Quantifying Pile Rebound with Detection Systems Best Suited for Florida Soils

Task Work Order BDV28 Two 977-07

PI: Paul J Cosentino PhD, P.E.,
Ci-PI's: Matthew Jensen PhD Charles Bostater PhD

Florida Institute of Technology
Melbourne FL 32901-6975
321-674-7555 Direct

PM: Juan Castellanos, P.E

Outline

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- Objective
- Approach
- Schedule of Tasks
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  - Task 2 Viscoelastic Analysis of Existing Cyclic Triaxial Load versus Time Data
  - Task 3 Wave Equation Software Damping Factor Sensitivity Analysis
  - Task 4 High Speed Camera Validation for Inopiles PDM LASER Measuring System
  - Task 5 Determine SPT and PDA Test Pile Field Testing Locations
  - Task 6 Measuring System Evaluations
    - SPT Systems
    - Test Pile Systems
  - Task 7 Draft Final Report and Closeout Teleconference
  - Task 8 Final Report

FDOT Sites Tested to Date

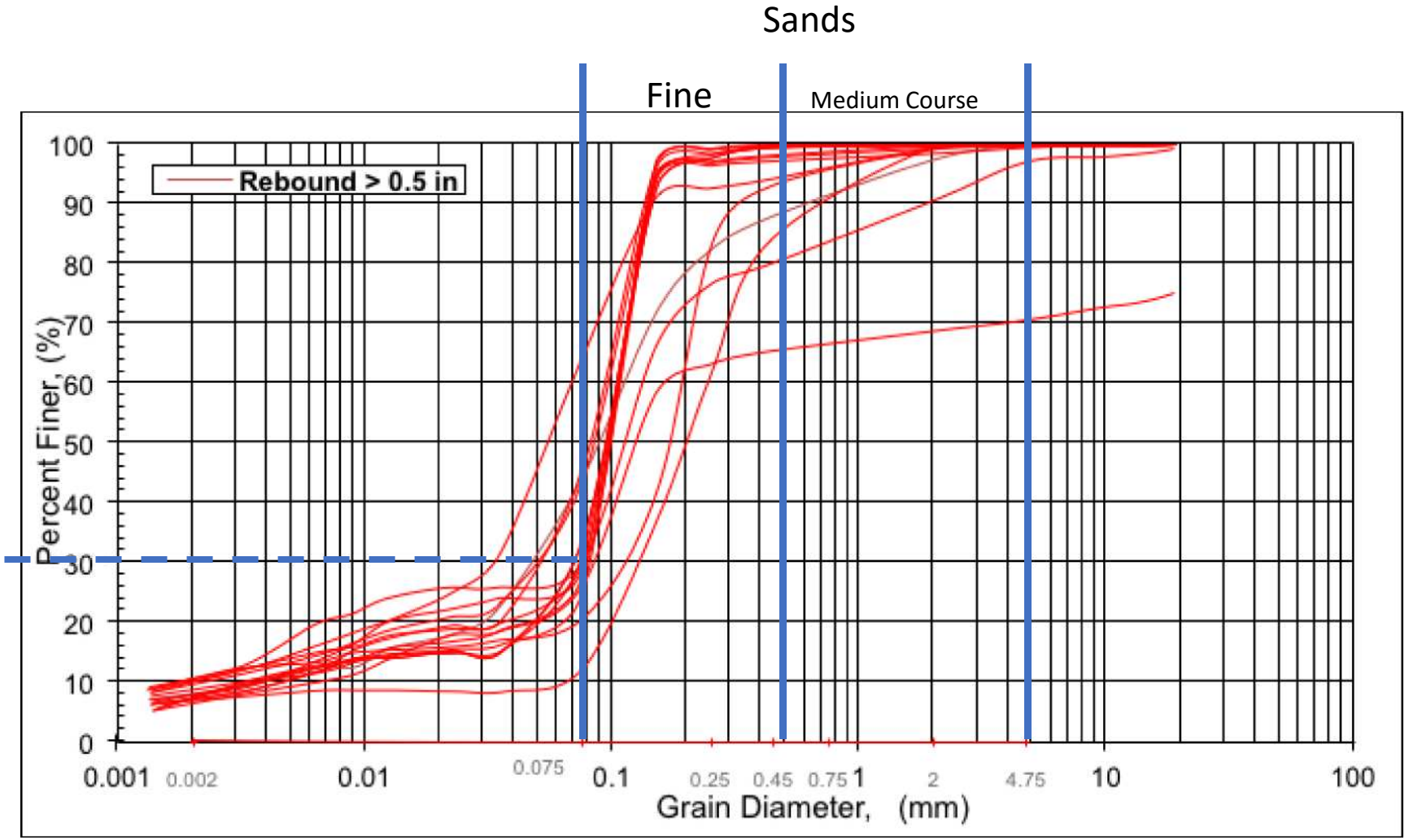
- SPT on 11 of 12
- CPTu on 8 of 12
- Shelby on 6 of 12

Number	Description	Testing		
		SPT	CPTu	Undisturbed
1	I-4 / US-192 Interchange / Osceola County / Florida.	✔	✔	✔
2	State Road 417 International Parkway / Osceola County / Florida.	✔	✔	✔
3	I-4 / Osceola Parkway / Osceola County / Florida.			✔
4	State Road 50 and State Road 436 / Orange County / Florida.	✔	✔	
5	I-4 / State Road 408 Ramp B / Orange County / Florida.	✔	✔	
6	Anderson Street Overpass at I-4/SR-408 / Orange County / Florida.	✔	✔	
7	I-4 John Young Parkway/ Orange County / Florida	✔		
8	I-4 Widening Daytona / Volusia County / Florida.	✔	✔	
9	SR 528 over Indiam River, Brevard County / Florida	✔		
10	Saint Johns Heritage Parkway, Brevard County / Florida	✔	✔	✔
11	I-10 Chaffee Road, Duval County / Florida	✔		✔
12	State Road 83 over Ramsey Branch Bridge / Walton County / Florida.	✔	✔	✔

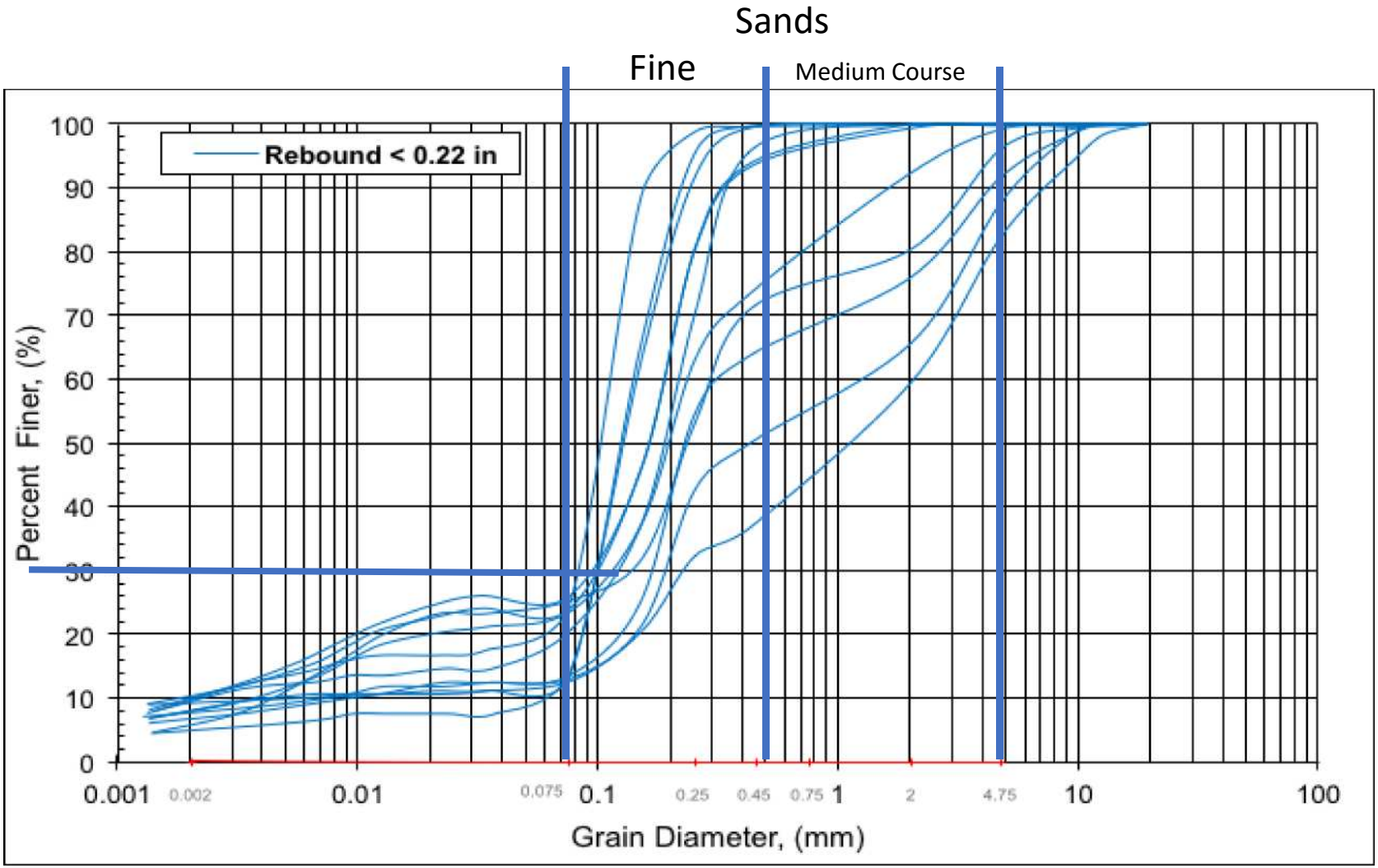
HPR Soils

- Classified as SP
- Are Fine Sands!
- Fine Content is Critical
  - > 30% % Passing # 200
- Silts and Clays % meet certain criteria
  - Silts 20 to 40%
  - Clays LL> 50% PI > 30%
- Conclusions: based on rebound data averaged over 1’

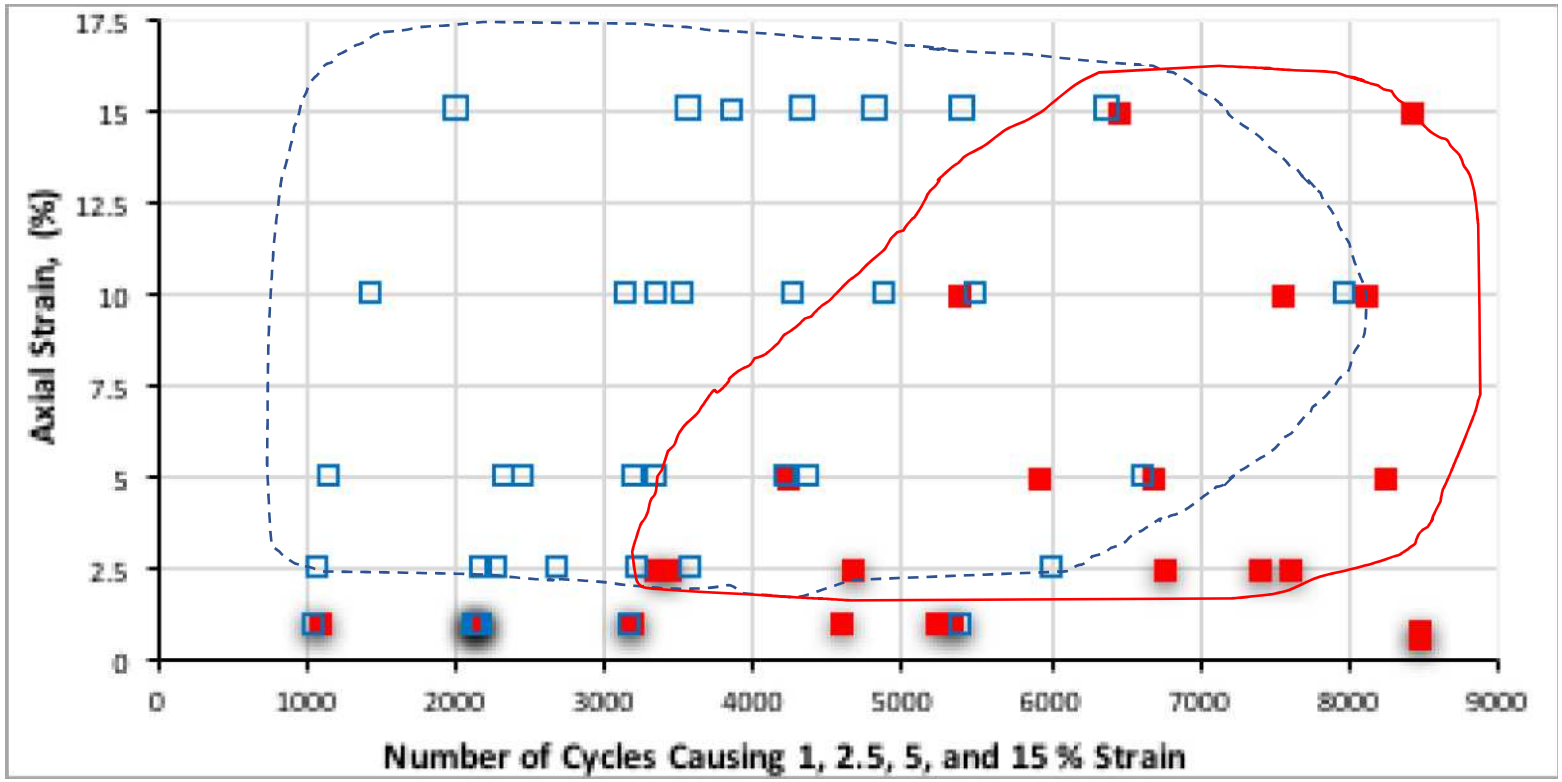
Grain Sizes of Fine HPR Sands



Grain Sizes of NonHPR Sands



Cyclic Triaxial Results show HPR Soils are Much More Resilient



- Solid Red Points from Rebound Soils
- Open Blue Points from Non-Rebound Soils

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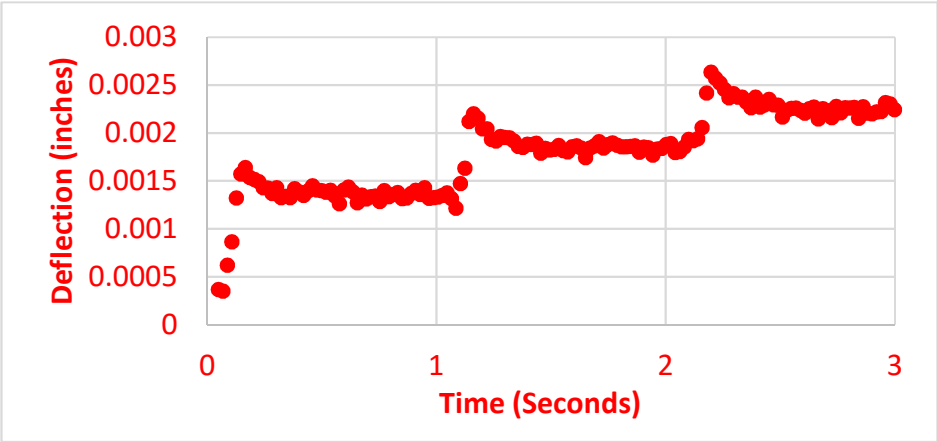
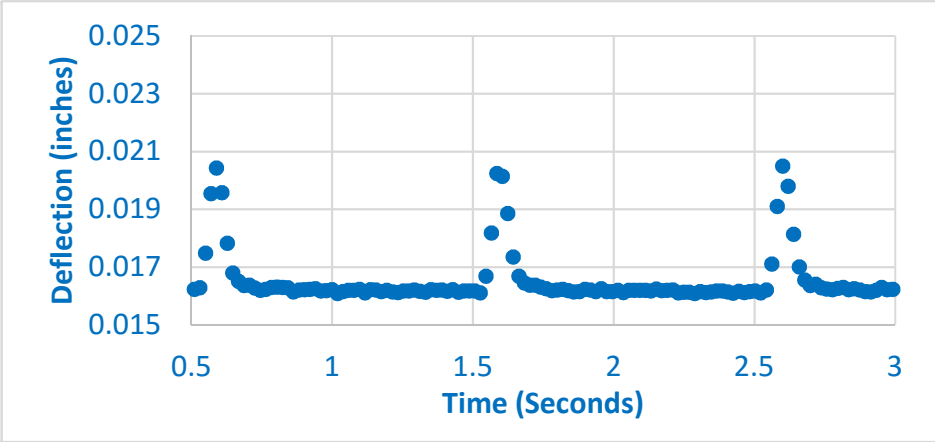
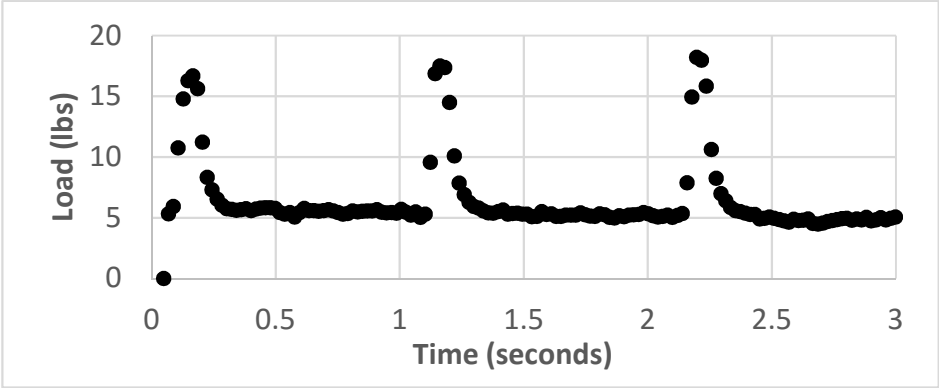
Cyclic Results Also show HPR Soils are Viscoelastic



Three deflection versus time cycles @ Ramsey Branch - 63' Site 12



Three deflection versus time cycles @ Heritage Parkway -57 ' Site 10

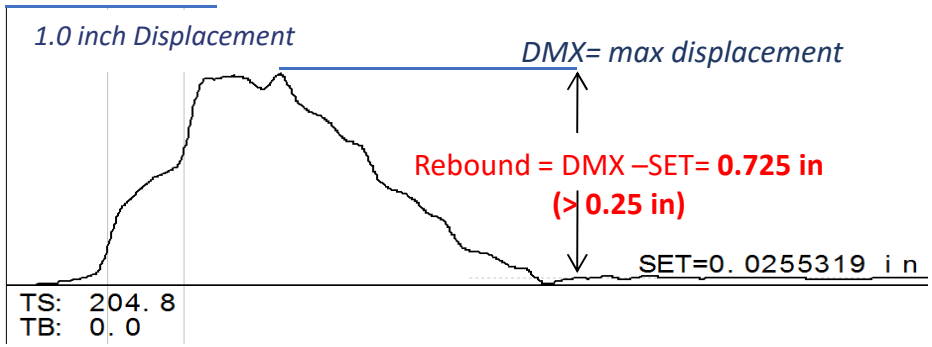


Three generic load versus time cycles

Existing Data from 34 tests (Phase II) to be analyzed for trends Tasks 2 & 3

PDA Sensors plus Inspection Process May Produce Errors

- Acceleration *Numerically* Double Integrated
- If Pile is Moving at Start Errors Occur
- A Field Check needs to be validated
- Inspector Set is average over 1 foot and may not produce enough data



New Technology

- Inopiles LASER Measuring System
- Needs Validated
- High Speed Cameras can produce visual confirmation
- FDOT needs verification that this works

SPECIFICATIONS

PDM Opto-Electronic Unit*
Vertical movement resolution ±0.1mm at 10m standoff distance
Vertical velocity resolution ±0.1m/s at 0.1m standoff distance and 1kHz
Measurement of pile set, rebound, velocity, capacity and damage
Measurement of vibratory frequency, amplitude and penetration rate
On-board accelerometers for ground vibration monitoring
Standard software
Driven pile installation monitoring and capacity evaluation
Optional Software Modules
Vibratory Installation, Marine Piling, Pile Damage, Ground Vibration, Hammer Performance, SPT Testing
Accessories
Tablet PC, Electronic Distance Measurement Device, Battery, Charger, Serial Cable, USB Cable, Reflective Marker, Transit Case, Instruction Manual, Cabin Mount with Wireless connection (optional), GPS module (optional)

*Patent Pending

Objective

- Evaluate how the Inopiles PDM LASER deflection-measuring system in conjunction with PDA deflections can be used to quantify pile rebound in the viscoelastic fine Florida sands with silts and clays.

Approach

- Task 1 Literature Search:
  - Existing Pile Deflection Measuring Systems
  - Soil Damping
- Task 2 Viscoelastic Analysis: Existing Cyclic Triaxial Data
- Task 3 Wave Equation Software Damping Sensitivity Analysis
- Task 4 High Speed Camera Validation of Inopiles LASER System
- Task 5 Determine SPT & PDA Test Pile Field Testing Locations
- Task 6 Measuring System Evaluations
  - SPT Systems
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- Task 7 Draft Final Report & Closeout Teleconference
- Task 8 Final Report

Schedule of Tasks (overview)

FLORIDA DEPARTMENT OF TRANSPORTATION
RESEARCH CENTER

PROJECT SCHEDULE

Project Title	**Measuring System for Pile Rebound During Construction and Design Geotechnical Investigation**																										
FDOT Project No.																									FY	2017	Month	April
Research Agency	**Florida Institute of Technology**																										
Principal Investigator	Paul J. Cosentino, Ph.D. P.E.																										
	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19				**Comments**
RESEARCH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				
TASK																												
Project Kickoff Meeting	1																											Cosentino
Task 1 Literature Search on Existing Pile Driving Deflection Measuring Systems and Soil Damping	1	2	3	4	5																							Cosentino
Task 2 Viscoelastic Analysis of Existing Cyclic Triaxial Load versus Time Data		1	2	3	4	5	6	7	8	9	10	11	12															Cosentino
Task 3 Wave Equation Software Damping Factor Sensitivity Analysis		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15												Cosentino
Task 4 High Speed Camera Validation for Inopiles PDM LASER Measuring System					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15									Jensen/Cosentino
Task 5 Determine SPT and PDA Test Piles Field Testing Locations			1	2	3	4	5	6	7	8																		Cosentino
Task 6 Measuring System Evaluations						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15								Cosentino/Jensen
Task 7 Draft Final Report and Closeout Conference																		1	2	3	4			1				Cosentino/Jensen
Task 8 Final Report																						1	2	3				Cosentino/Jensen

Task 1 Literature Search on Existing Pile Deflection Measuring Systems and Soil Damping

- This task will include the following
  - A summary of the literature on existing pile movement measuring systems
  - BDV28 977-01 Final Report contains a recent summary which will be updated
  - If promising system available that is not part of this scope research team will evaluate its benefits and costs and make a recommendation to FDOT SMO
  - The soil damping literature to relative pile driving.

Literature Search to Date

- Laser Measurement System or Meter Summary
- LDS/LMD suitable for this project sold by: Rotalec, Acuity, Banner, and Jenoptik

Reference	Measurement Type
Park et. al., 2013a:	Displacement of a structure for health monitoring with a wireless sensor node
Park et. al., 2013b:	Deflection of structural members in an irregular building using a customized wireless sensor node
Tian et. al., 2014:	Displacement of medium and short span bridges with wireless data acquisition and transmission.
Islam et. al., 2016:	Interstory drift or movement of building frames with a novel technique utilizing an angled target plate.
Hwang et. al., 2016:	Error reduction for measurements

LASER Detection (Park et al 2013a)

Data wirelessly recorded as LASER Focused on Truss

Concrete Wall Cutout Exposing Truss Support System

Task 2 Viscoelastic Analysis of Existing Cyclic Triaxial Load versus Time Data

- Using existing results (BDV 28 977-01) from 30 cyclic triaxial tests, the unloading deflection versus time responses will be analyzed
- The results will include
  - a list of the sites evaluated,
  - soil profiles from each site that include
    - the locations of undisturbed samples,
    - SPT N values,
    - pile driving blow counts and
    - displacement per hammer blow data,
  - results from the cyclic triaxial data analyses and
  - correlations between the rebound near the sample depth and cyclic responses.

Task 3 Wave Equation Software Damping Factor Sensitivity Analyses

- Will Involve Subcontract with GRL Orlando
- GRL Wave equation software available will be used
  - Various damping factors will be input to perform a sensitivity analyses on how the damping factors affect pile capacity.
  - Test pile PDA data from HPR and non-HPR sites will be evaluated.
  - PDA deflections will be used in a signal matching process with the CAPWAP software to further clarify the effect of damping factors on the pile movement

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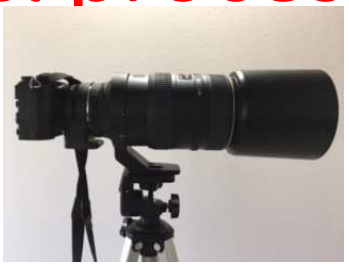
Task 4 High Speed Camera Validation for Inopiles PDM LASER Measuring System

- Video processing based on existing work by Dr. Charles Bostater Professor of Oceanography

- Proper camera use will require:
  - Where to locate the camera
  - The required lens or focusing
  - Where and how measuring tape if any should be placed on the pile
    - *Pile rebound encountered & driving temporarily halted while tape applied*
    - *Tape placed on the pile before it is lifted into the leads?*
  - Camera video synchronization with PDA and PDM data
  - Efficient video processing to validate PDM and PDA deflections

Overview of image; signal acquisition & processing



High speed multispectral camera.

Step 1
- Obtain a series of image sequences during pile driving using high speed frame rates. Test for required acquisition speed, lens, focus & aperture settings, etc.

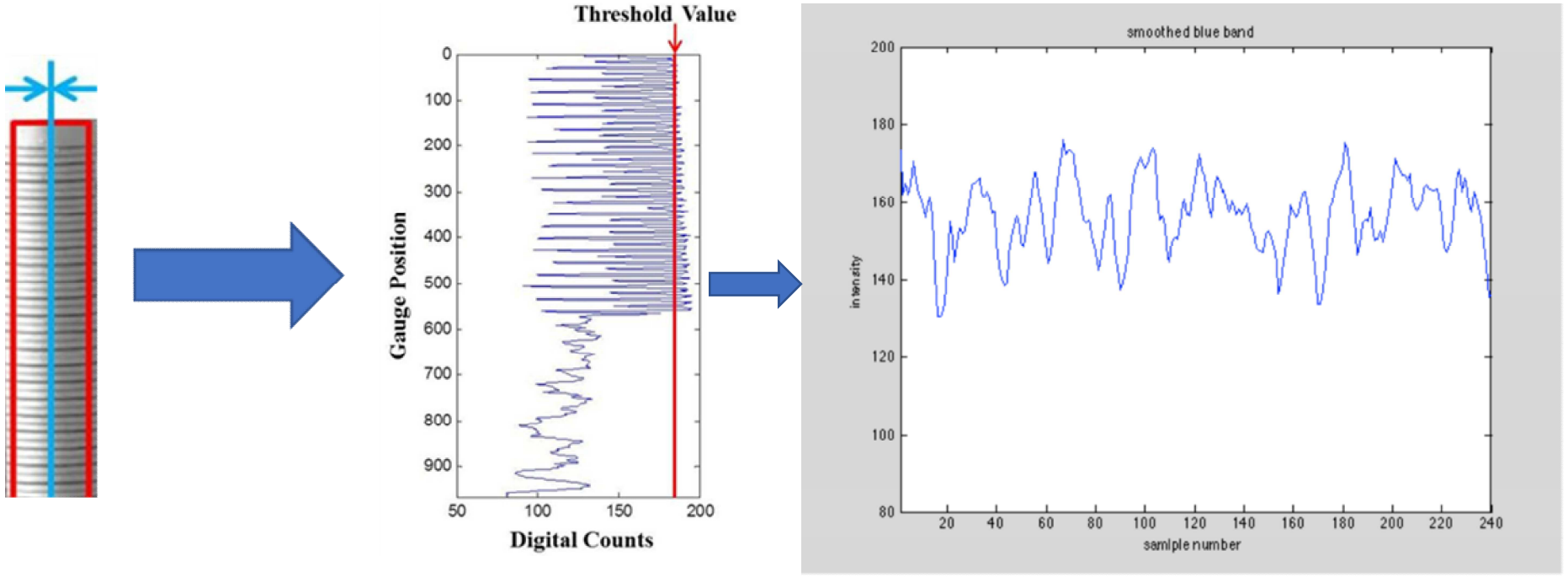
Step 2
- Analyze image signals of line targets (physical, laser targets).

Step 3
- Generate vertical displacement time series signal of pile driving from image sequences.

Step 4
- Modify steps 1 thru 3 to obtain optimal acquisition and signal.

Step 5
- Acquire and test methods on additional pile setup configurations. Personnel and equipment safety is mandatory throughout the setup and signal acquisition process.

Example image sequence signals from high speed vertical displacement study (Bostater, 2014).



Task 5 Determine SPT and PDA Test Piles Field Testing Locations

- Separated into two subtasks
- Task 5a Identification of the SPT field-testing locations
  - Five sites are being identified where SPT borings will be completed about 50 feet from the test piles
    - *Several from 15 month project are good sites*
  - FDOT SMO personnel are assisting in determining these sites, supplying an instrumented SPT calibration rod and drilling equipment
- Task 5b Identification of the PDA test piles locations
  - FDOT SMO are assisting in identifying five rebound sites for using the Inopile PDM LASER system as a check on the PDA data
- A summary with the following will be developed:
  - Descriptions of the sites chosen and the existing site generalized soil profile
  - Basic soil properties in relation to the BDV 28-977-01 HPR identification flow chart
  - The design pile-hammer system
  - The pile driving records

Task 6 Measuring System Evaluations

- Also separated into two subtasks (closely related)
- Task 6a will be the SPT measuring evaluations
- Task 6b will be the test piles measuring evaluations
- From both 6a & 6b the following will be completed
  - *Movements from all devices (PDA, PDM, Camera) will be analyzed and compared.*
  - *Correlations between all the device movements will be made*
  - *The results will be used to update the BDV 28 977-01 Decision Tree*
  - *Conclusions will then be formulated that can be included in the report*

Final Two Tasks

- Task 7 Draft Final Report and Closeout Teleconference
  - Contains two deliverables (*Draft Report and Teleconference*)
  - Identified as 1 item in budget
  - A well written document will be submitted and reviewed for approval
- Task 8 Final Report
  - After revisions Final Report will be submitted on 2 Professionally labeled CD's
  - Each CD will contain the report in both a word and pdf format

Questions ?