.00 BPI (%)

- o Internet-based, SaaS model
- o Highly advanced analytics
- o Simple dashboards for various types of users
- o Mobile accessible
- o Pile Driving Analysis
- o Soil Simulation
- o Signal Matching
- o Materials asset management
- o Jobsite/facility monitoring
- o MRO & Condition-based maintenance
- o Disaster risk management
- o Inspection & rating

Application-Specific Software



*Host (Laptop, Desktop, Headless)
Software tightly linked to portal for data and asset management ...*

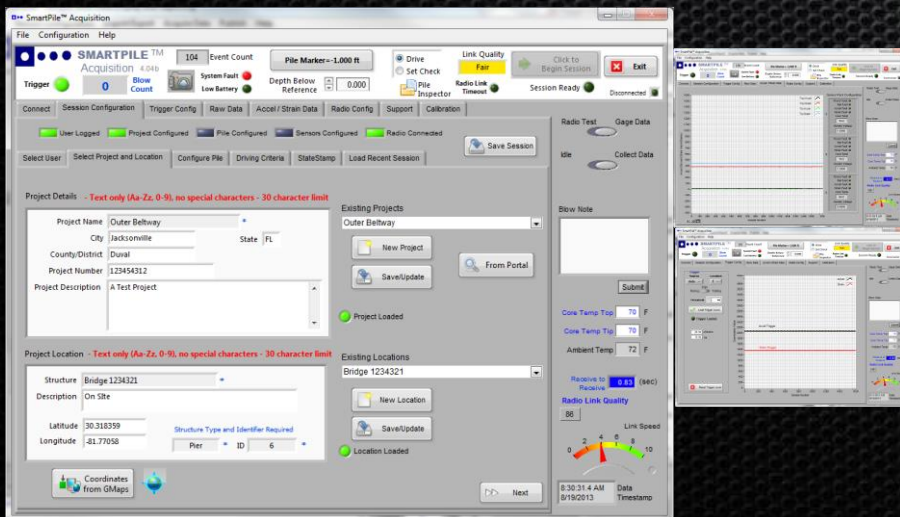
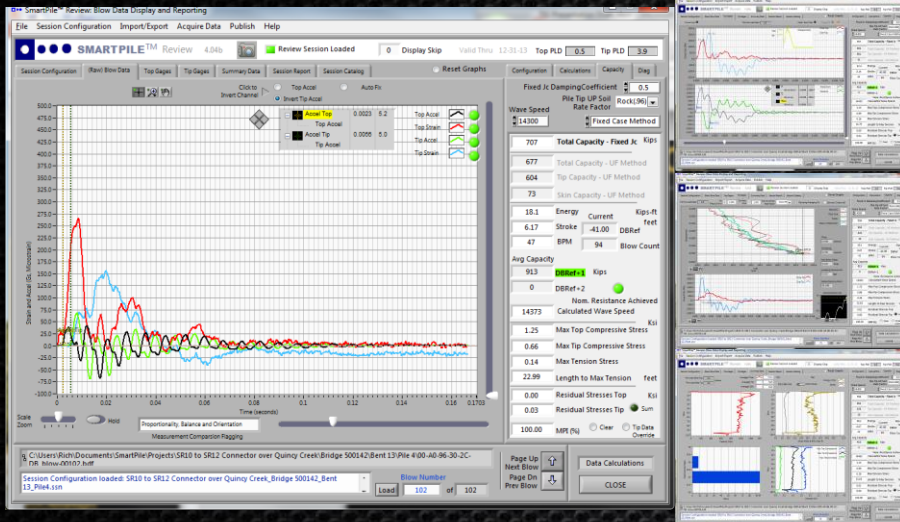
For Driven Concrete Pile ...

SmartPile® Review

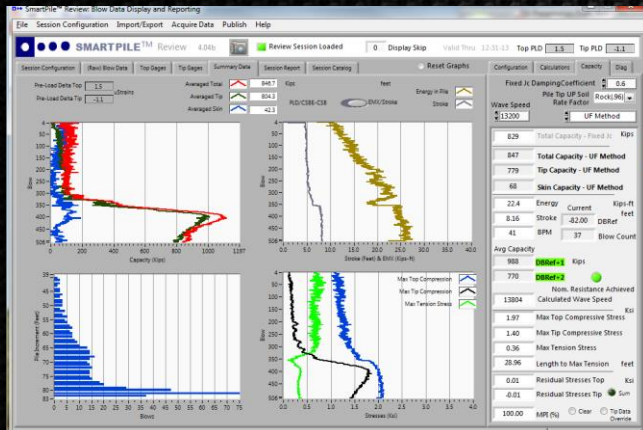
- Strain and Accel (Top and Tip) →
- Force, Velocity, Displacement
- Dynamic Damping, Tip Unloading
- Max Case Capacity, UF Capacity
- Results reporting in real time:
Excel (CSV) and PDF

SmartPile® Acquisition

- EDC Connectivity and Setup
- Drive configuration (User, Project, Location, Pile Properties)
- Radio Diagnostics
- Calibration Data loaded from Radio

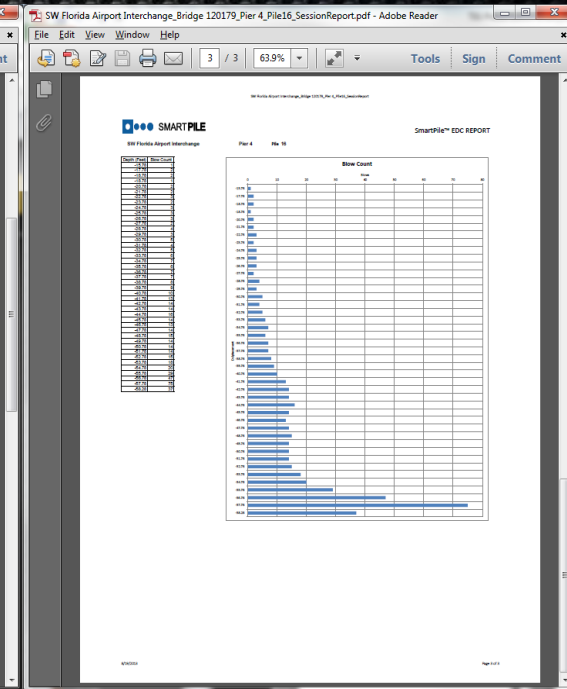
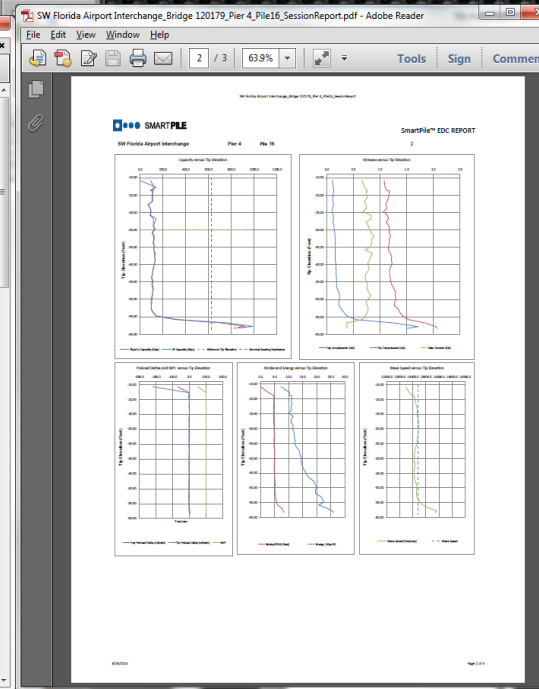
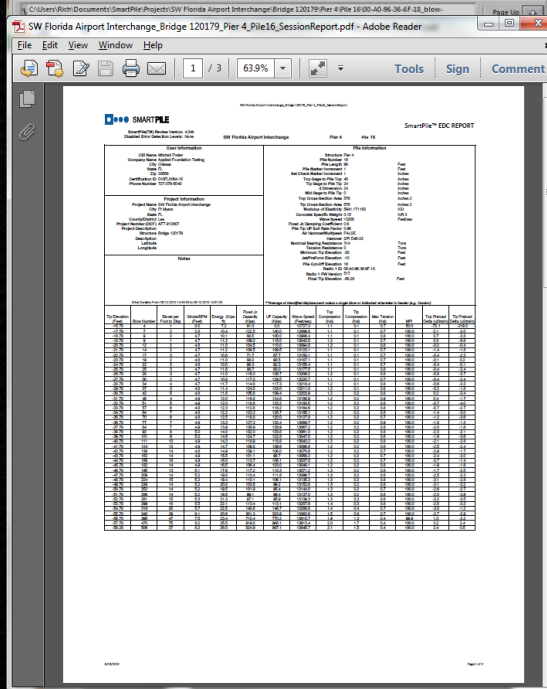


Focus of Simplicity



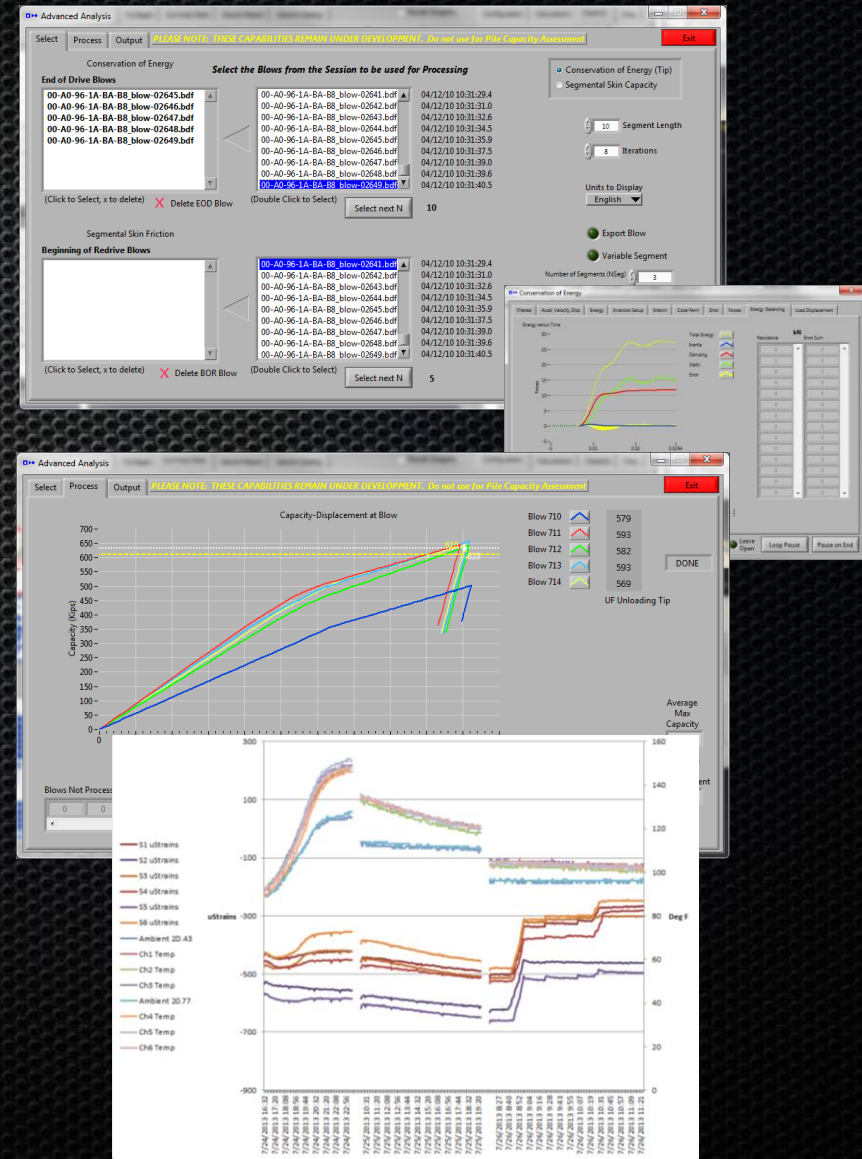
Collect the Data and generate the Final Report on-site

- Tabular Results
 - Capacity, Integrity, Energy Stroke
 - Blow Distribution
- Other comprehensive reports also available

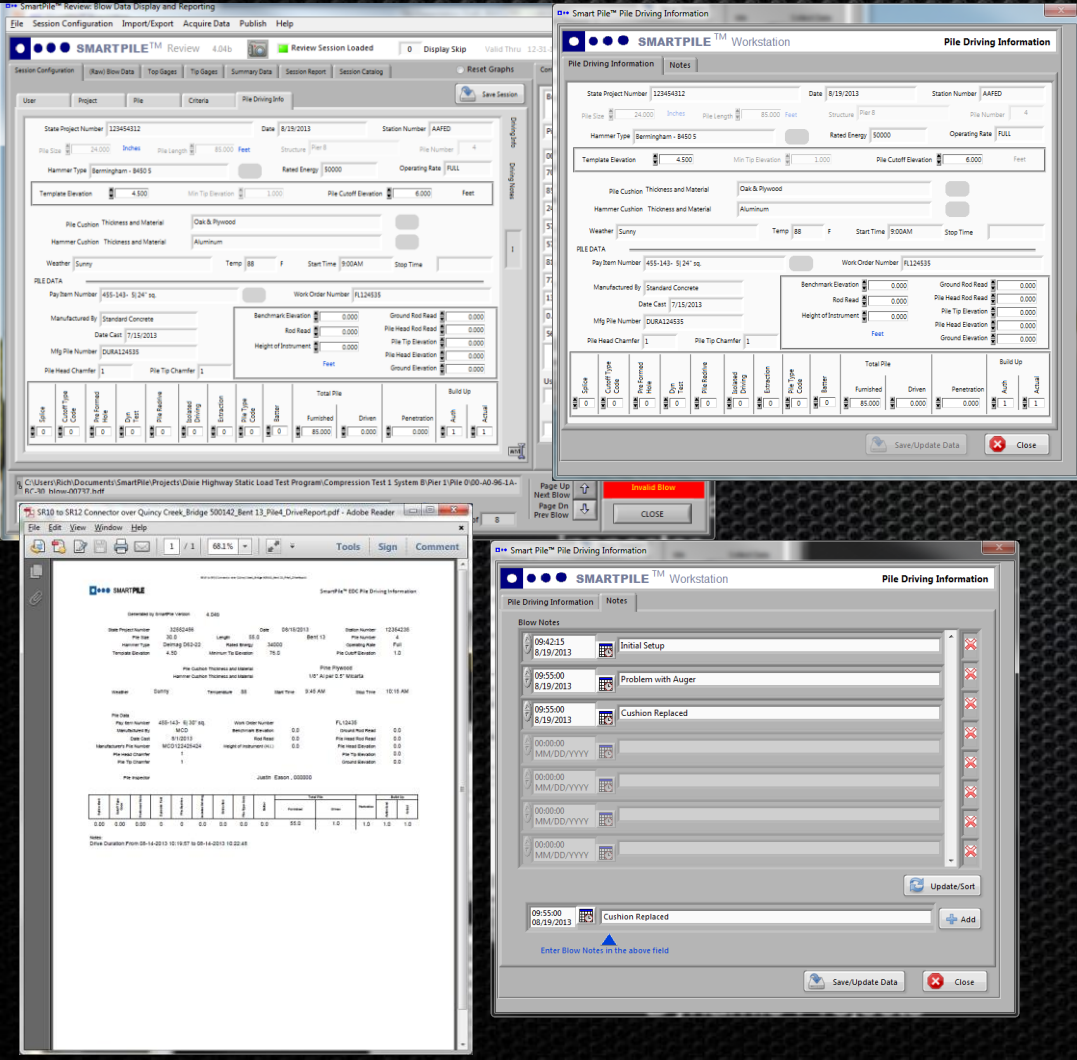


Futures

- Using Tip Data:
 - Conservation of Energy
 - Segmental Skin Friction
- Casting Yard Monitoring
 - Temperature Curing Profile
 - True Pre-stress
 - Wave Speed → Modulus
- Long Term Monitoring
 - Static Monitoring using installed gages



Futures: Pile Inspection



- Combine SmartPile Data Collection and Reporting with Pile Inspector reports
- Eliminate the cost of having and EDC Operator and Pile Inspector on Full Dynamic Projects
- Has not yet been approved by FDOT

EDC Benefits

- The Method
- Embedded Wireless Sensors
- Tip Data / Validated Signal Matching
- Advanced Integrity Assessment
- Real Time Capacity
- Simple Software / Deterministic Results
- Direct Measurements - Accuracy
- Configurability / Application Flexibility

The Method

- Perform pile capacity analysis on every hammer blow in real-time
- Damping value computed from top and tip sensor data
- Minimum operator influence on results due to direct measurements (Consistent results)
- Art versus Science

Embedded, Wireless Sensors

- Fast Setup
- Embedded Calibration
- Safety, no climbing leads
- Embedded sensors can be used for long term asset monitoring
- Embedded sensors detect conditions/changes not possible with externally mounted sensors



Top / Tip Instrumentation Benefits

- Measured Pile Integrity (MPI)
 - Change in static pre-stress tracking aids in advanced detection of pile damage
 - Ability to assess proper load transfer at pile toe in cases of damage detection
 - Numerous pile extractions have confirmed results
 - Two published papers by authors internationally well known in wave mechanics
- Measured wave speed
 - No pile end location assumptions
 - Ability to confirm wave speed used for key calculations at the end of drive – **Known sensitivity on total capacity results**
 - Able to detect the onset and monitor material fatigue during driving

Extraction Example #1

Pre-Load Delta (microstrain)



Extraction Example #2

Pre-Load Delta (microstrain)



— Preload Delta Top Strain (μStrain) — Preload Delta Tip Strain (μStrain)

Extraction Example #3

Pre-Load Delta (microstrain)



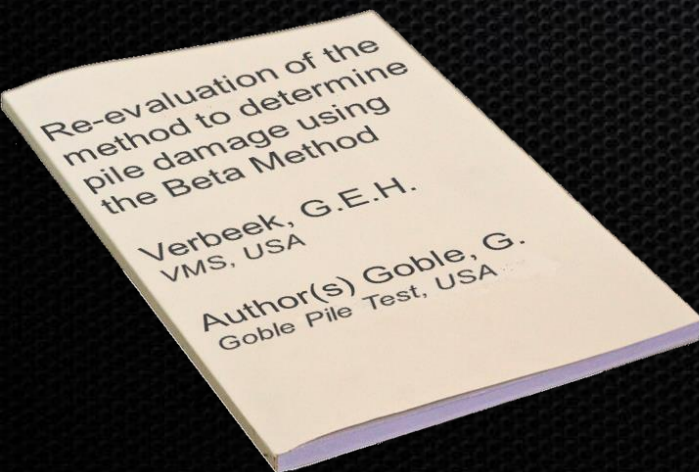
28

Leading Engineers Support EDC Findings

ABSTRACT: In 1979, a paper was published by Rausche and Goble describing a method to determine damage in driven piles using the Beta Method. Over the years this method has become the standard for pile damage assessment in many parts of the world....

Recently developed technologies have begun to shed a different light on the reliability of this method, suggesting that a thorough assessment of the method derivation would be appropriate.

Taken together the results of this re-evaluation clearly demonstrate that this widely applied method cannot be considered a reliable indicator and should therefore be used with extreme care.



“The theoretical review of the method showed clearly that the Beta Method cannot be a reliable indicator of pile toe damage... ..the Beta method should not be used to protect against pile toe damage.”

Verbeek, G.E.H. / Goble, G.

Benefits of Early Detection

Collision Avoidance

– vs. –

Costly Recovery/Replacement

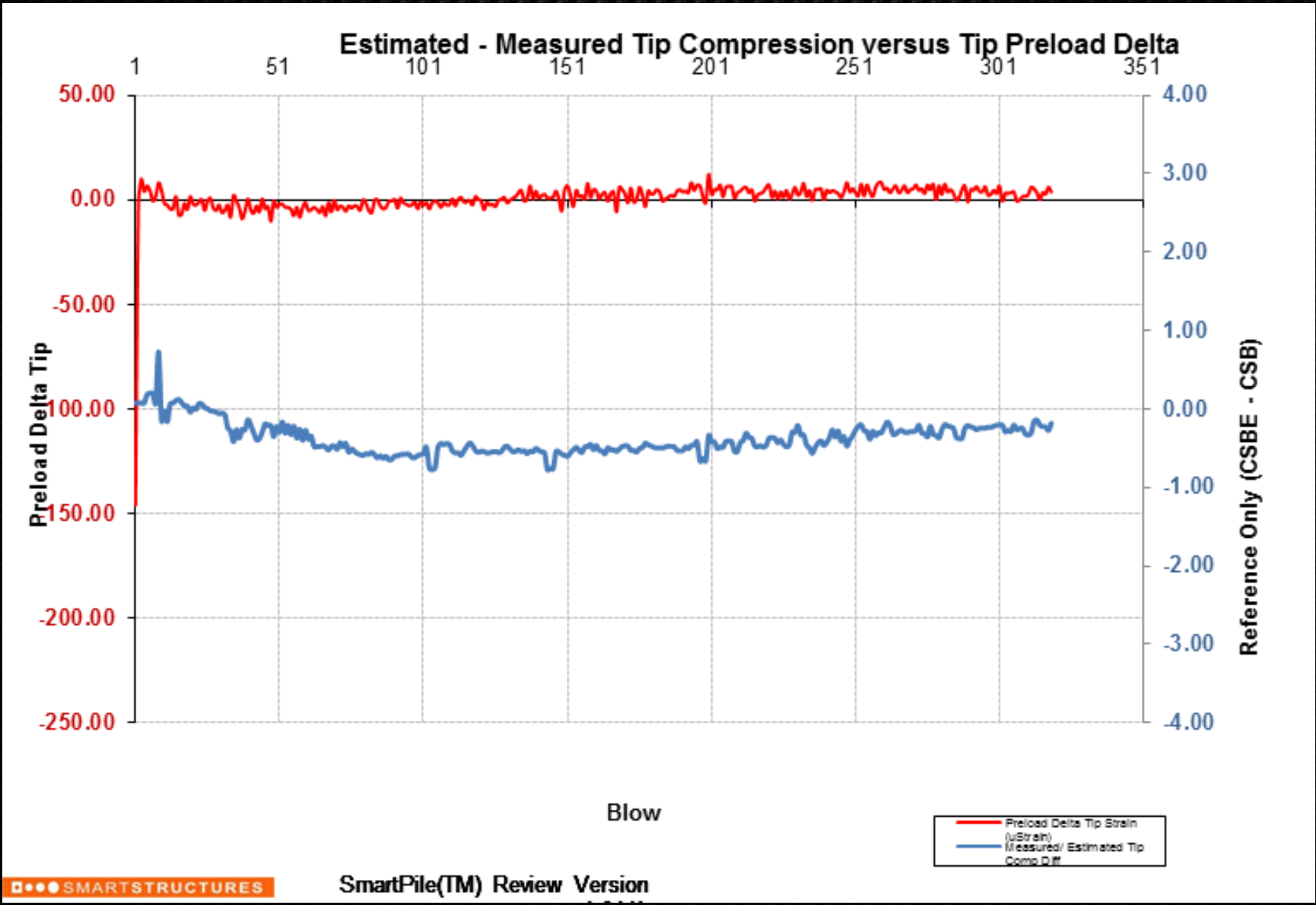


It's not about damage being detected, but **real damage going undetected!**

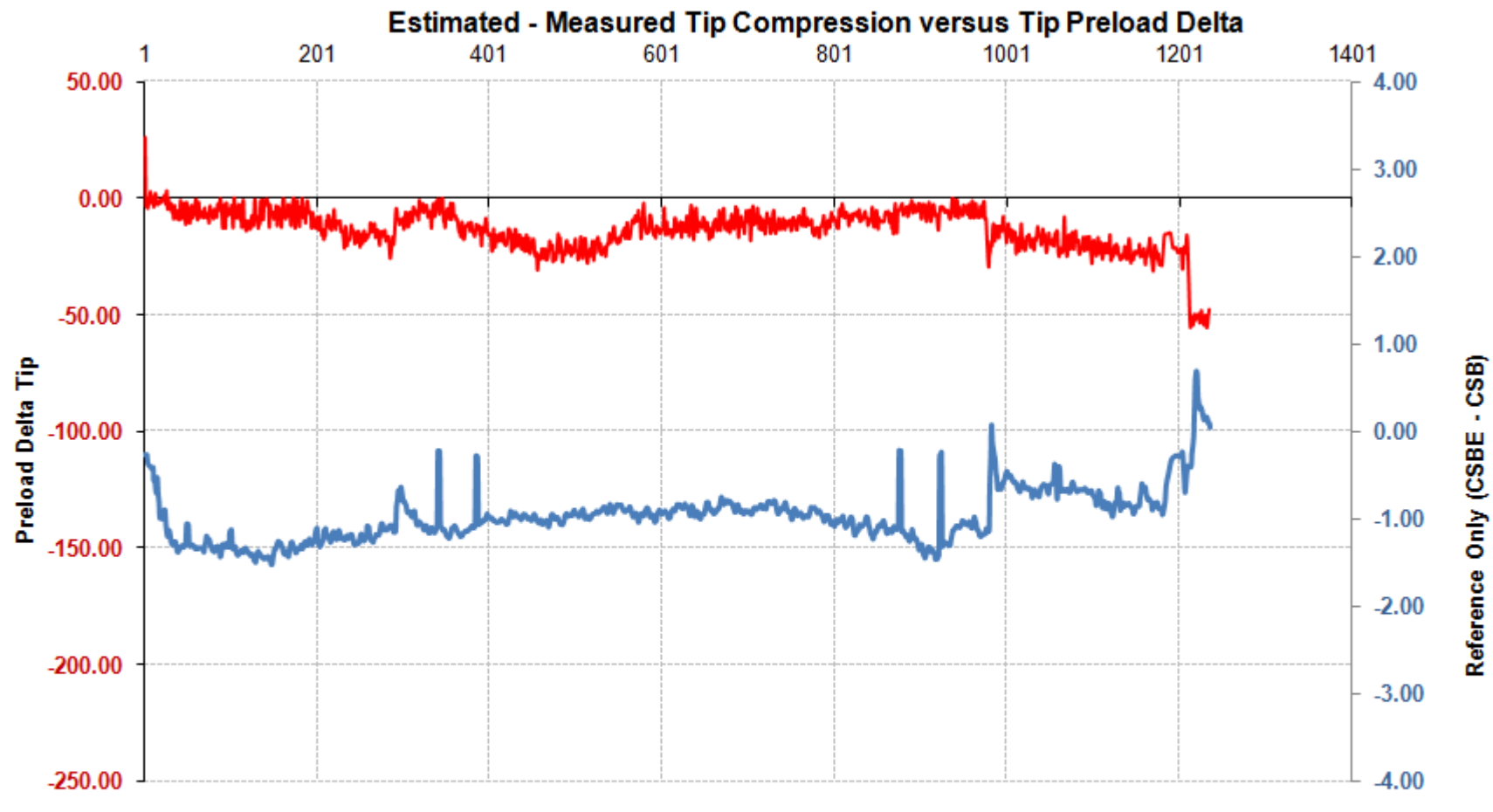
Limitations of damage detection measured at pile top only well documented

Ability to assess proper load transfer at pile toe in cases of damage detection – confirm vs. assume performance

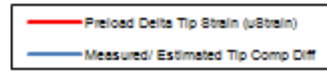
No Loss of Pre-stress example



Loss of Pre-stress example



Blow



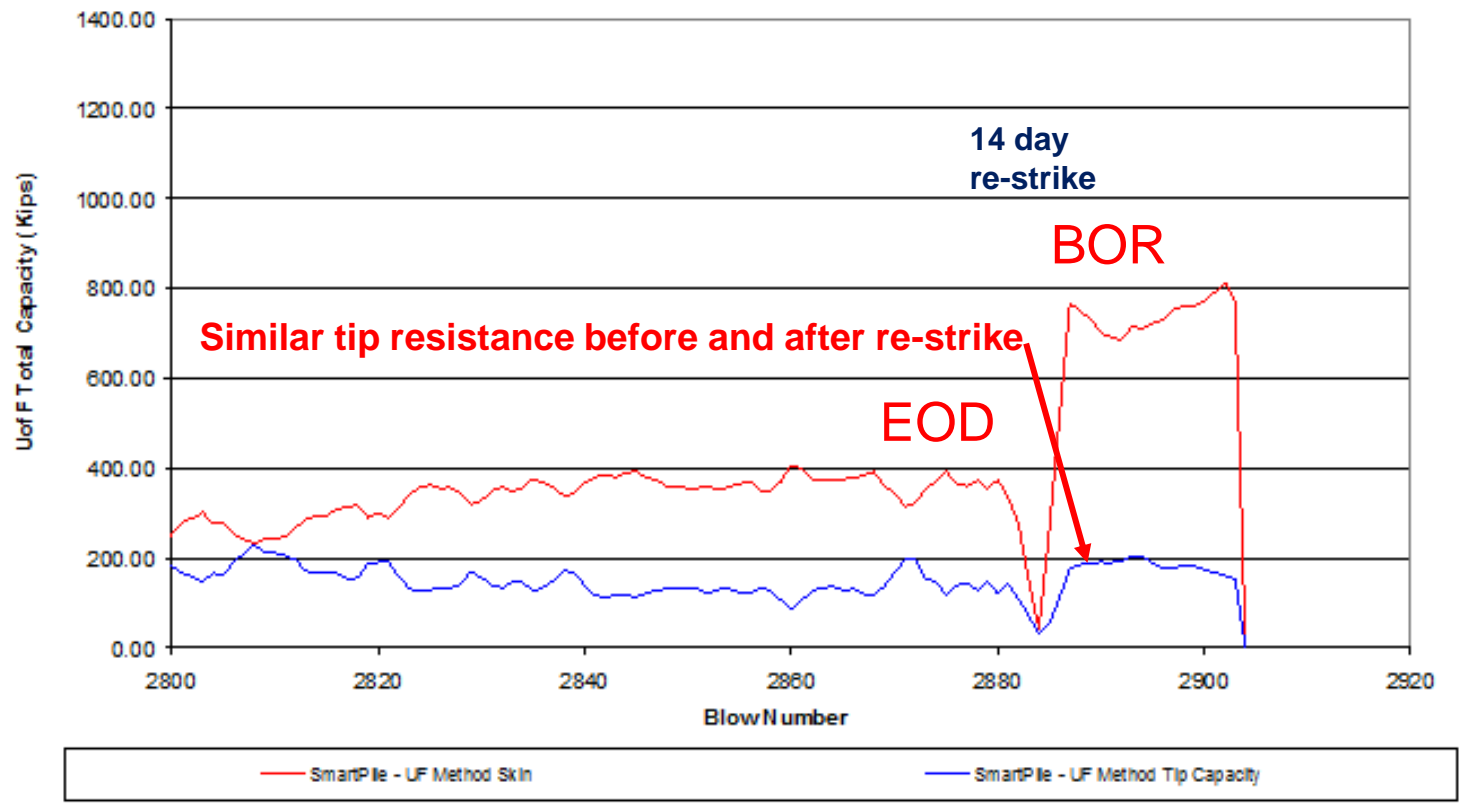
Tip Instrumentation Benefits

- Understanding driving resistance contribution by direct measurement (%tip vs. %skin)
- Measured static tip resistance and end of initial drive (EOID)
- Soil Freeze - understanding true skin contribution (only) during restrrike
 - confirming un-mobilized pile tip (total capacity = skin capacity with un-mobilized pile tip)
- Improves quality by preventing potentially damaging and unnecessary overdriving of piles

Comprehending Composite Capacity (EOD/BOR)

SR 46 over Lake Jesup Lake Jesup, Bent 36 Pile 1

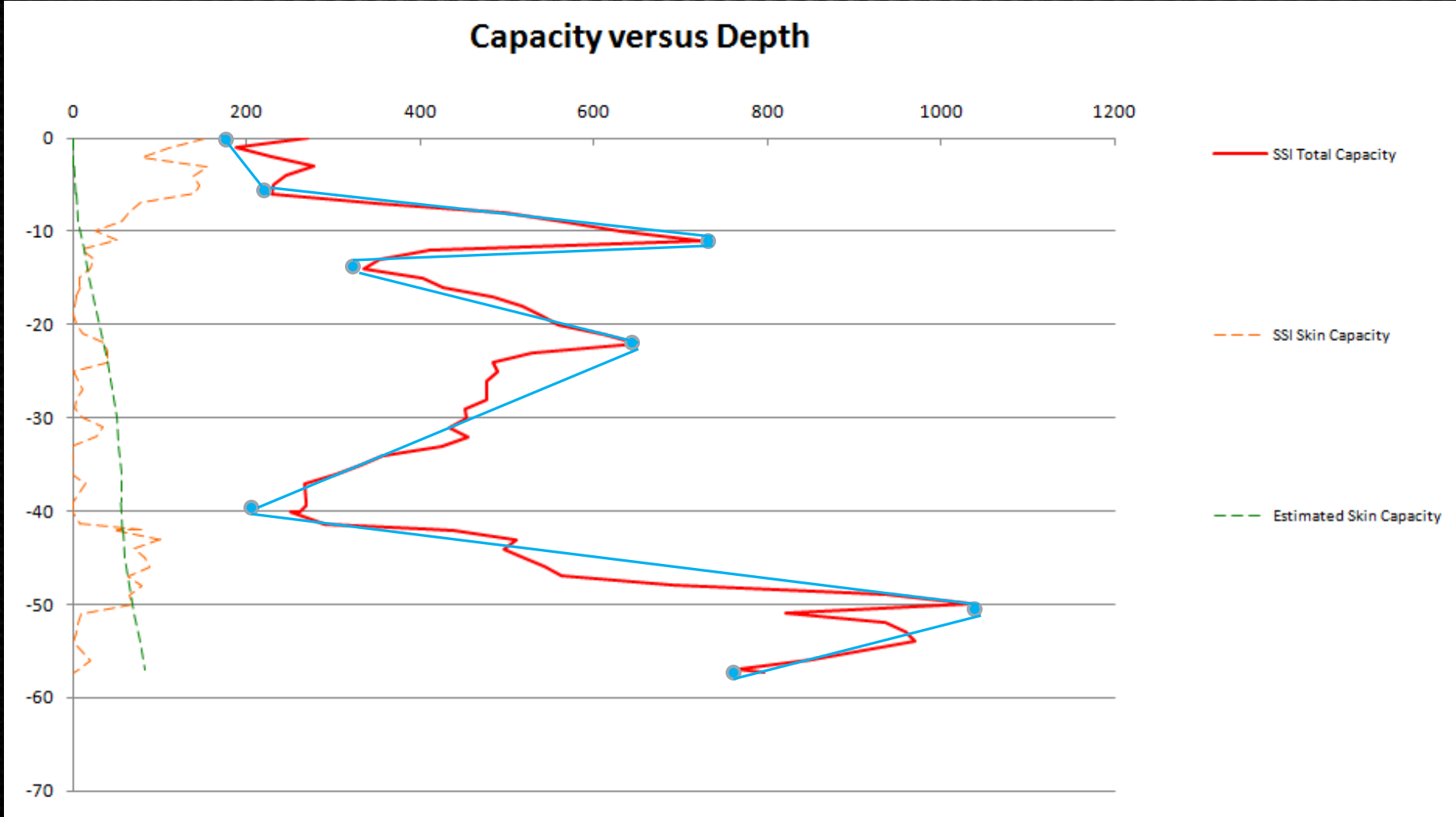
UF Capacity Method



Tip Data Signal Matching

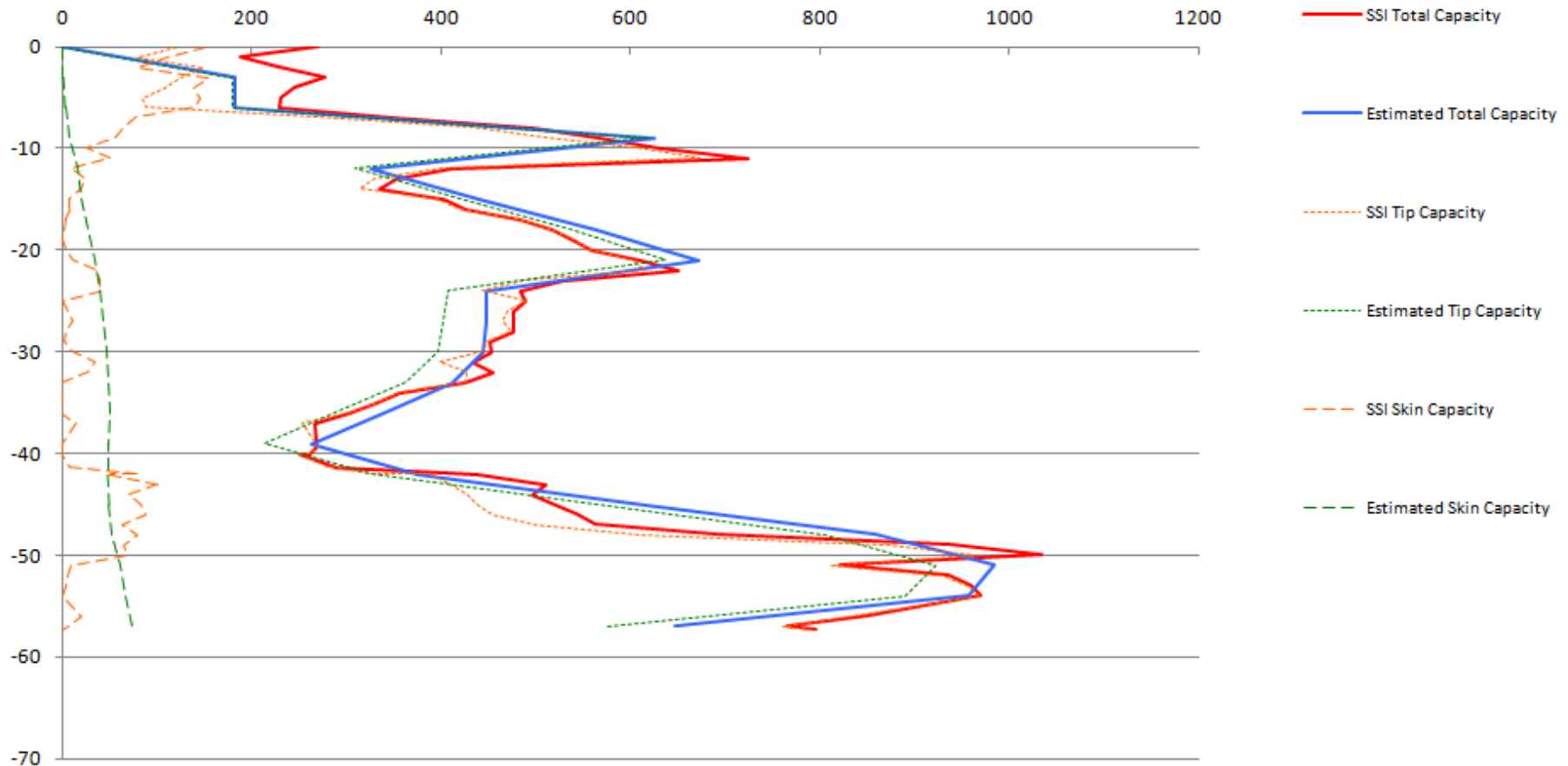
- Signal match performed at pile top, and results validated using pile tip data
 - Validated solution for given pile top and pile tip boundaries
 - Soil model provides initial conditions
 - Results used to better understand and characterize soil properties and behavior
- Eliminates estimates, assumptions, and subjective interpretation

Simulate - Establish Target Soil Profile

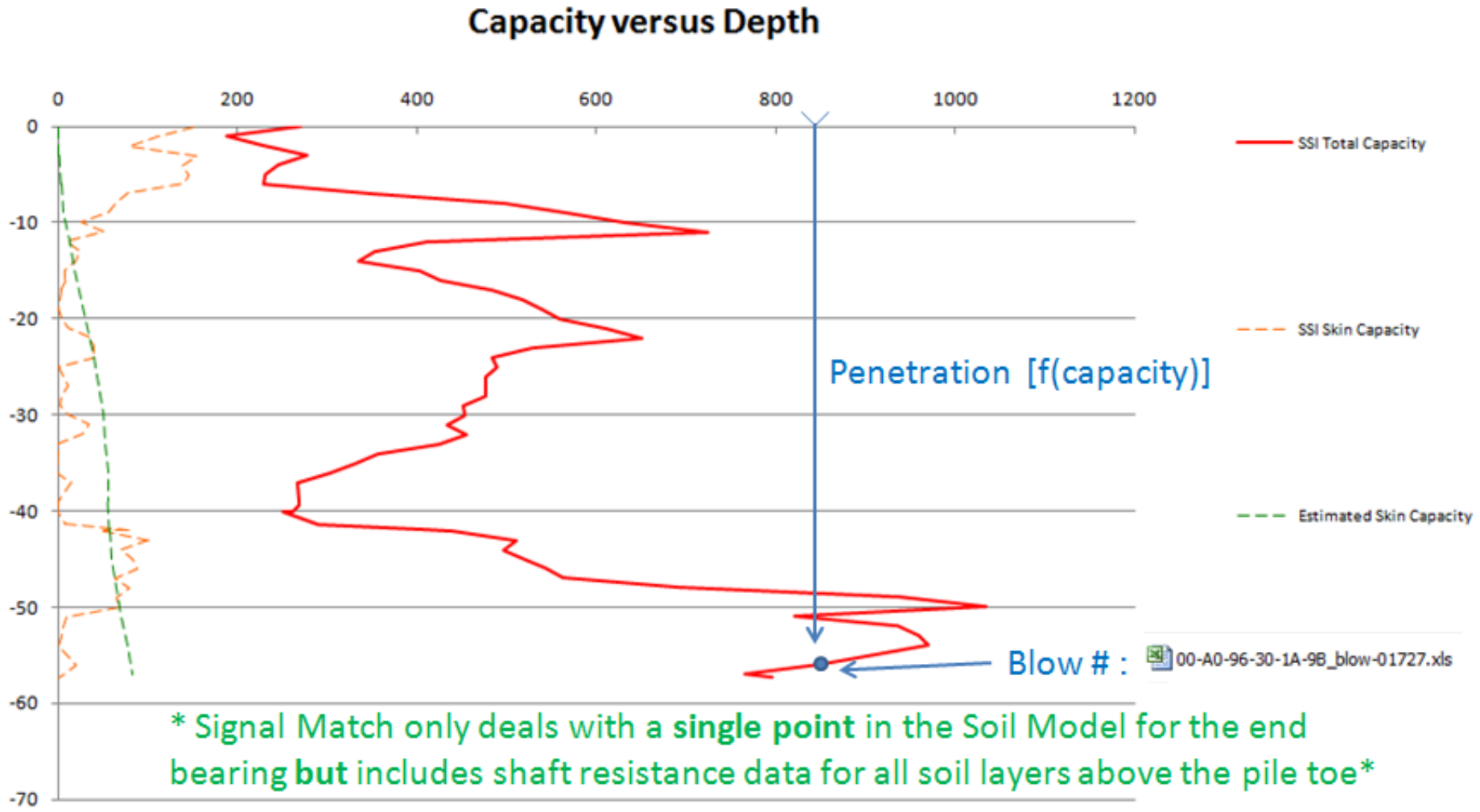


EDC Match – Confirm Soil Model

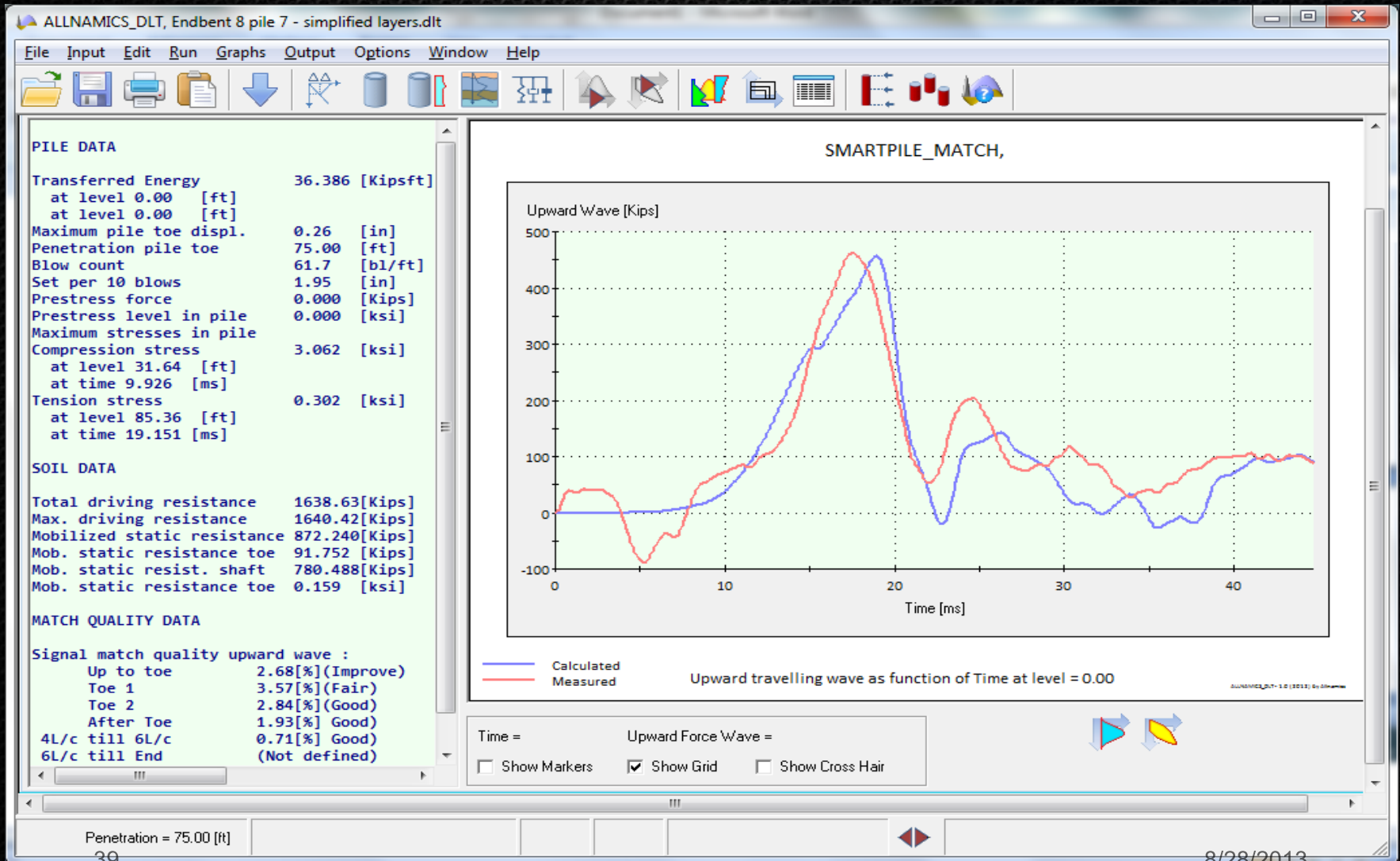
Capacity versus Depth



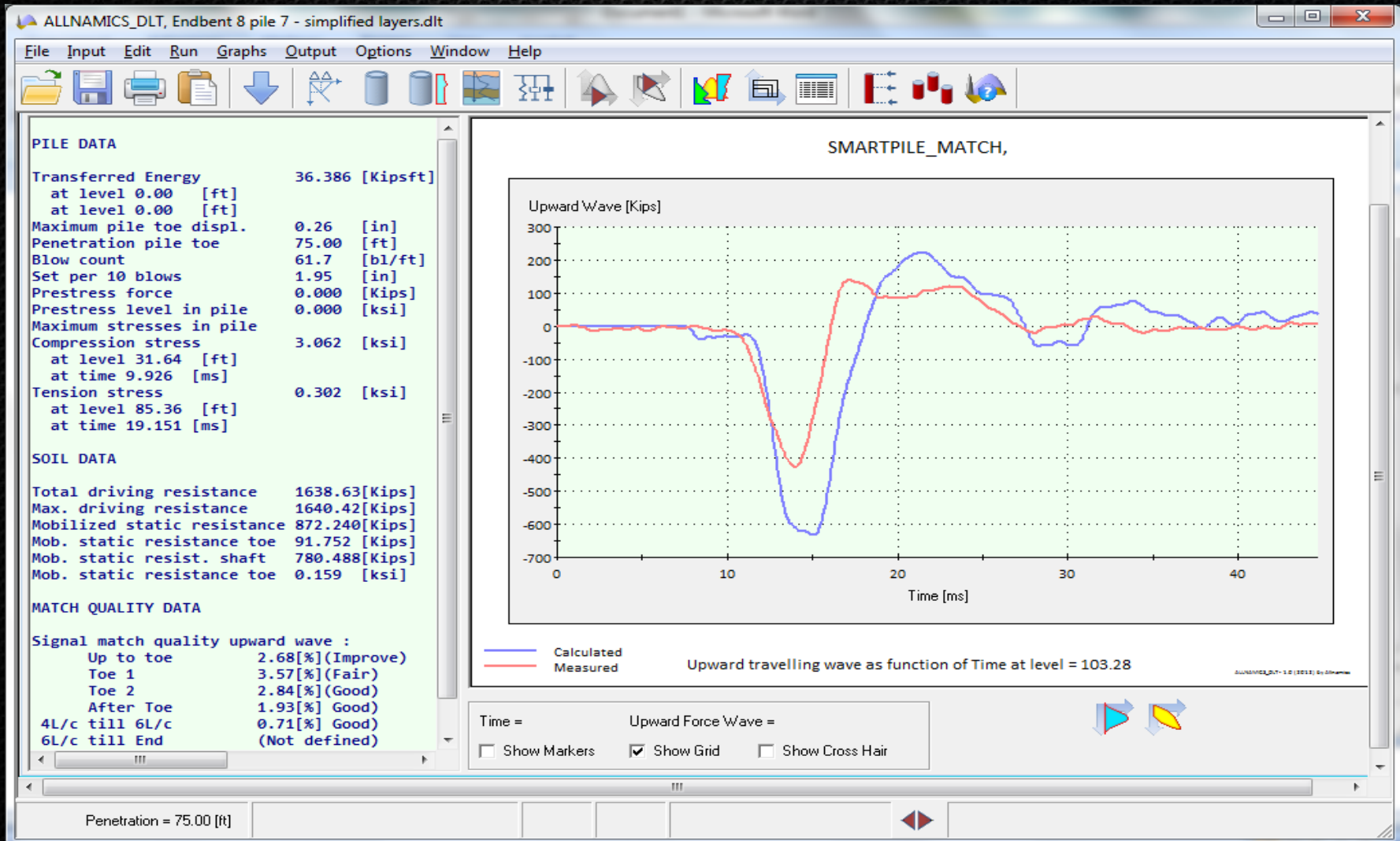
Prepare for Signal Match



Signal Match - Top

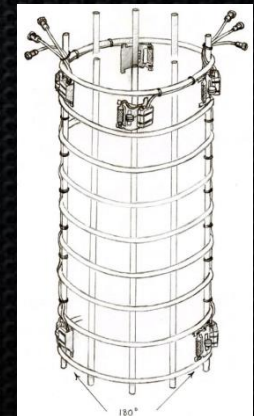


Signal Match – Validated Toe



Drilled Shaft Monitoring

- Leverage EDC in 2 Configurations
 - Static Load Monitoring: Strain Gages
 - Dynamic Impact Testing: Strain / Accel Data
- Dynamic:
 - Supplements CSL data to help mitigate shaft integrity concerns and provides options to shaft coring (\$\$\$)
 - Measure concrete wave speed for material quality testing – Top – Tip (w/o reflection)
 - Look for early reflections coming from voids or other material defects
 - Assess measured load transfer at shaft tip (or at other instrumented locations)
 - Measured set at shaft tip indicates presence of loose or soft material



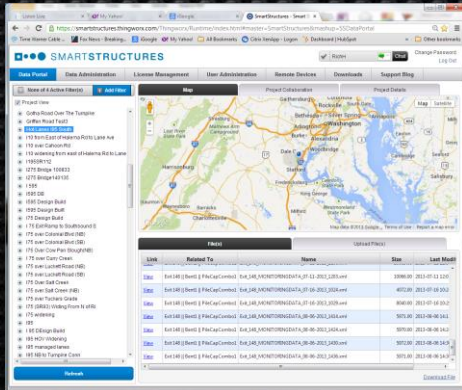
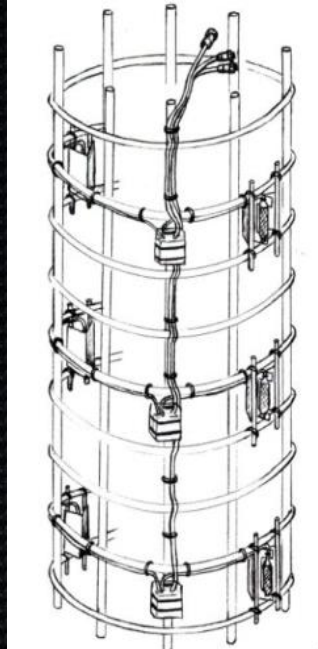
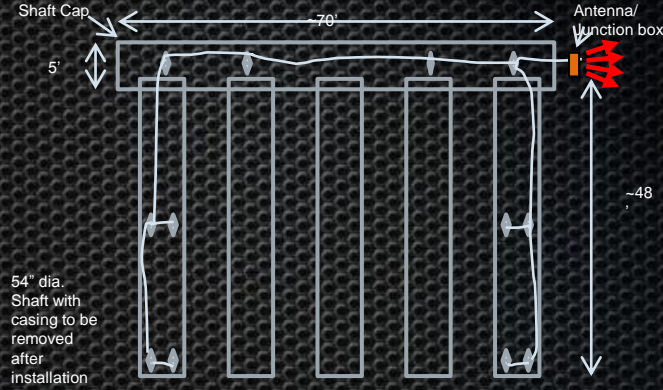
Structural Health Static Monitoring

Monitor Changes in Pile and Cap Strain

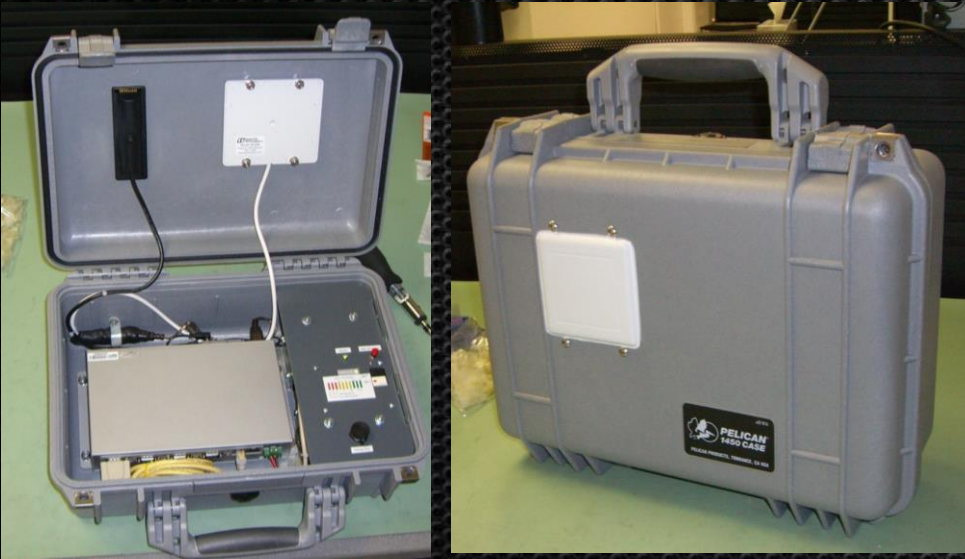
Detect changes in Static loading over extended periods

Walk up or Gateway Monitoring

All data send to Portal



Structural Health Remote Monitoring



- Remote Monitoring Gateway To-Go
- Walk-up, drive-by monitoring
- Battery powered
- No user controls or operation

- Remote Monitoring Gateway permanently mounted
- Plug powered
- No user controls or operation

Mainstream Infrastructure Monitoring

- By being part of the construction process ...
 - Make monitoring part of the construction process
 - Leave sensors behind and make monitoring an incremental cost
 - Work to minimize labor costs
- Through innovative pricing models
 - Pilot Pricing (FDOT/FHWA)
 - Small Project Pricing
 - Large Scale Full Dynamic Testing
 - Sensors as a Service: SaaS

Roadmap: EDC Technology Applications



Beyond Piles

- Drilled Shafts
- Machine Foundations
- Pipelines



Beyond Bridges

- Ports
- Petrochem
- Energy/Industrial



Beyond Testing

- Condition-based Monitoring
- Asset Management
- Situational Awareness

Structural Health Monitoring (SHM)

DOT Pilot Programs

For DOT's, State Agencies, Federal Agencies and Municipalities – PILOT PROJECTS

SMARTPILE® *FastStart* Package

\$9,995.00

Includes:

EDC

- ✓ Ten (10) Embedded Data Collectors (SP_402)
- ✓ Installation kit
- ✓ Installation at casting yard

SmartStart for DOTs Program

- ✓ 90-minute online (web) briefing on System

12-month SmartPile® Workstation lease

- ✓ Hardware
- ✓ embedded software
- ✓ wireless data services
- ✓ remote support
- ✓ 24-hour hardware break/fix/replace

EDC Plus Software Suite for DOTs

- ✓ SmartPile® Review
- ✓ Named account access
- ✓ Unlimited phone/web technical support during standard business hours

Small Project Pricing

EDC

\$ 899.00/set*

- ✓ Embedded Data Collectors (SP_402)
- ✓ Installation kit
- ✓ Installation at partner casting yard

* Large volume reductions apply

Large Scale Testing Projects

Standard Embedded Data Collector Data Service _____ **\$29.00/month**

- ✓ SP_402 EDC device with top and tip sensor packs
- ✓ Installation kit and all required accessories
- ✓ Installation
- ✓ EDC data service

EDC Review & Management Software Services _____ **\$99.00 /month**

- ✓ Named account on EDC Portal with Project Dashboard
- ✓ EDC Review application
- ✓ Unlimited online and telephone technical support

Online Project Database Software Services _____ **\$250.00 /month**

- ✓ Storage and management of all EDC data and reports
- ✓ Automated backup of all project Workstations
- ✓ Online Software & Portal User Introductory Training

*On average, cost per instrumented pile for projects is around \$550.00. Please note, that there are minimum terms on duration.

Remember

There is a cost to have a person in the field regardless of the type of instrumentation (Collecting Data, part of the Verification process).

Field Equipment Lease

Work Station _____ **\$ 999.00/month**

- ✓ Rugged Laptop
- ✓ Acquisition software
- ✓ Review software
- ✓ Discounts for long duration projects

Conclusion

- A new approach to dynamic testing enabling all structural elements to be efficiently tested during installation
- Owner Advantages over “Top Only” Dynamic Testing:
 - Final Capacity dependent on wave speed used in key calculations – EDC provides ability to **confirm correct wave speed at the end of drive!**
 - It’s not about damage being detected, but **real damage going undetected!**
 - %tip vs. %skin - Need to know in two places? Measure in two places!
 - Signal Matching results validated using pile tip data!
 - Estimates, assumptions, and subjective interpretation replaced with measured data!
- It’s not about more data, but more reliable data, providing for checks and balances, to improve owner confidence, and warrant a higher resistance factor

Thank You!!

To Learn More (Contacts)

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Director of Business Development

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Southampton, PA 18966

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407-274-2080 (direct)

shelley@smart-structures-inc.com