FLORIDA INSTITUTE OF TECHNOLOGY - CIVIL ENGINEERING DEPARTMENT

FLORIDA DEPARTMENT OF TRANSPORTATION

BDV28 977-04

Development and Testing of the Miniaturized Pressuremeter Test for Use in Unbound Pavement Layers

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Project Manager: David J. Horhota, Ph.D., P.E.

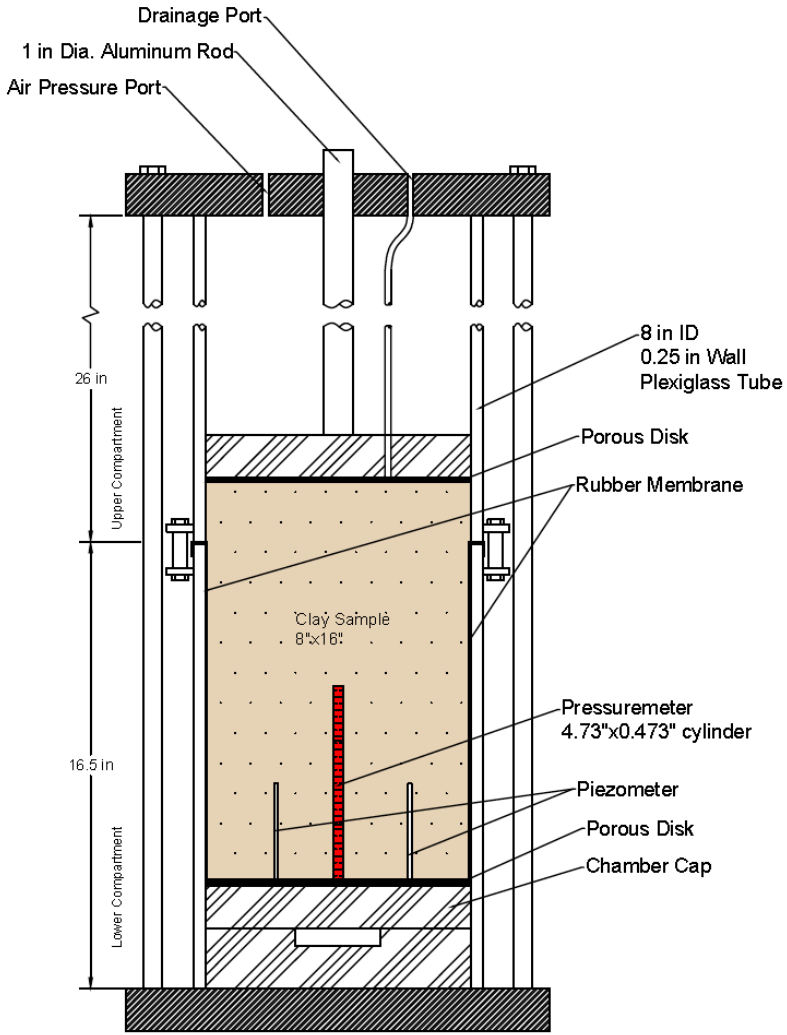
[2017-GRIP MEETING]

Background

- *Nuclear Density Gage Testing yields Density and Moisture*
- *Strength and Stiffness of Pavement Layers is critical*
- *In situ pavement properties of strength and stiffness are only available from Pressuremeters*
- *A 6-inch long Mini-PENCEL Pressuremeter without a metallic sheath produced reliable strength and stiffness for unbound layers*
- *Pavement Engineers could benefit from PMT testing in NDG hole*

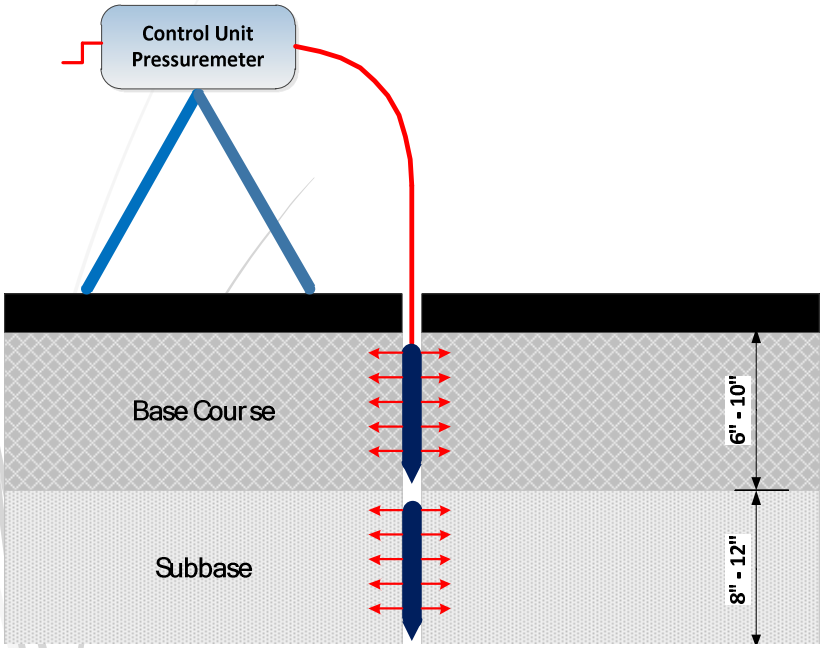
Literature

- Field Quality Control
  - Falling Weight Deflectometer
  - Lightweight Deflectometer
  - Klegg Impact Hammer
  - Nuclear Density Gauge
  - Dynamic Cone Penetrometer
- Miniature Pressuremeter
  - Purdue University
    - 4.73 inches x 0.473 inches

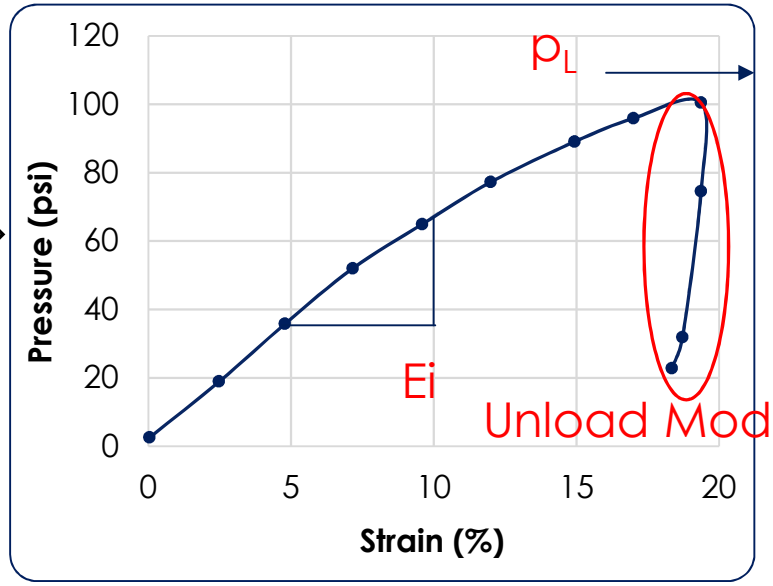


Triaxial Chamber with Pressuremeter

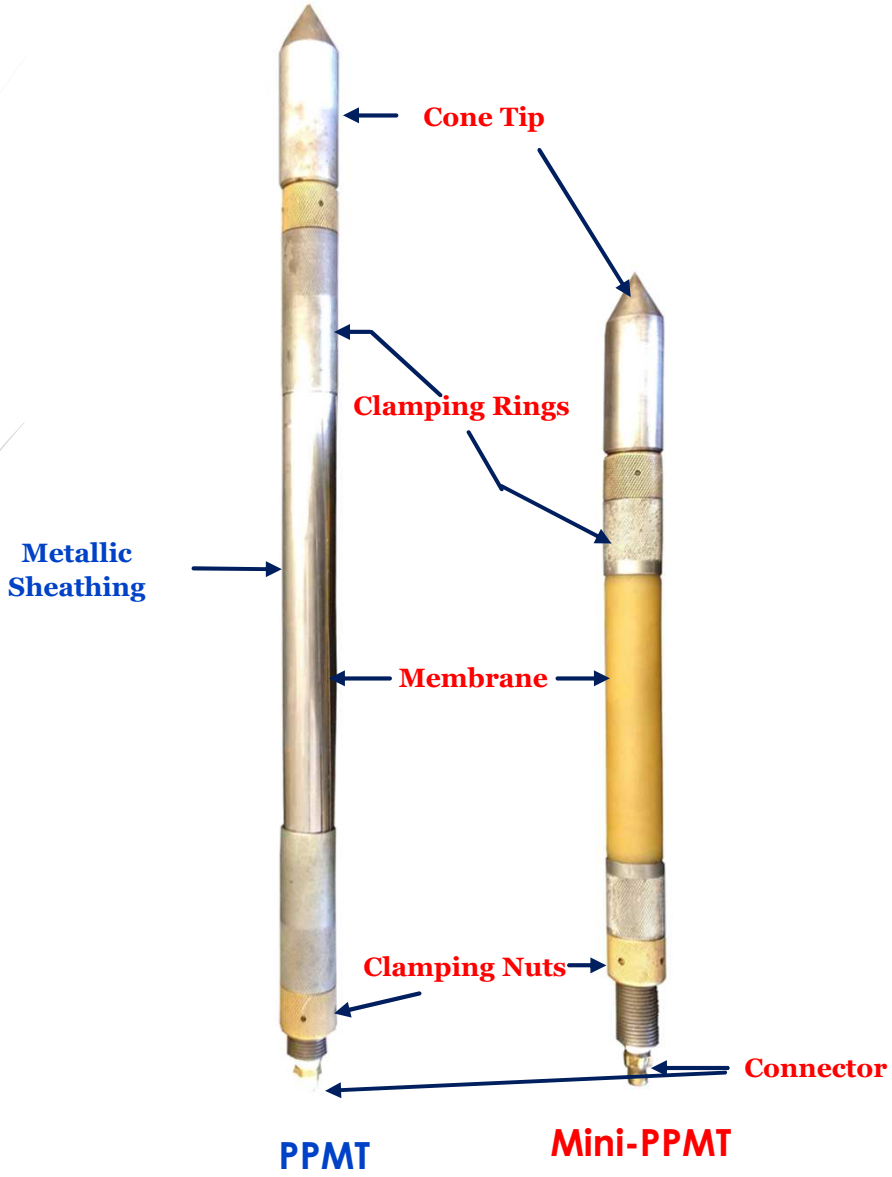
Pavement or PENCEL Pressuremeter



• Typical PMT Stress-Strain Curve



10” PENCEL To 6” Mini-PENCEL

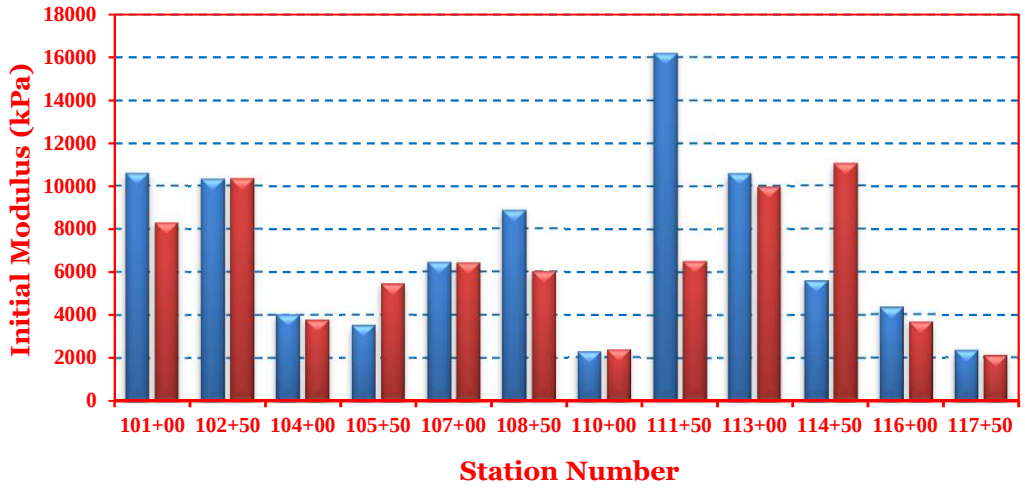


Both 1.3 inch diameter

Consistency of Field Testing Measurements

PPMT

Mini-PPMT



Average [E_i]

Initial Modulus (kPa)	
PPMT	Mini-PPMT
7090	6327

Conclusion: Very Similar, **PPMT** E_i may be higher due to; a) longer probe length or b) protective metallic sheathing or c) outlier at Station 111+50

Research Objective

Develop a 5-minute automated and miniaturized PMT field test using a probe that fits in the NDG hole to evaluate 6 and 12 inch unbound layers thereby producing in-situ stress-strain responses.

Project Tasks

- 1 Literature Search – Complete: Invoiced &Paid☺
- 2 Miniaturize the Pressuremeter Probe- Complete: Invoiced &Paid☺
- 3 Determine Field Testing Sites- Complete: Invoiced &Paid☺
- 4 Conduct Field Comparison Testing – 99% Complete
- 5 Conduct Laboratory Comparison Testing – 95 % Complete
- 6 Analyze and Finalize SDPMT Testing Results – 60 % Complete
- 7 Draft and Final Report & Close-Out Mtg- 50 % Complete

Tasks for Miniaturization of PMT Probe

- **Must fit properly into the same hole as the NDG**
- **Must test the entire pavement layer**
  - **Research limited to 6 & 12 inch probes**
- **Prove the new probe provides consistent results**
  - **Termed Small Diameter Pressuremeter SDPMT**
- **Determine if correlations exist between other field tests and mini-PMT**

Overview SDPMT Probe Designs

Metal Probe

Copper Crimps
& Membrane

3D Printed

Plastic
No Membrane

CNC

Aluminum

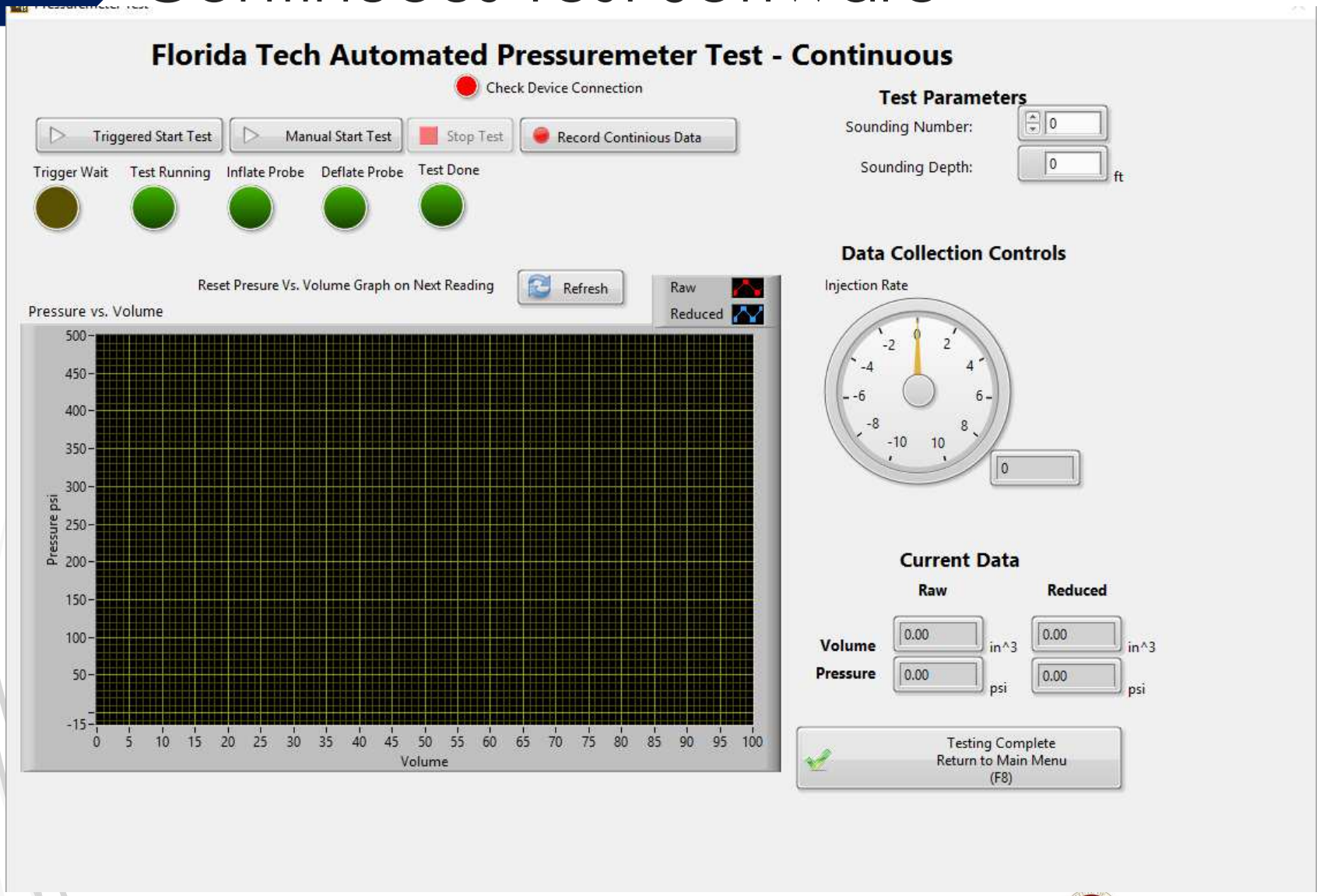
Field Testing

Florida Institute of Technology

New Mini-PMT Test Procedure

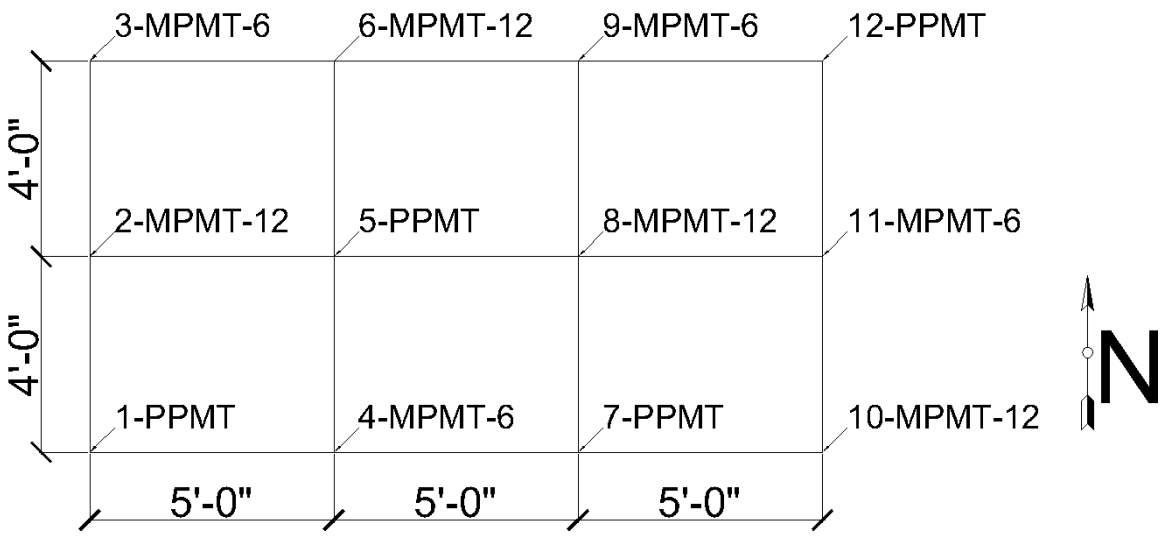
- Develop and Validate a Continuous PMT Test
  - Constant Strain Rate Test
  - 20 – 50 cc injected volume
  - Software Allows Estimation of E_0 , P_0 and P_L^*
  - Software Guides Operator Through Test Sequence

Continuous Test Software



Preliminary SDPMT Testing

- 12 Tests Total
  - 4 – PPMT
  - 4 – SDPMT-6



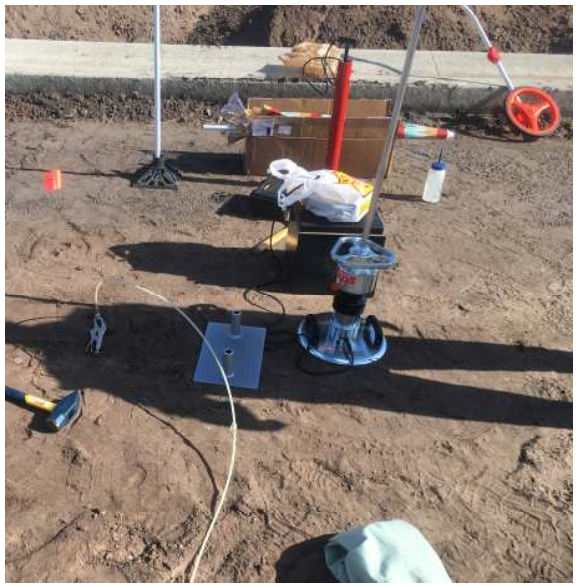
Tests are identified as Sounding Number - PMT Type

Preliminary Data

Probe Type	Test No.	Sounding No.	E0 kPa	P_L kPa	Soil Type
SDPMT-6	1	3	4881	450	Med Dense Sand
	2	4	3229	300	Loose Sand
	3	9	3903	350	Loose to Med Dense Sand
	4	11	1395	200	Loose Sand
		Average	**3352**	**235**	
SDPMT-12	5	2	2464	150	Loose Sand
	6	6	3112	250	Loose Sand
	7	8	3050	225	Loose Sand
	8	10	4396	250	Loose to Med Dense Sand
		Average	**3255**	**219**	
PPMT	9	1	2391	225	Loose Sand
	10	5	2889	225	Loose Sand
	11	7	2774	260	Loose Sand
	12	12	2530	200	Loose Sand
		Average	**2646**	**228**	

Field Testing Sites

- FIT Campus Overflow Parking
- FIT Campus Southgate Intramural Field
- Cypress Landing Residential Development
- Saint Johns Heritage Parkway
  - Cemented Coquina Base



Field Testing Program

1. SDPMT-6 Incremental
2. SDPMT-12 Incremental
3. SDPMT-6 Continuous
4. SDPMT-12 Continuous
5. DCP
6. Zorn LWD
7. Dynatest LWD
8. FWD
9. Nuclear Density Gauge
10. Clegg Impact Test

St. John's Heritage Parkway

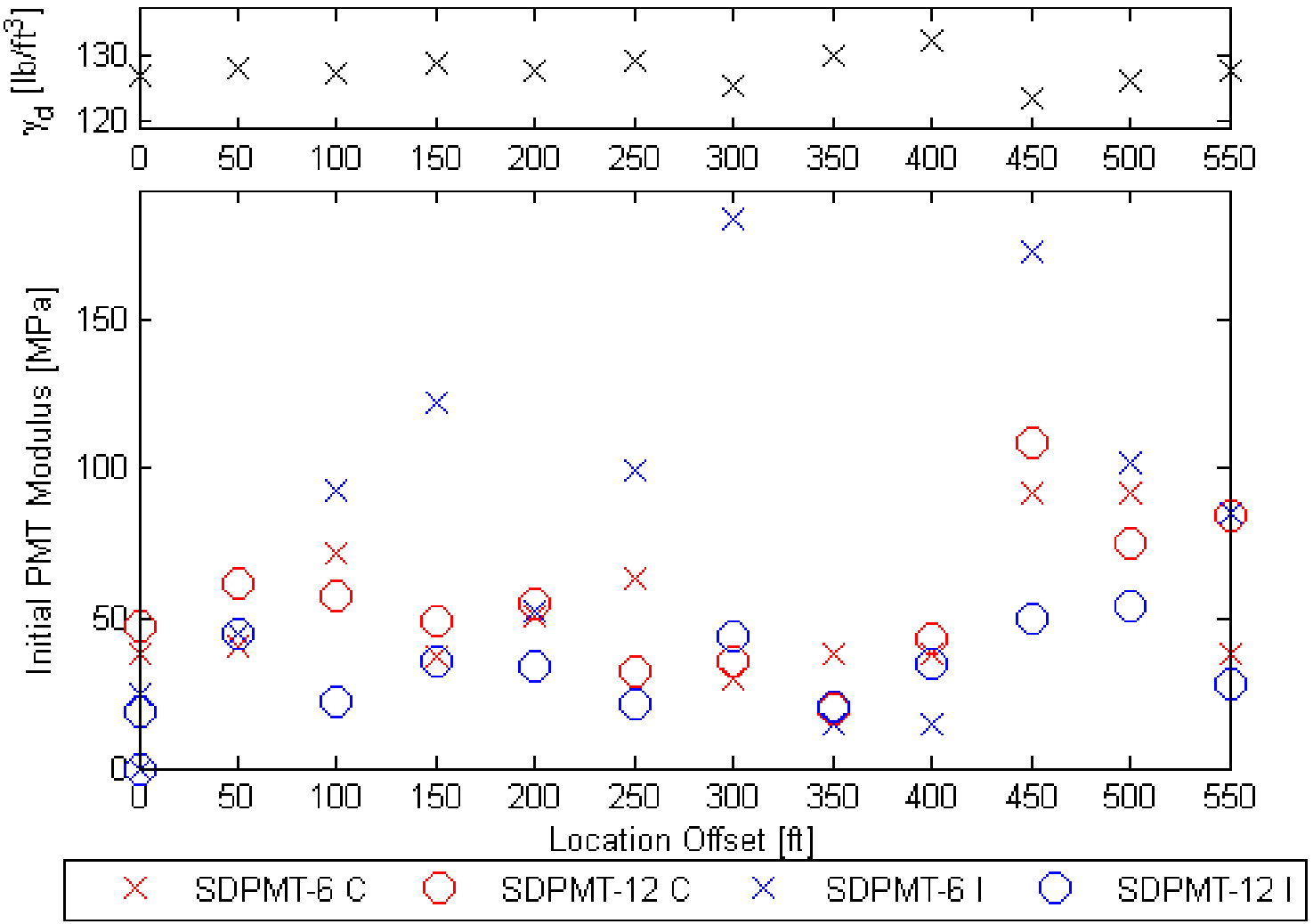
Probe Insertion Methods

- Standard NDG Drive Pin
- 0.75 in Diameter NDG Drive Pin
- Drill Assisted Insertion
  - 5/8 Masonry Drill Bit
  - Rotary Hammer Drill
  - 0.75 in Diameter NDG Drive Pin

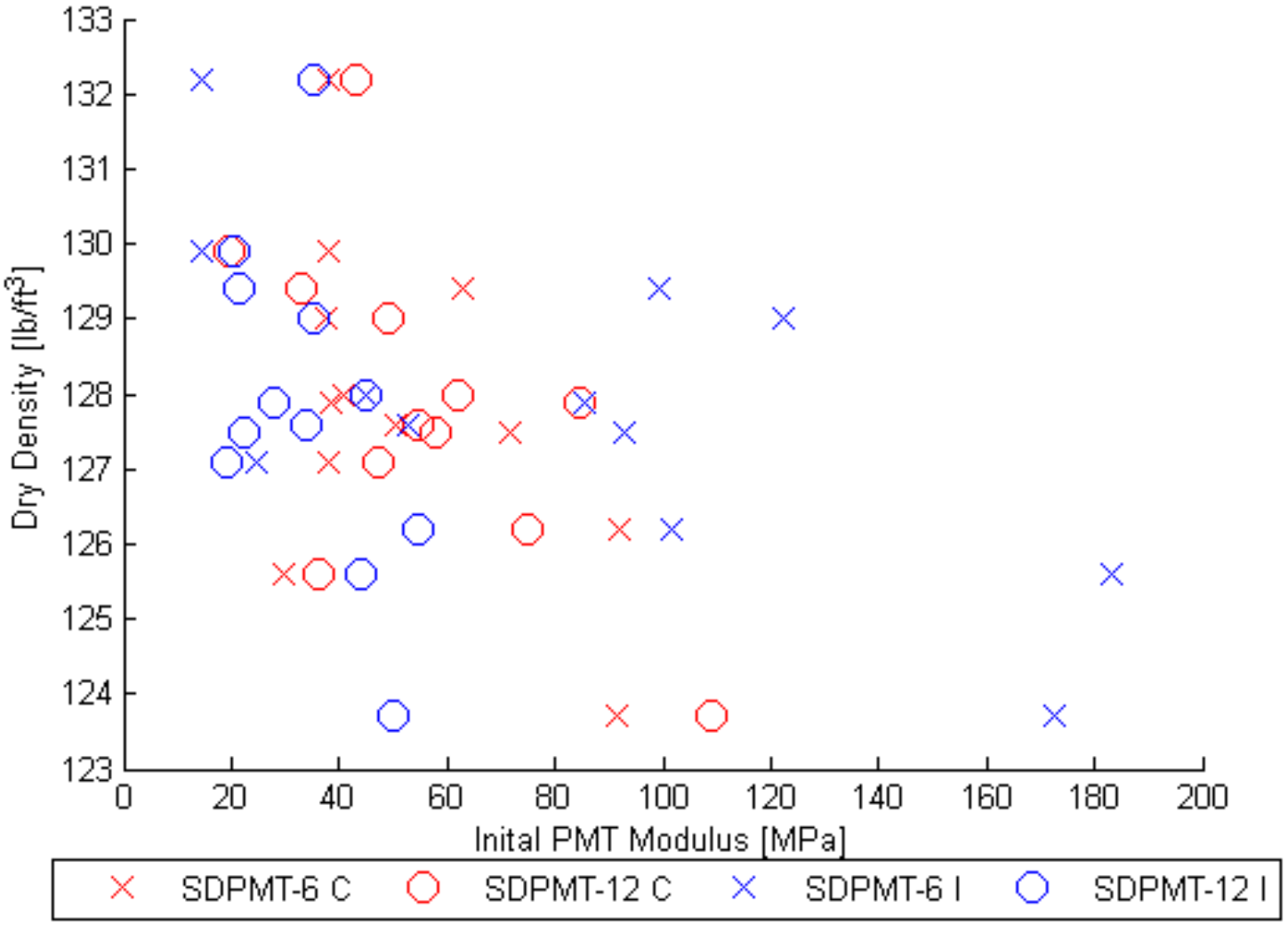
St. John's Heritage Parkway

- 10 inch Base
- Edge of Roadway / Shoulder
- 12 Testing Locations
- Tested Every 50 Feet
- Base too dense to conduct DCP

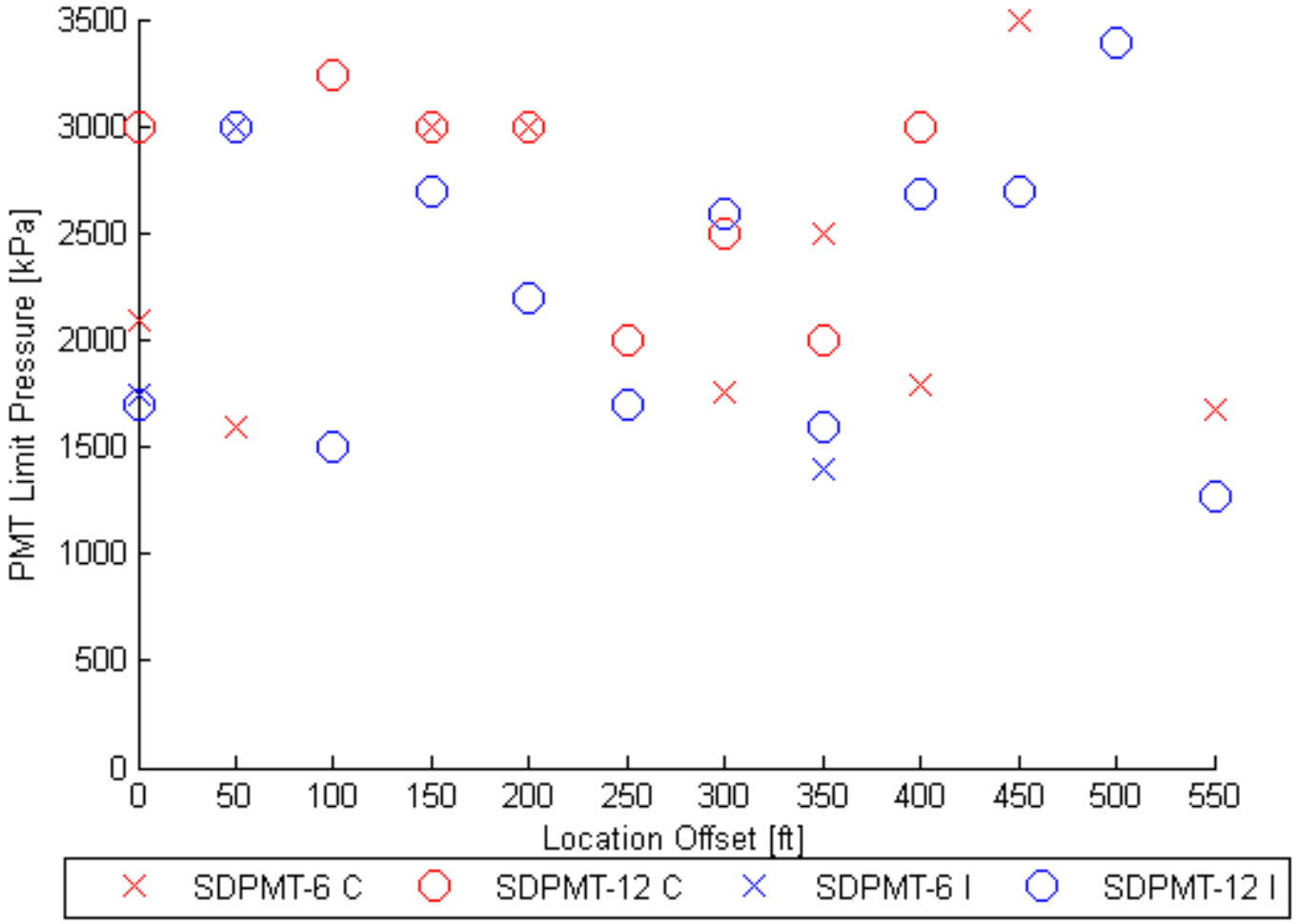
SDPMT Modulus



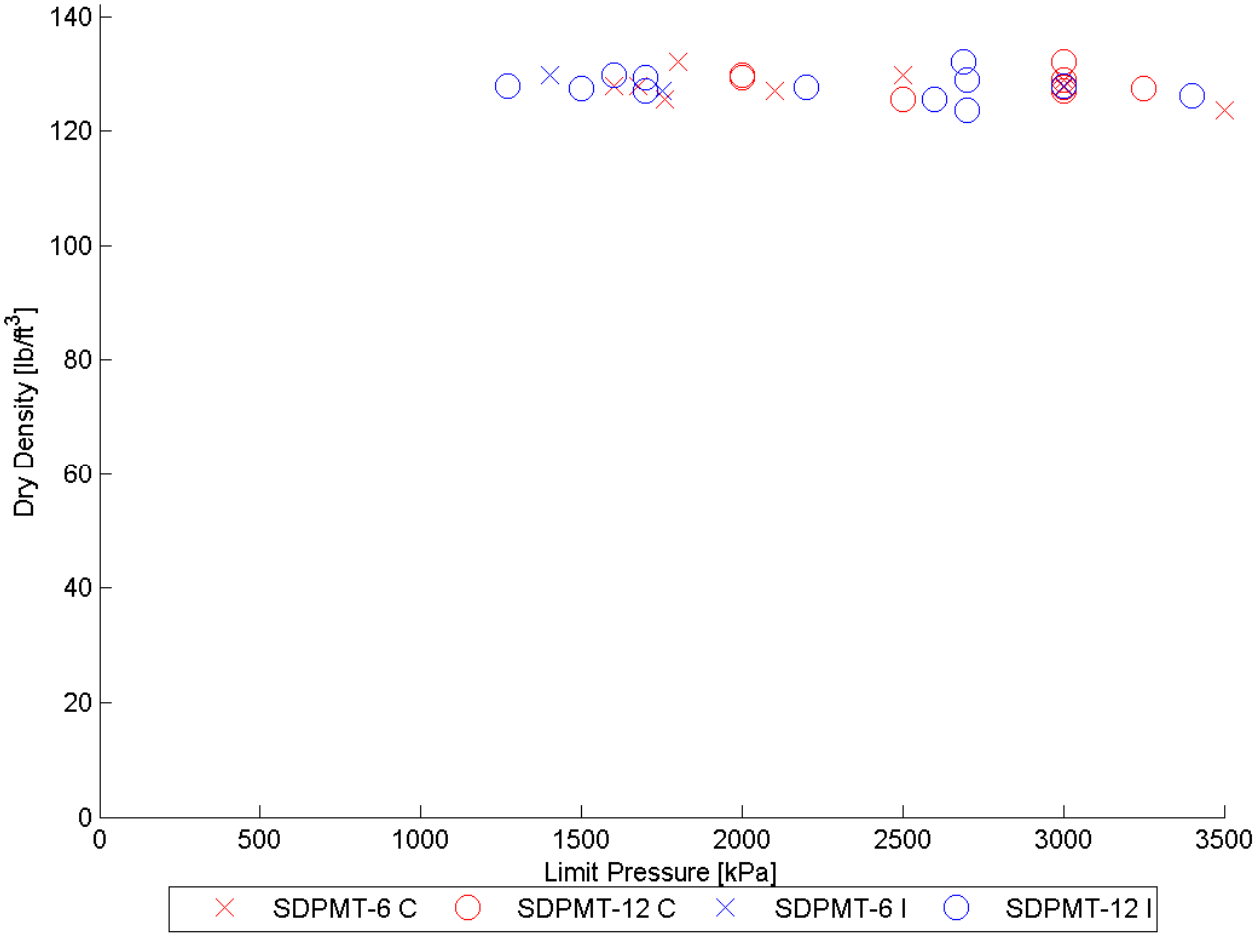
SDPMT Modulus vs Dry



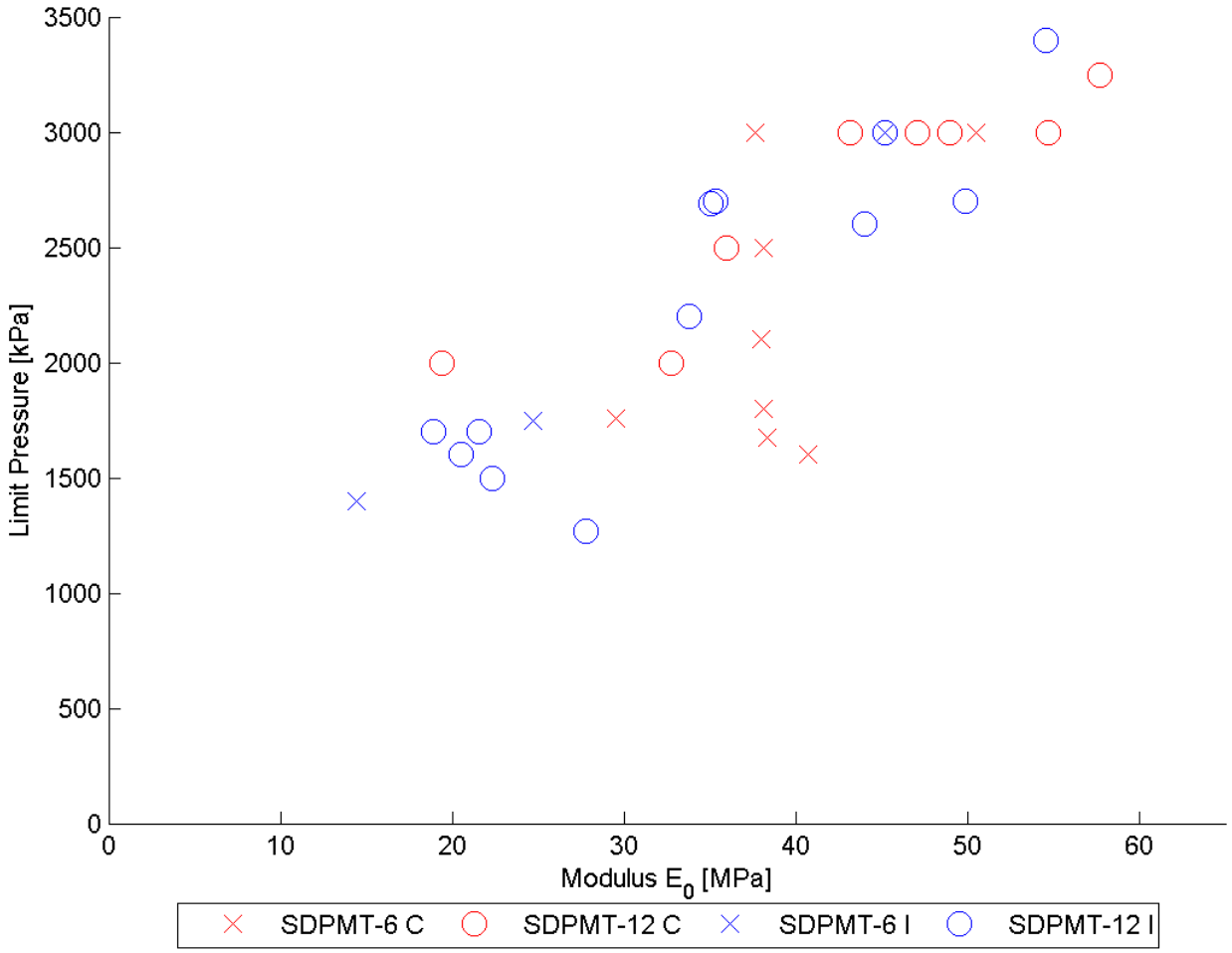
SDPMT Limit Pressure



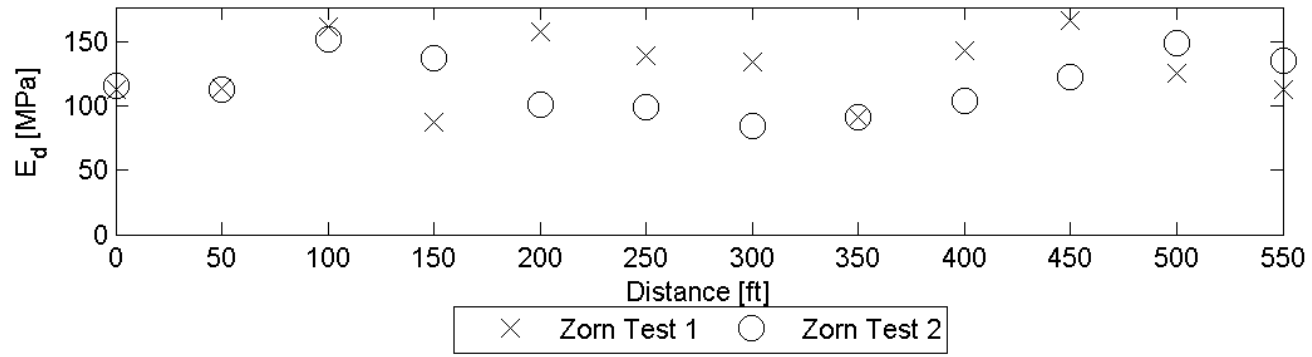
SDPMT P_L vs Dry Density

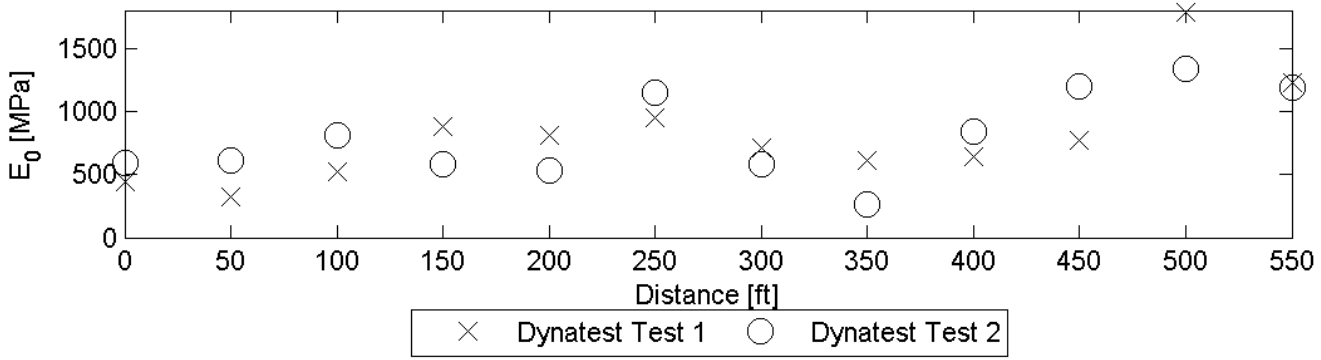


SDPMT E_0 vs P_L

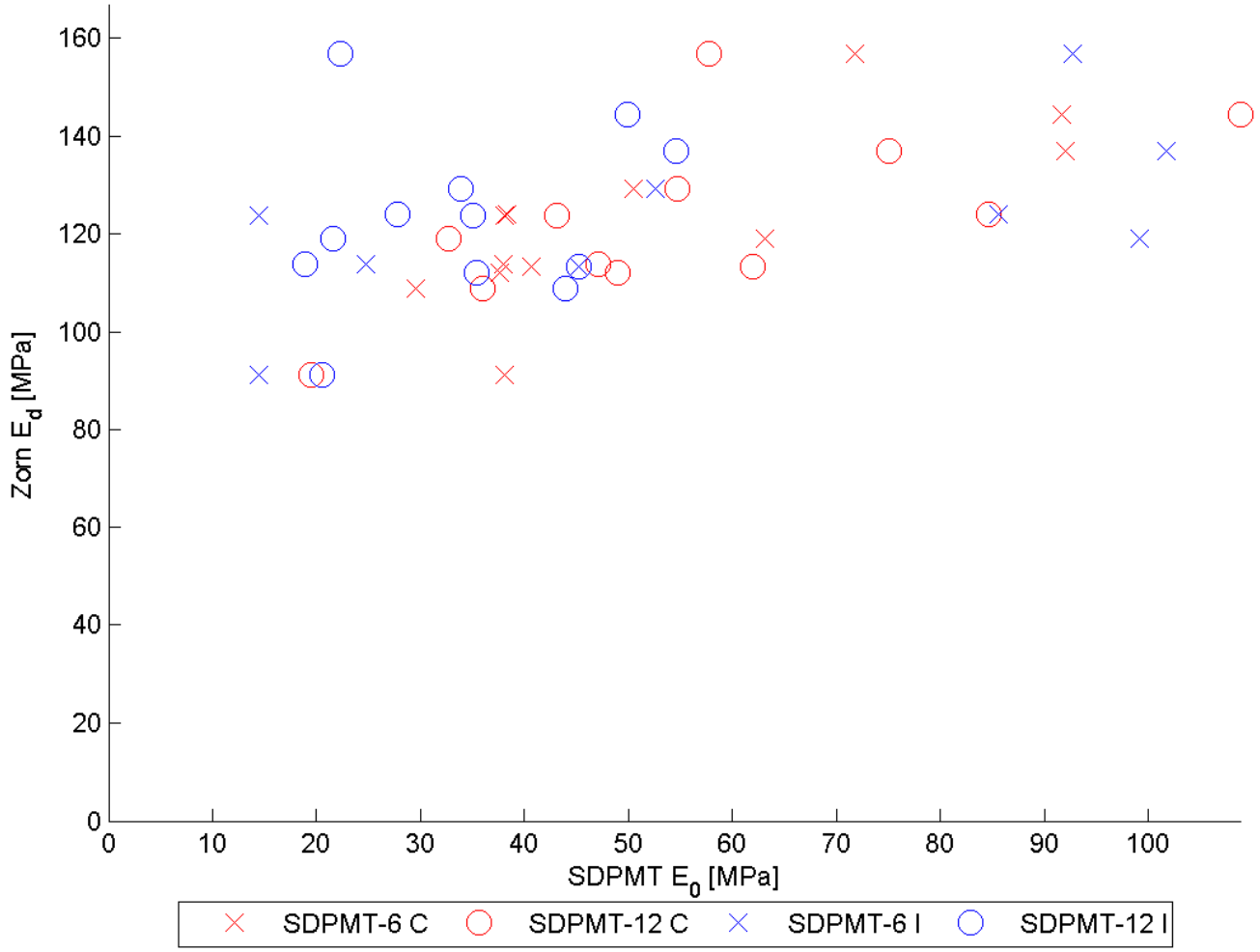


Zorn and Dynatest LWD Modulus

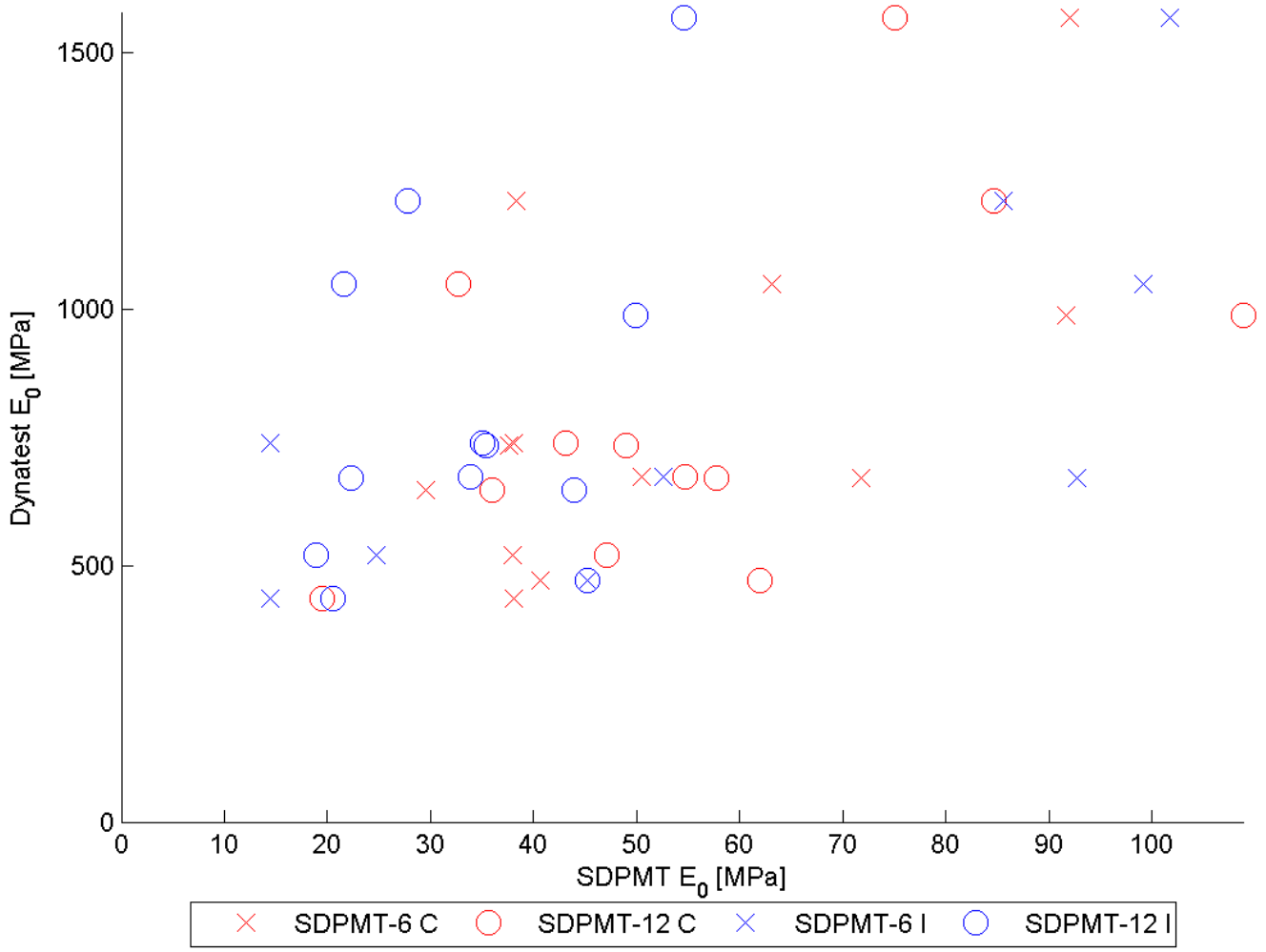




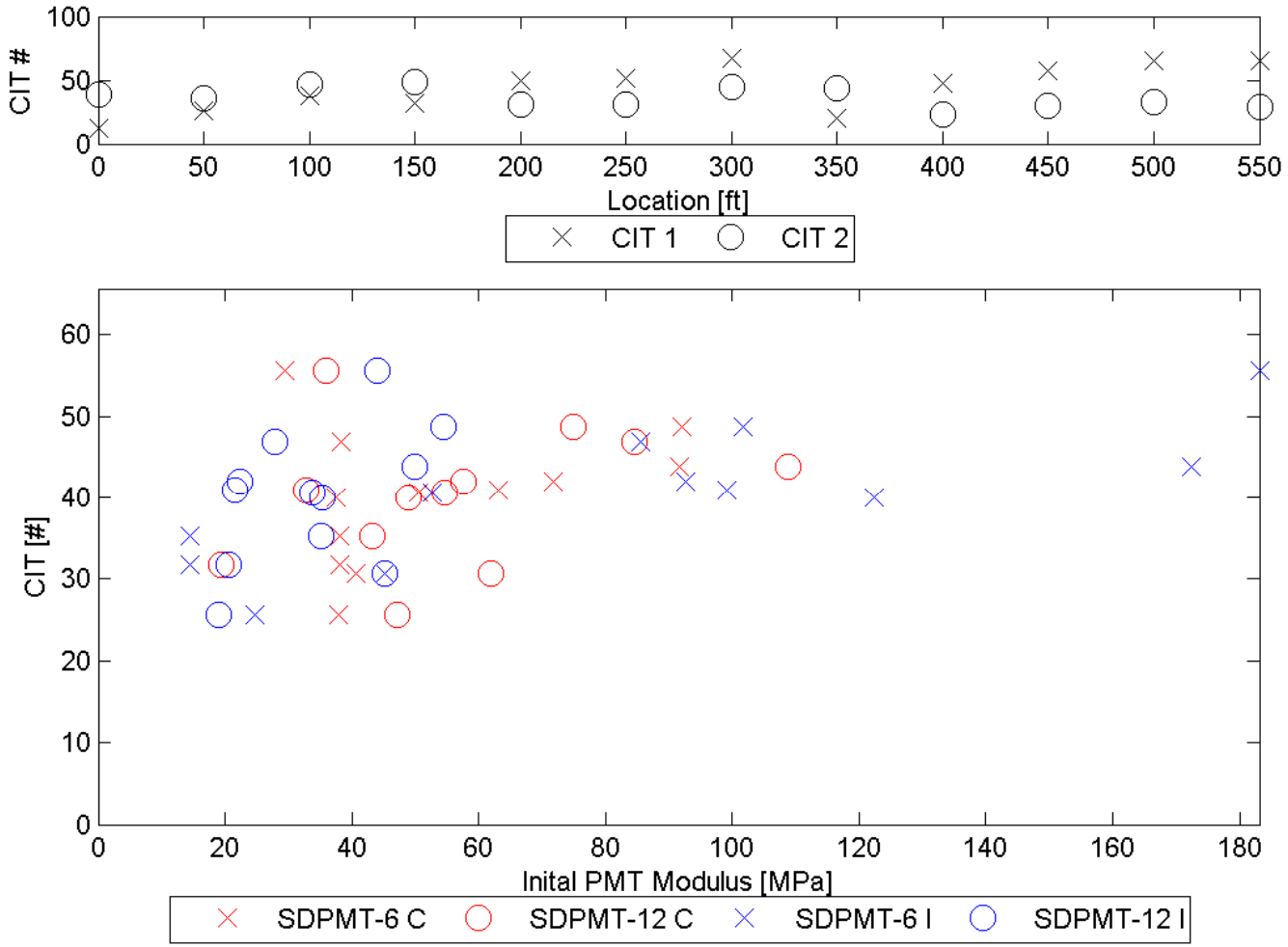
SDPMT vs Zorn LWD Modulus



SDPMT vs Dynatest LWD



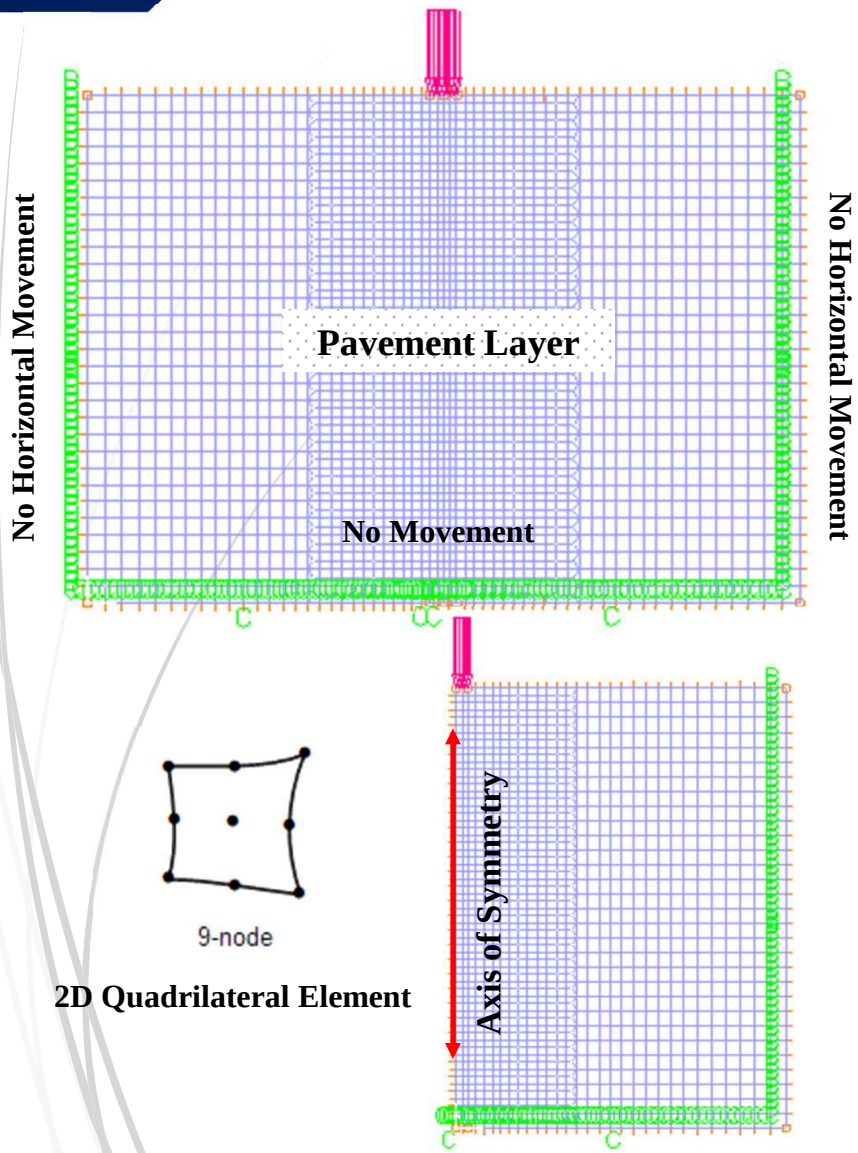
Clegg Impact Test



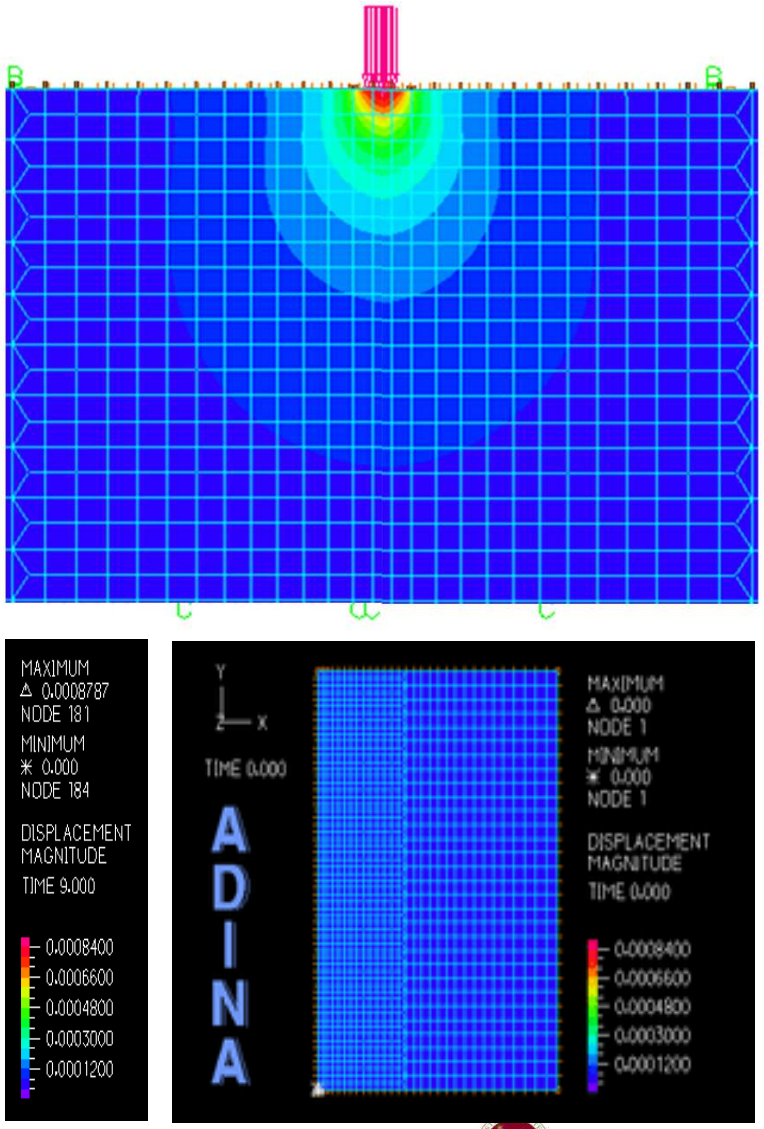
Laboratory Testing

- Grain Size Distribution
- Atterberg Limits
- Moisture Density
- LBR
- Resilient Modulus

Finite Element - Simulation

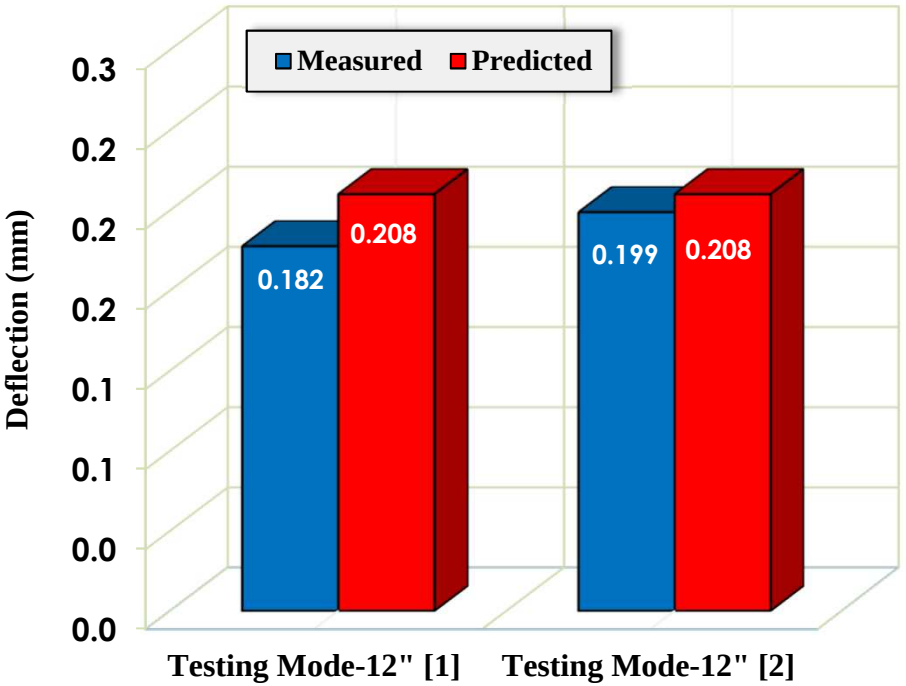


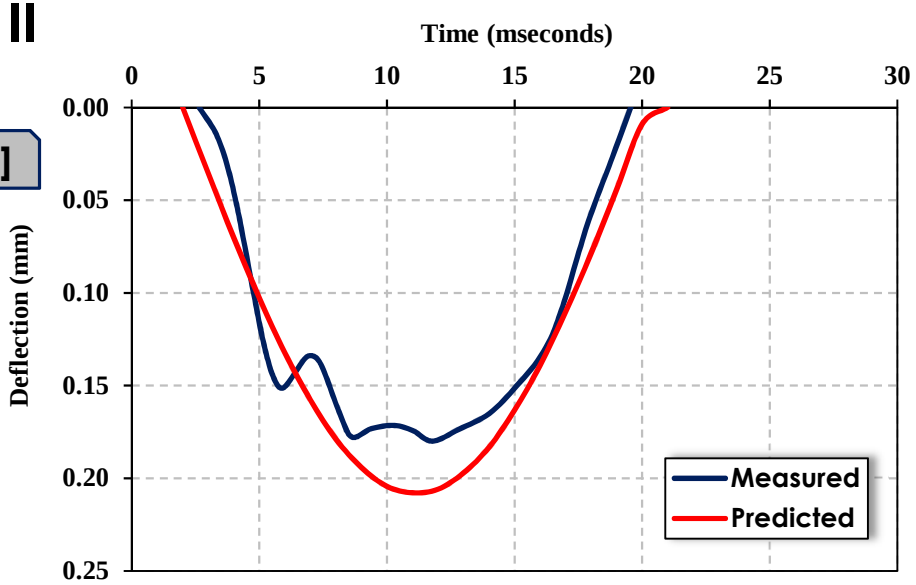
LWD Impact Load



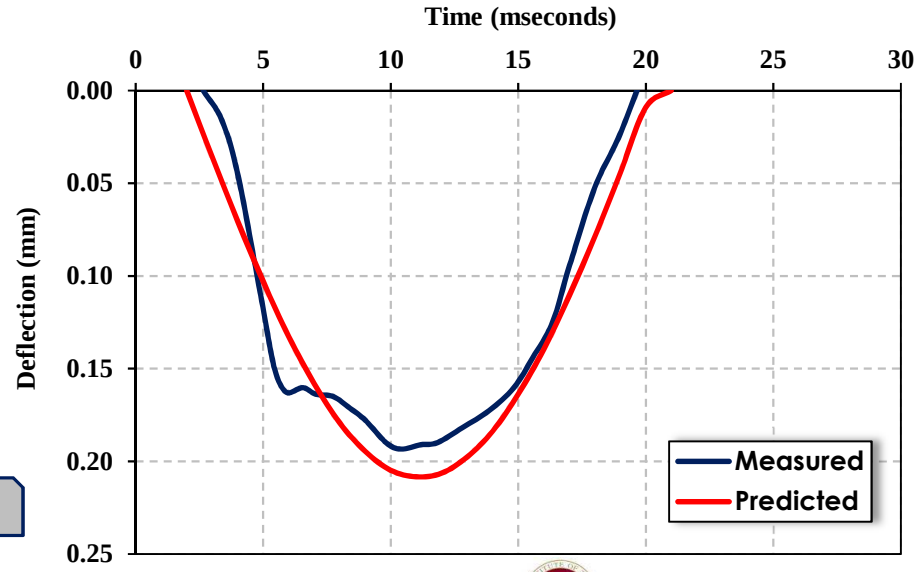
Heritage Parkway – Phase II

Testing Mode – 12 inch [1]





Testing Mode -12 inch [2]



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QUESTIONS?

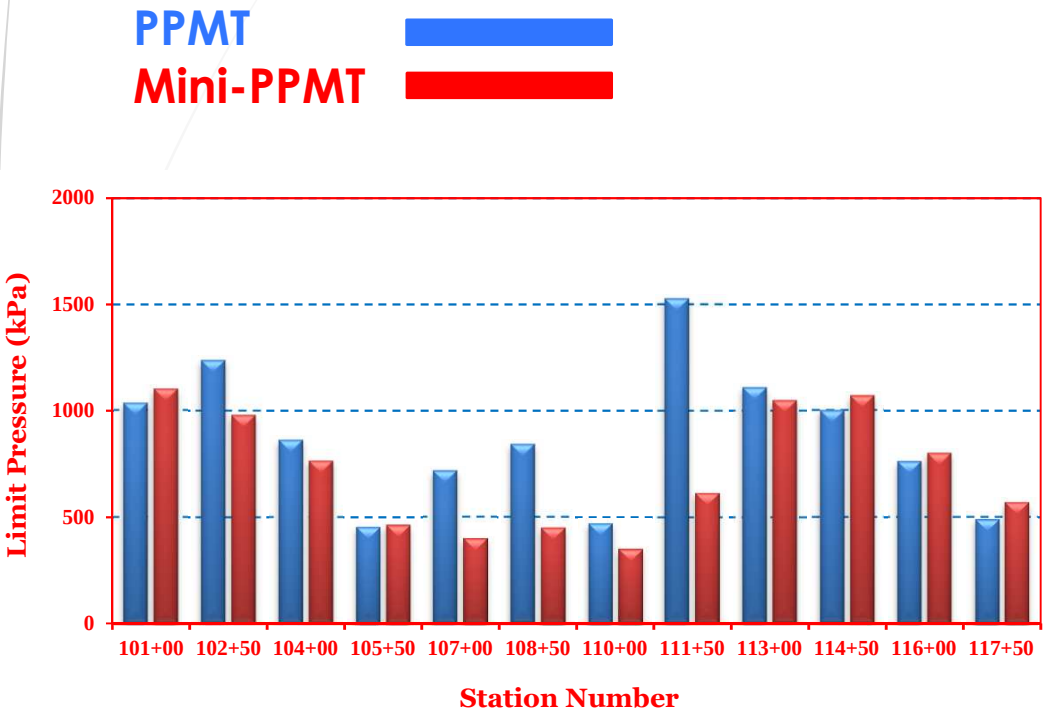
Problem Statement

Testing Limitations of NDG

- Radioactive source.
- Requires significant administrative effort.
- Produces density and moisture content not strength and stiffness.

Nuclear Density Gauge

Consistency of Field Testing Measurements (cont.)



Average [P_L]

Limit Pressure (kPa)	
PPMT	Mini-PPMT
875	717

Conclusion: Very Similar, **PPMT** p_L may be higher due to; a) longer probe length or b) protective metallic sheathing or c) outlier at Station 111+50

Project Schedule

RESEARCH TASK	1-Nov 2015	1-Dec 2015	1-Jan 2016	1-Feb 2016	1-Mar 2016	1-Apr 2016	1-May 2016	1-Jun 2016	1-Jul 2016	1-Aug 2016	1-Sep 2016	1-Oct 2016	1-Nov 2016	1-Dec 2016	1-Jan 2017	1-Feb 2017	1-Mar 2017	1-Apr 2017	1-May 2017	1-Jun 2017	1-Jul 2017	1-Aug 2017	1-Sep 2017	1-Oct 2017	1-Nov 2017	1-Dec 2017	1-Jan 2018	1-Feb 2018	1-Mar 2018	1-Apr 2018
Task 1 Literature Search	1	2	3	4																										
Task 2 Miniaturization of PMT Probe		1	2	3	4	5	6	7	8	9	10																			
Task 3 Determine Field Testing Sites				1	2	3	4	5	6																					
Task 4 Conduct Field Comparison Testing					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
Task 5 Conduct Laboratory Comparison Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25				
Task 6 Draft Final Report and Technology Transfer																								1	2	3	4			
Task 7 Final Report																												1	2	3

Field Comparison Testing

Miniaturized Pressuremeter Test

- P_o = Lift-off Pressure
- E_i = Initial Modulus
- P_L = Limit Pressure

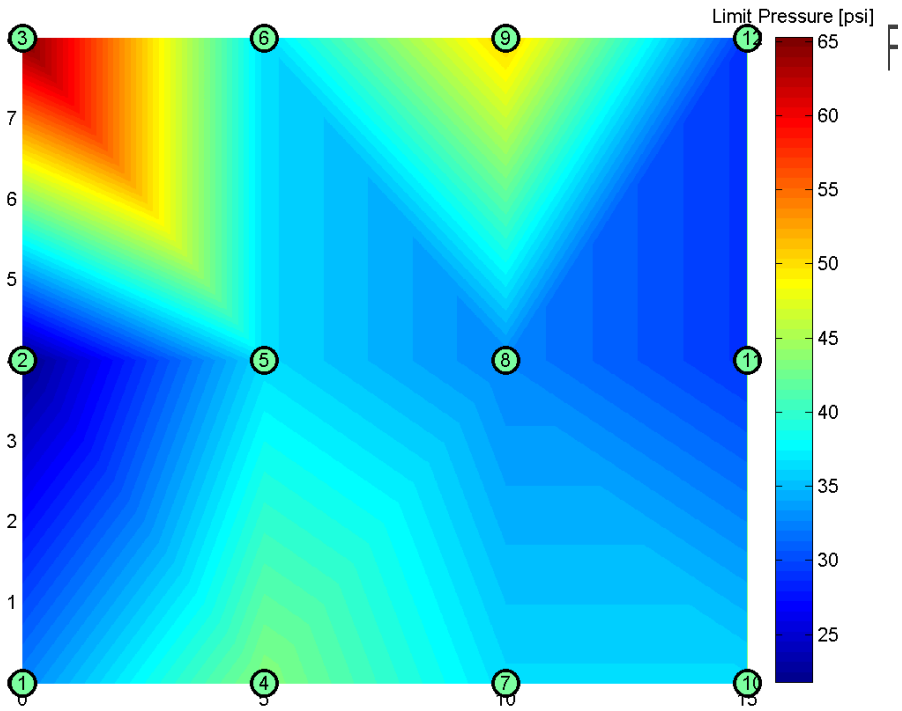
Light Weight Deflectometer	S_d = Surface Deflection	D_c = Degree of Comp	E_d = Dynamic Modulus
Nuclear Density Gauge	γ_w = Wet Unit Weight	W = Moisture Content	γ_d = Dry Unit Weight
Dynamic Cone Penetrometer	DCPI = Pen. Index	CBR = Bearing Ratio	M_r = *Resilient Modulus*

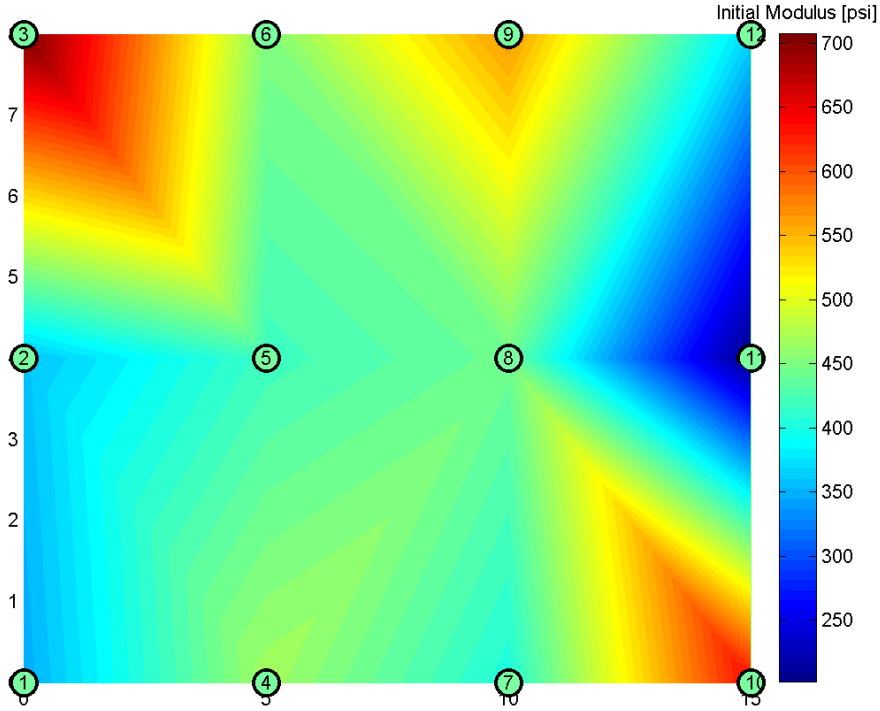
Field Testing Measurements

Pavement Layer	Modulus Parameters			Strength Parameters			Compaction Parameters		
Soil Property	**Mr**	**Ed**	**Ei**	**CBR**	**PL**	**Po**	**DC**	**γ_d**	**w**
Subgrade Soils	↑	↑	↑	↑	↑	↑	↑	↑	↑
	DCP	LWD	MPMT	DCP	MPMT	MPMT	LWD	NDG	NDG
Base Course	↓	↓	↓	↓	↓	↓	↓	↓	↓

$$\text{Mean} = \frac{\sum x_i}{N} \quad \Rightarrow \quad \text{Std.} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{N}} \quad \Rightarrow \quad \text{COV} = \frac{\text{Std.}}{Mean}$$

Preliminary SDPMT Results



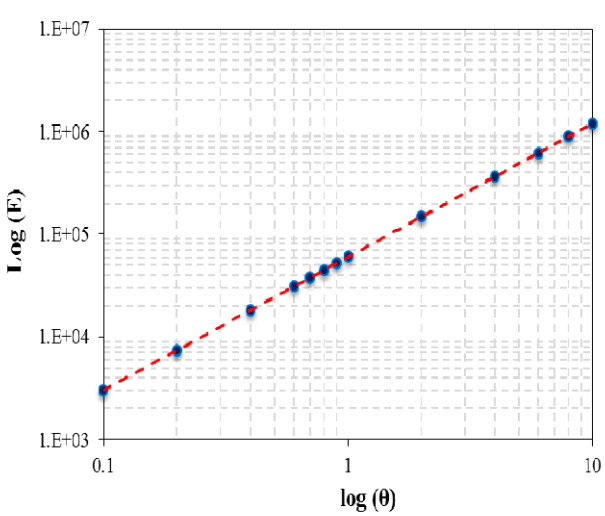


Laboratory Testing Measurements

Resilient Modulus Test

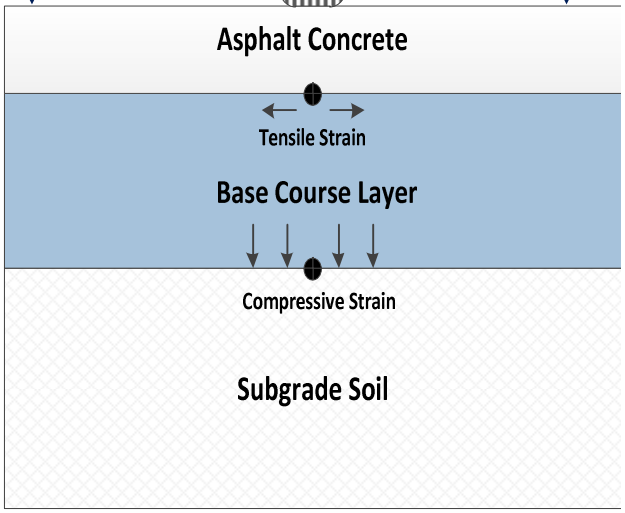
k-Θ Model

$$\left[E = k\left(\frac{\theta}{P_a}\right)^{n_s}\right]$$



ILLIPAVE 2005
Non-linear Finite Element Software for Pavement Analysis and Design

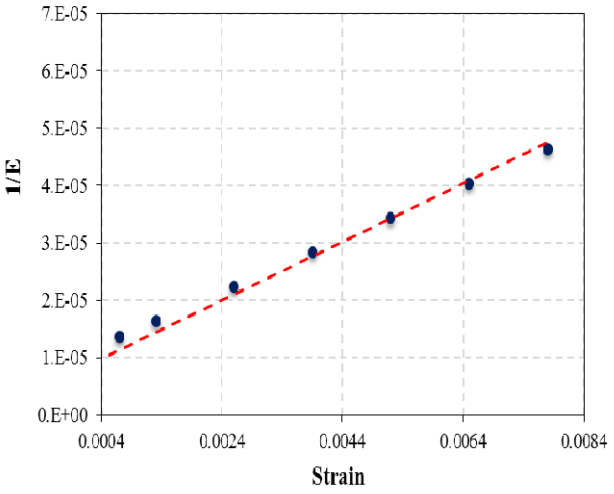
Single Axle with Single Wheel



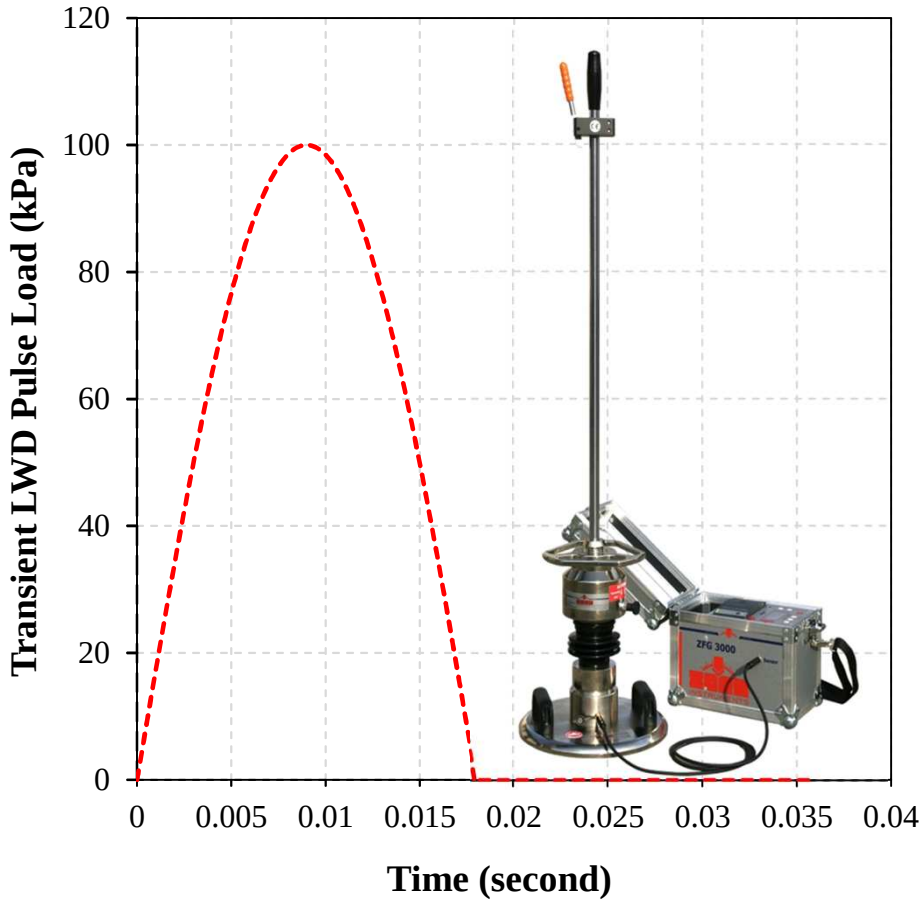
Miniaturized PMT Test

Strain Model

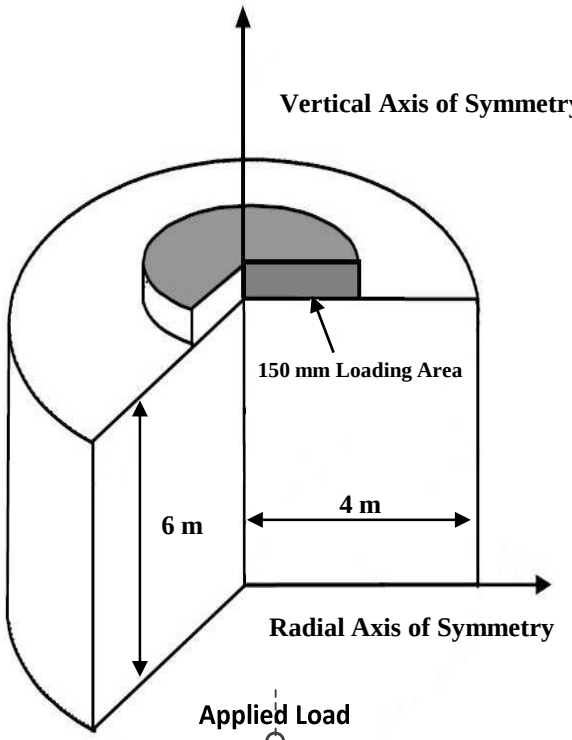
$$\left[\frac{1}{E} = a + b\varepsilon\right]$$

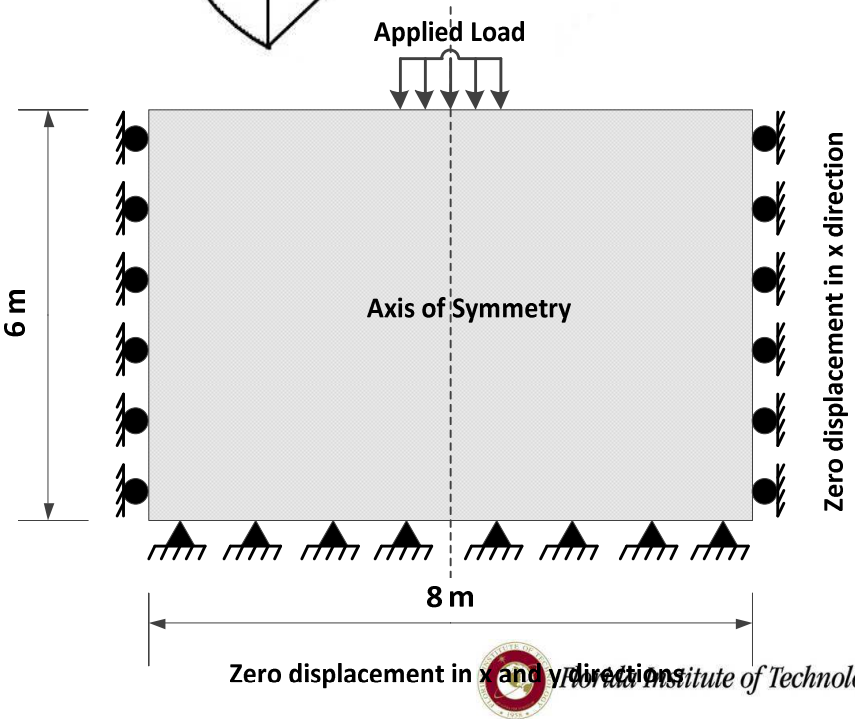


Finite Element - Geometry

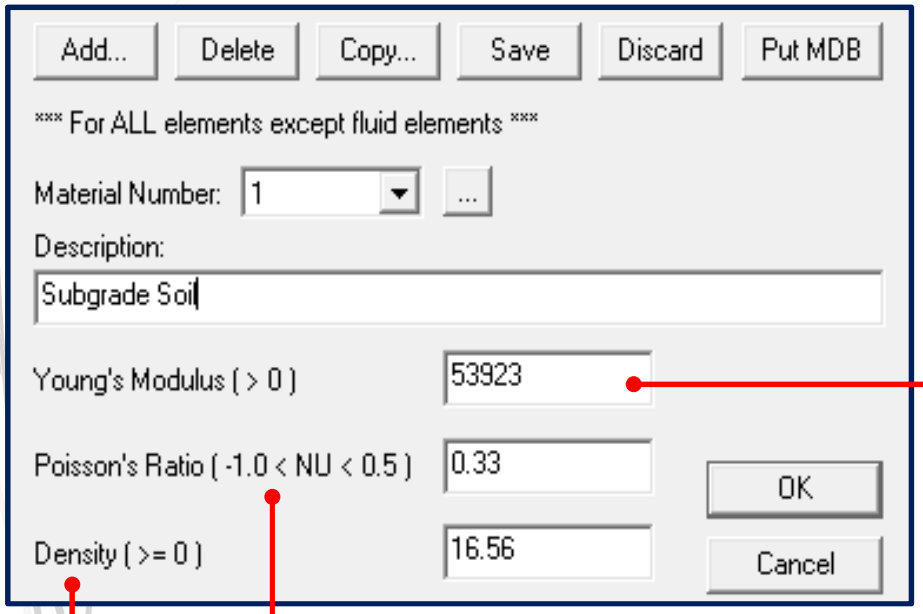


LWD Dynamic Loading Condition



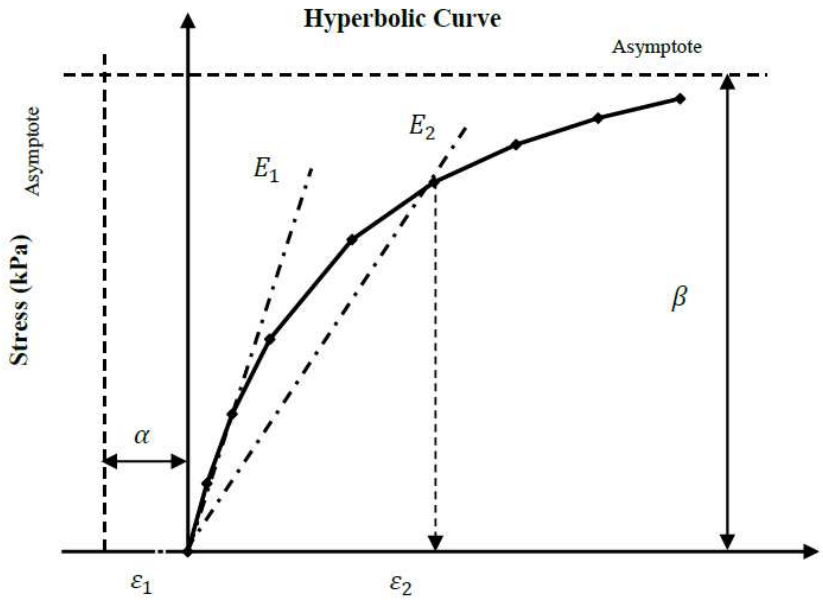


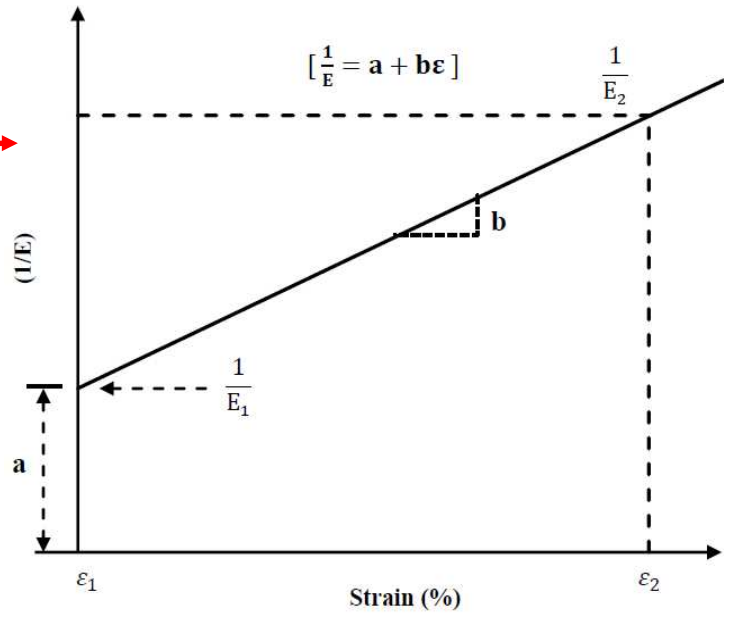
Finite Element - Inputs



Poisson's Ratio = 0.33 (Assumed)

Density obtained from NDG Measurements

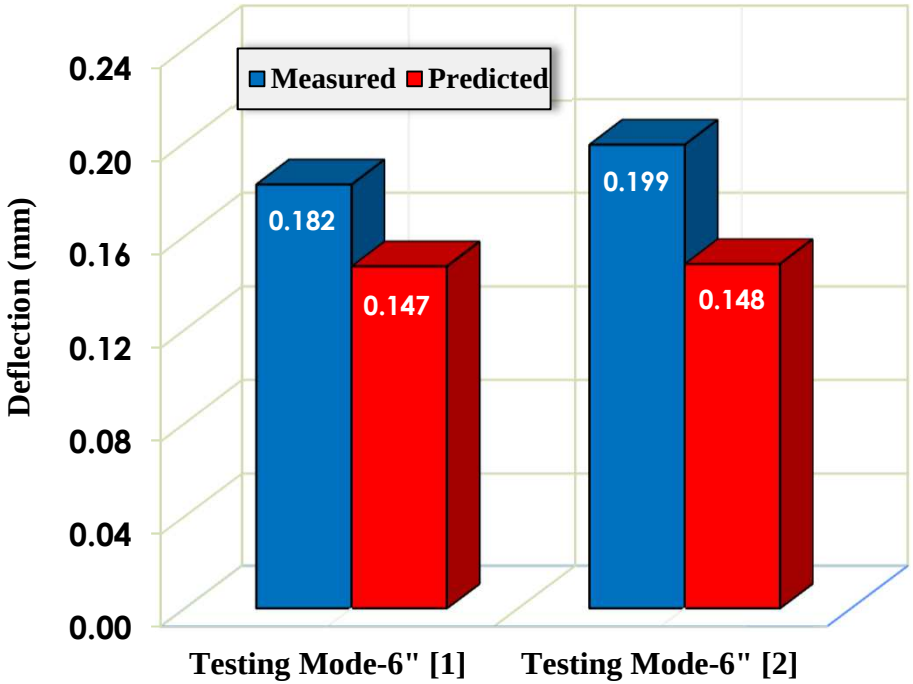


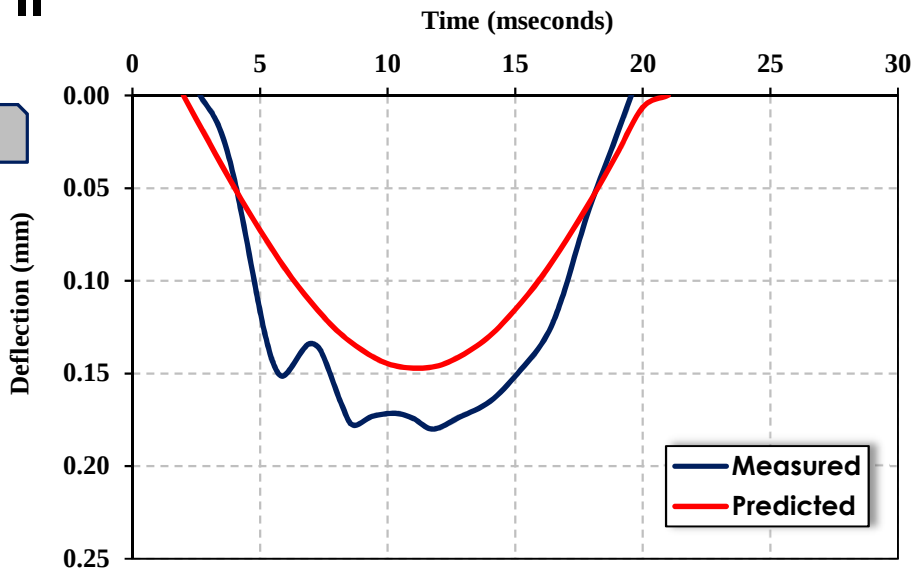


nology

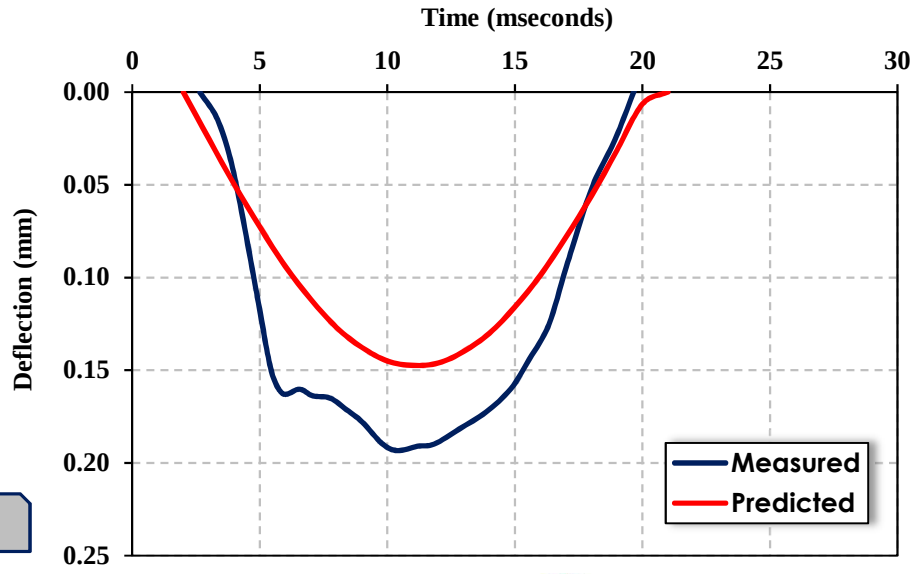
Heritage Parkway – Phase II

Testing Mode – 6 inch [1]





Testing Mode -6 inch [2]



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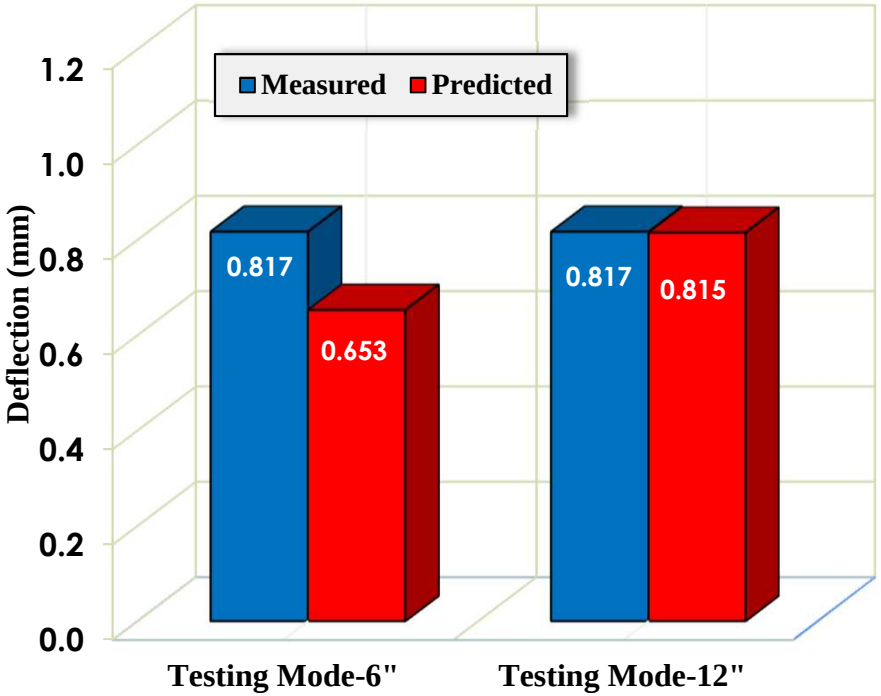
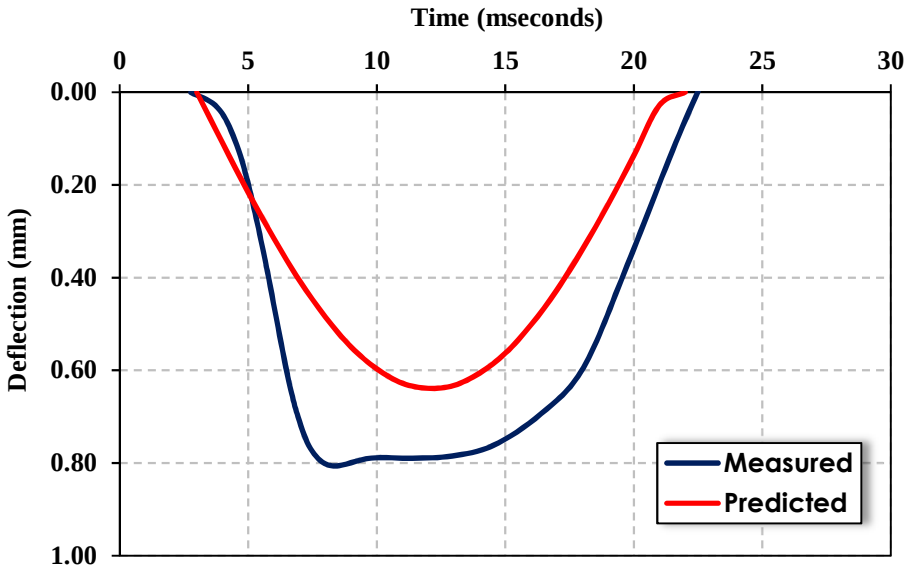
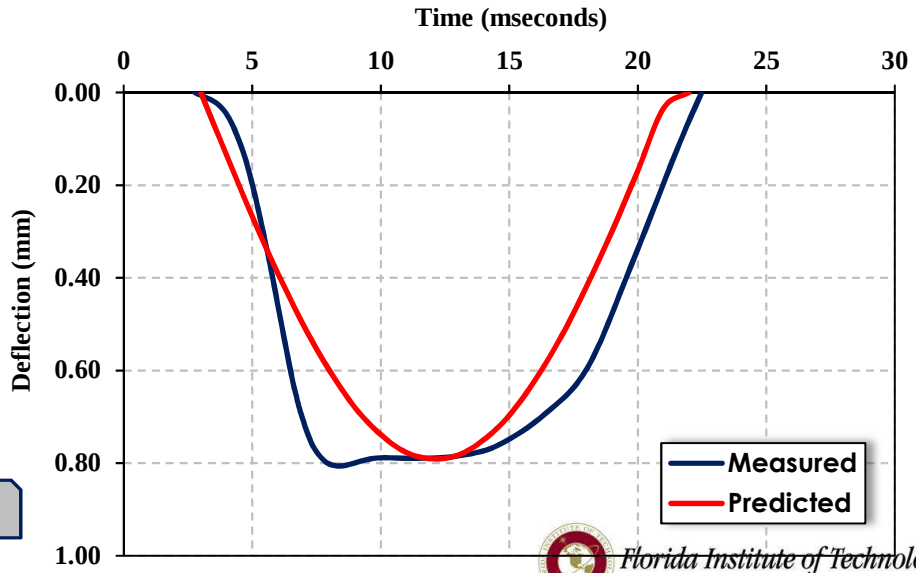
OverFlow Parking Lot - FIT

Testing Mode – 6 inch



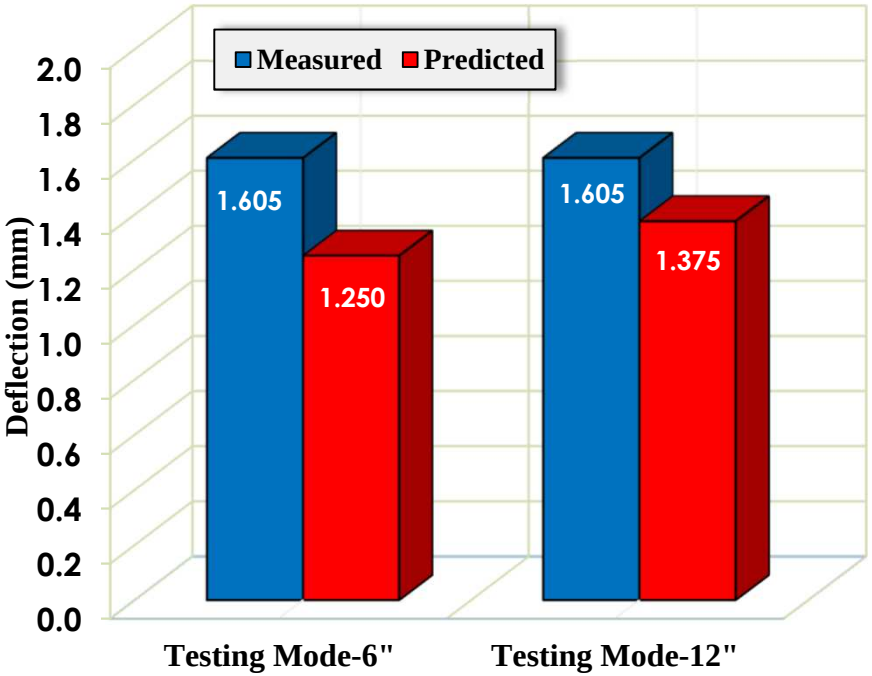


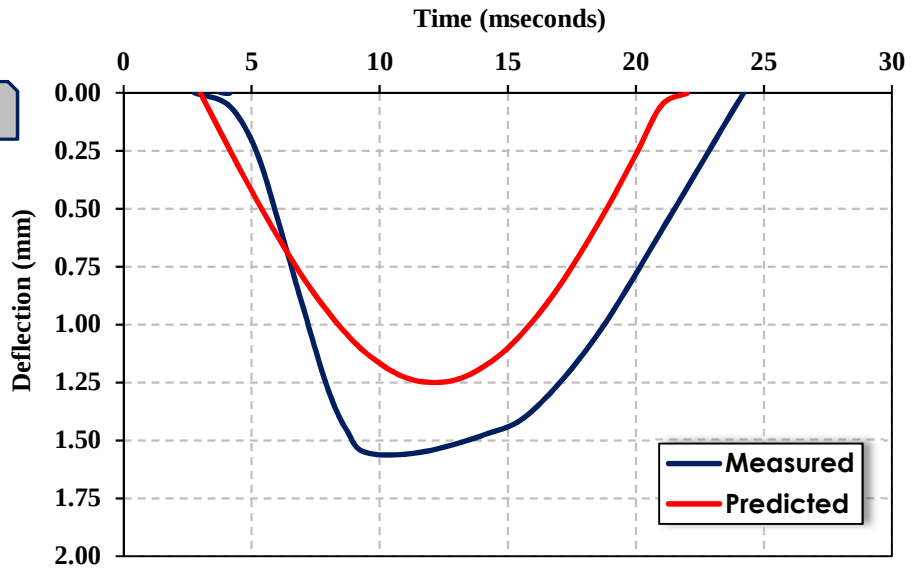
Testing Mode -12 inch



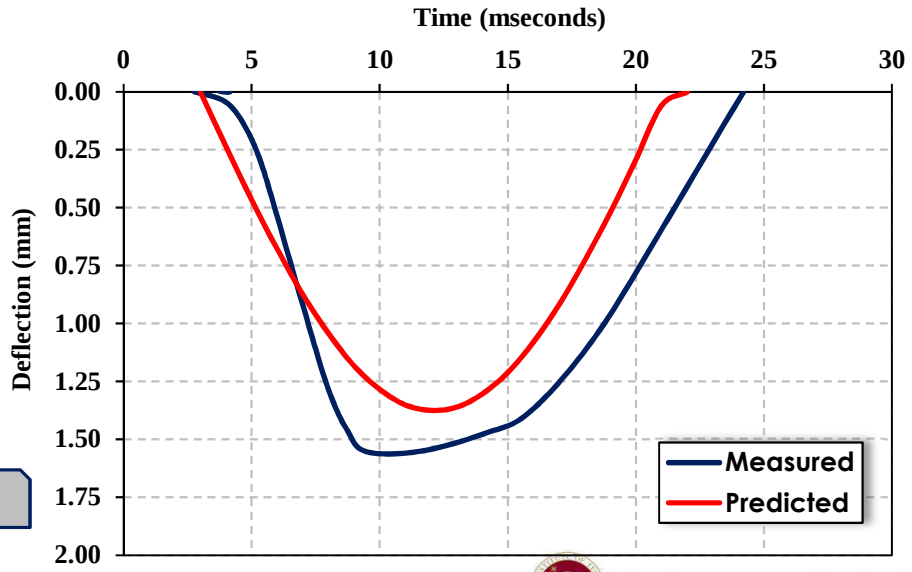
Southgate Recreation Field -FIT

Testing Mode – 6 inch





Testing Mode -12 inch



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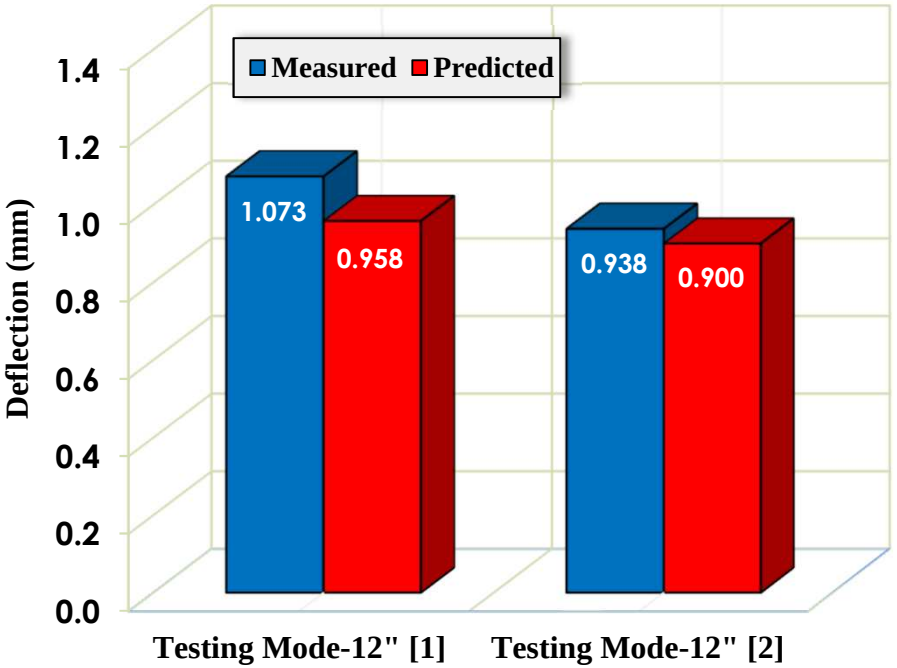
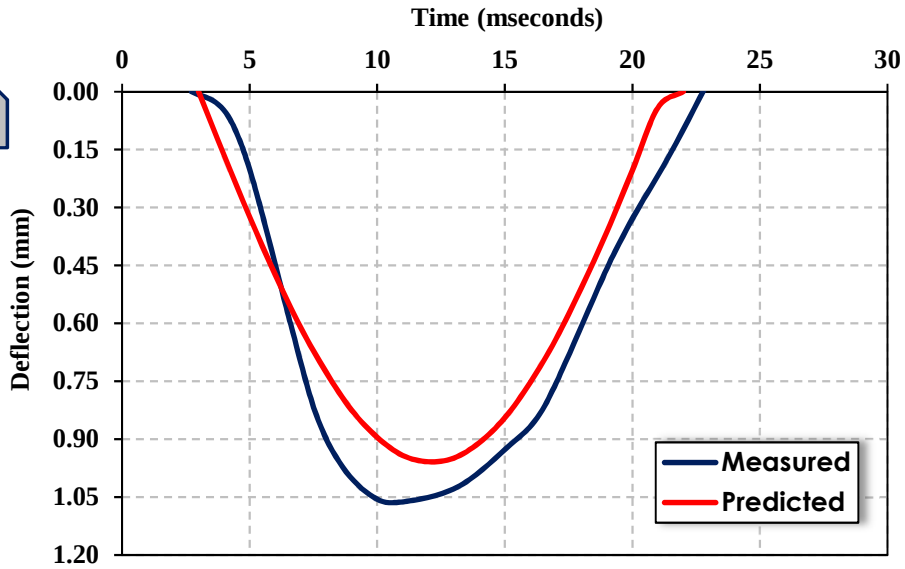
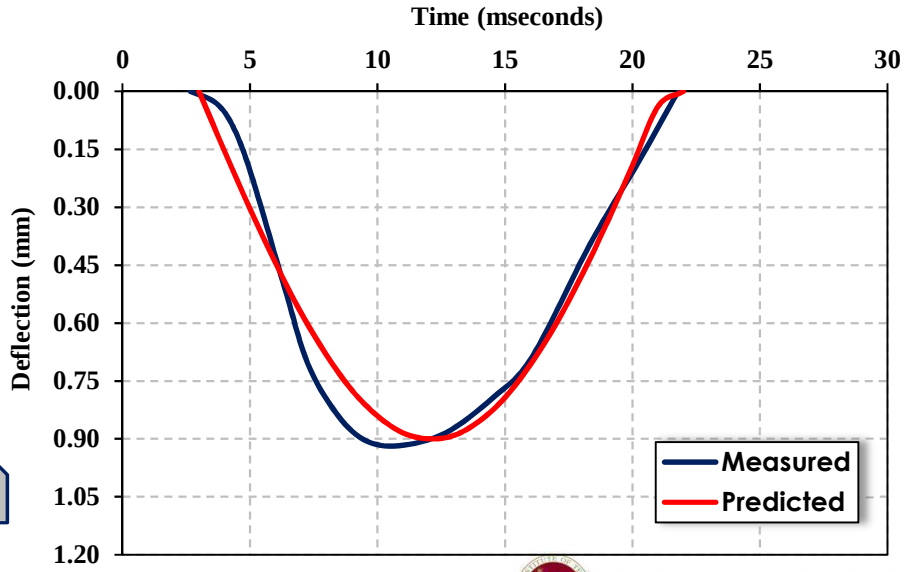
Cypress Landing

Testing Mode -12” No.1





Testing Mode -12” No.2



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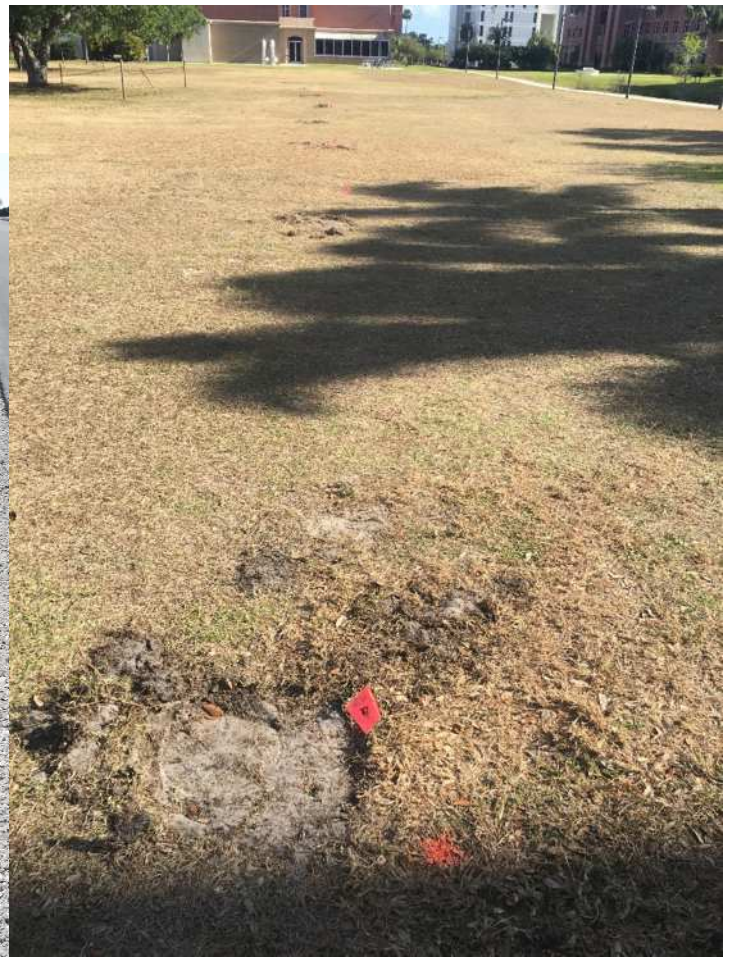
Field Test Sites



Field Testing Program

- 4 Tests Sites
  - Cypress Landing
    - Subdivision
    - Subgrade
  - FIT Olin Complex
    - Overflow Parking
    - Heavily Compacted
  - Heritage Parkway
    - City Bypass
    - Base Material
  - FIT Southgate Field
    - Athletic Field

- Testing Program
  - SDPMT-6 Incremental
  - SDPMT-12 Incremental
  - SDPMT-6 Continuous
  - SDPMT-12 Continuous
  - Dynamic Cone Penetrometer
  - Lightweight Deflectometer
    - Zorn
    - Dynatest
  - Falling Weight Deflectometer
  - Nuclear Density Gauge
  - Clegg Impact Test

Testing Summary

Test	Cypress Landing	FIT Olin Complex	Heritage Parkway	FIT Southgate Field
NDG	24	24	36	24
SDPMT-6 Incremental	0	12	12	12
SDPMT-12 Incremental	11	12	12	12
SDPMT-6 Continuous	0	12	12	12
SDPMT-12 Continuous	10	12	12	11
Zorn LWD	24	12	24	12
Dynatest LWD			24	12
Clegg Impact	24	24	24	24
DCP	12	12	0	12
FWD	0	0	15	0