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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[2018-GRIP MEETING]

BACKGROUND

- *Nuclear Density Gage Testing yields Density and Moisture*
- *Strength and Stiffness of Pavement Layers is critical*
- *In situ strength and stiffness pavement properties only available from Pressuremeters*
- *Pavement Engineers could benefit from small diameter PMT testing in NDG hole*

OBJECTIVE

Develop and evaluate digital in-situ stress-strain responses for 6 & 12-inch long SDPMT probes using both incremental & rapid strain-controlled tests in 6 & 12 inch unbound pavement layers.

FIELD TESTING SITES

- FIT Campus Overflow Parking
  - A-3 / SP LBR: 10
- FIT Campus Southgate Intramural Field
  - A-3 / SP LBR: 7
- Cypress Landing Residential Development
  - A-3 / SP LBR: 6
- Saint Johns Heritage Parkway
  - Cemented Coquina Base
  - A-1-b / SW LBR: 99

FIELD TEST SITES

FIELD TESTS

- PMT Probe Sizes
  - SDPMT – 6-inch
  - SDPMT – 12-inch
- PMT Test Profiles
  - Incremental
  - Continuous / Rapid
- Nuclear Density
- Lightweight Deflectometers
  - Dynatest
  - Zorn
- Clegg Impact Test
- Dynamic Cone Penetrometer

LABORATORY TESTS

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

TESTING OBSERVATIONS

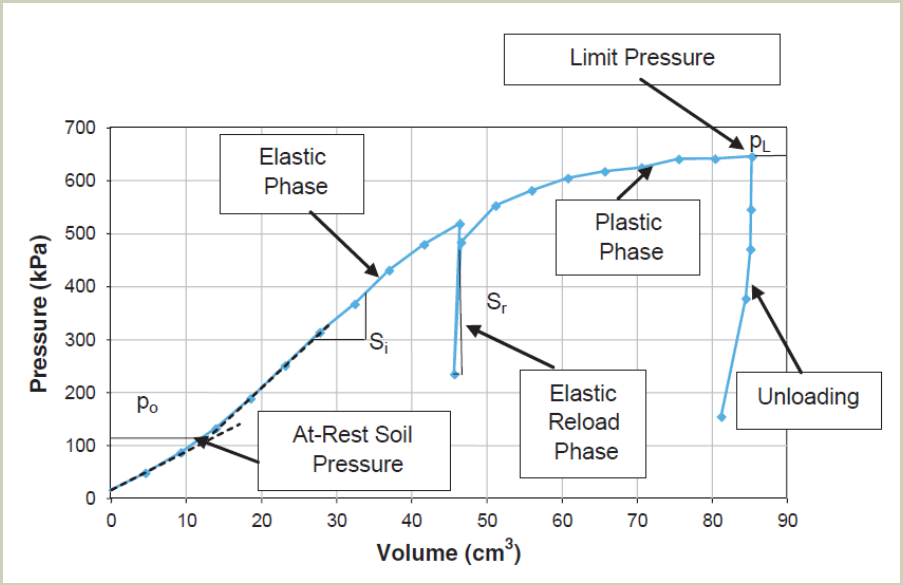
- Fits NDG Hole
  - Standard 7/8”
  - Modified SDPMT 3/4“
- Surface Cracking
  - Surcharge Plates
- Drill and Drive
  - 5/8” Bit
  - 3/4“ NDG Drive Pin

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	12	9	24	12
Clegg Impact	24	24	24	24
DCP	12	12	0	12
Resilient Modulus	6	6	8	6

TYPICAL PPMT CURVE

Typical PPMT Curve

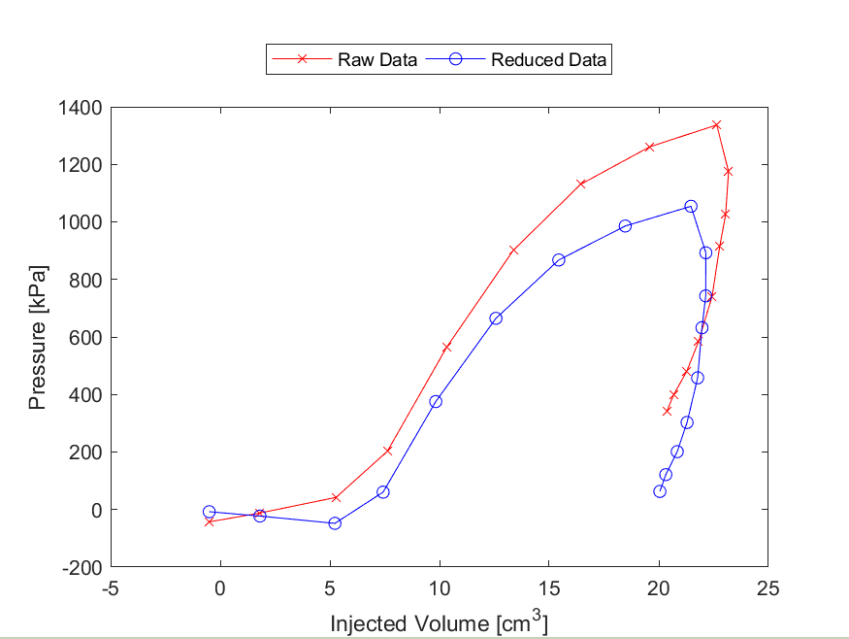


Key Parameters

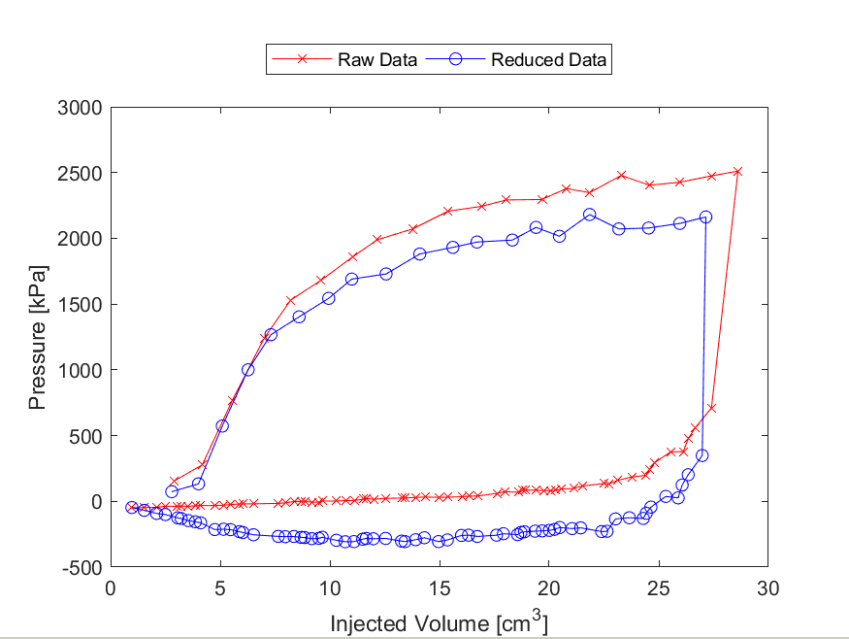
- Observe Elastic Phase
  - Initial Slope (S_i)
- Observe Plastic Phase
  - Estimate Limit Pressure (p_L)
- Unloading Phase
  - Strain verses 1/E vs
- At-Rest Soil Pressure
  - Lift-Off Pressure (p_0)
- Elastic Reload Phase

TYPICAL SDPMT 6-INCH CURVES

Incremental (6I)

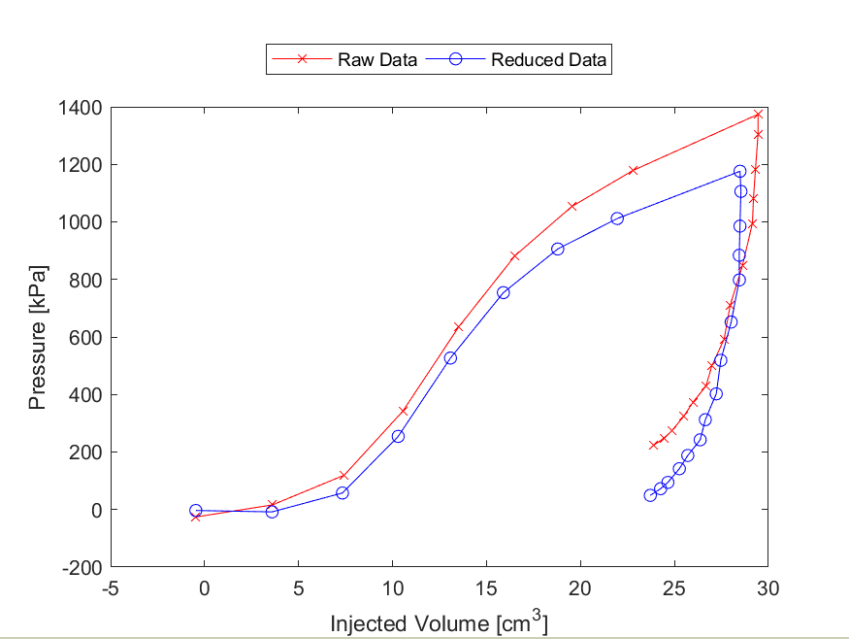


Continuous / Rapid (6C)

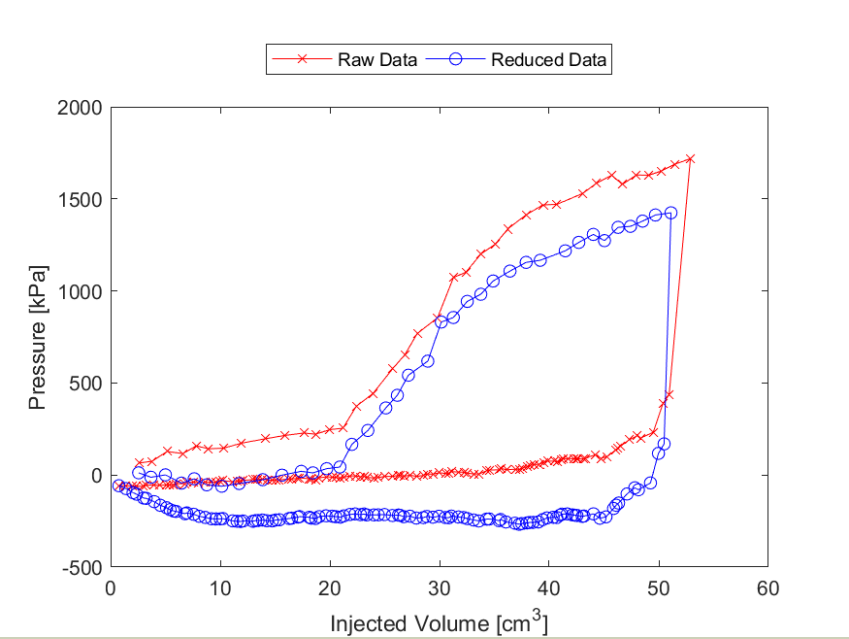


TYPICAL SDPMT 12-INCH CURVES

Incremental (12I)



Continuous / Rapid (12C)



STRESS – STRAIN RESPONSE CONCLUSIONS

- Observed that the stress – strain response from the incremental and continuous 6 and 12 inch tests resembles those of standard PPMT curve.
- Test quality indicator -- E_0/P_0-- for incremental SDPMT tests average ratio from 7.0 to 16.1 for both 6 and 12 inch probes; similar to Briaud's published ratios of 7 to 12; therefore the test quality is acceptable.
- The test quality indicator -- E_0/P_0 -- for rapid or continuous SDPMT tests ranged from 10.9 to 33.2 for 6 and 12 inch probes; although higher than upper range of 12; the tests are still of good quality.
  - Higher values due to the increased strain-rate compared to incremental test.

STRESS – STRAIN RESPONSE CONCLUSIONS

- pL/E0 for incremental tests ranged from 0.62 to 0.142; Briaud, 1992 estimated ratio of 0.125 and the Cosentino et al. (2008) ratio of 0.079 places the data from these tests in the same general area.
  - The lower values expected because of the stiffer material tested.
- Therefore the developed probes measure realistic stress – strain response of the unbound pavement layers.

CORRELATION OVERVIEW

Comparisons Between SDPMT Parameters

- E_0 verses p_0
- p_L verses p_0
- E_0 verses p_L

Comparison Between SDPMT Parameters and Other Tests

- γ_{dry} and γ_{wet} verses E_0, p_0, p_L
- E_d Zorn LWD verses E_0, p_0, p_L
- E_0 Dyanatst LWD verses E_0, p_0, p_L
- CIV verses E_0, p_0, p_L
- DCP Index verses E_0, p_0, p_L

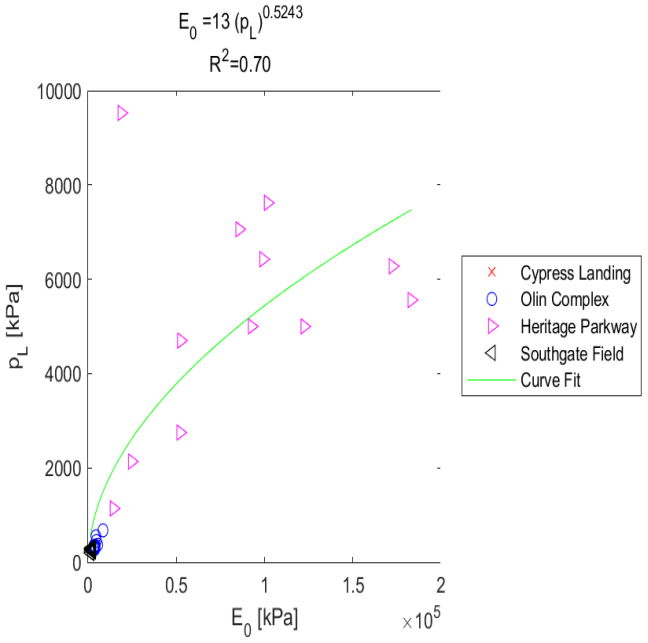
5 MODEL TYPES

Model Relationship	Generalized Model
Linear	$A = A * X + B$
Log – Linear	$\log_{10}(Y) = A * X + B$
Linear – Log	$Y = A \log_{10}(X) + B$
Log – Log	$\log_{10}(Y) = A \log_{10}(X) + B$
Exponential	$Y = A * (X)^B$

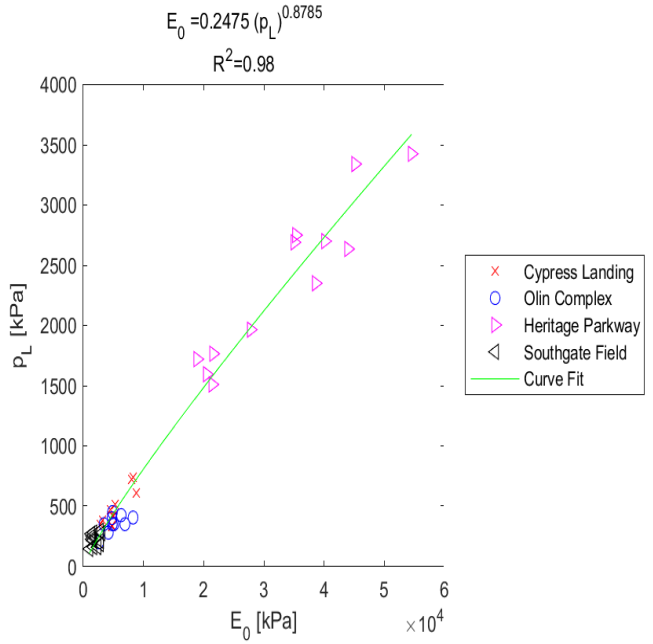
SDPMT INTERNAL COMPARISONS

		Linear	Log-Linear	Linear-Log	Log-Log	Exponential
E0 vs. p0	6I	0.10	0.12	0.13	0.16	0.10
	6C	0.09	0.24	0.19	0.39	0.16
	12I	0.42	0.47	0.46	0.47	0.48
	12C	0.06	0.09	0.12	0.16	0.11
pL vs. p0	6I	0.09	0.10	0.12	0.13	0.10
	6C	0.20	0.29	0.34	0.43	0.29
	12I	0.43	0.50	0.47	0.53	0.49
	12C	0.12	0.10	0.19	0.18	0.18
E0 vs. pL	6I	0.60	0.74	0.67	0.91	0.63
	6C	0.91	0.91	0.76	0.90	0.92
	12I	0.98	0.84	0.86	0.93	0.98
	12C	0.75	0.83	0.67	0.81	0.75

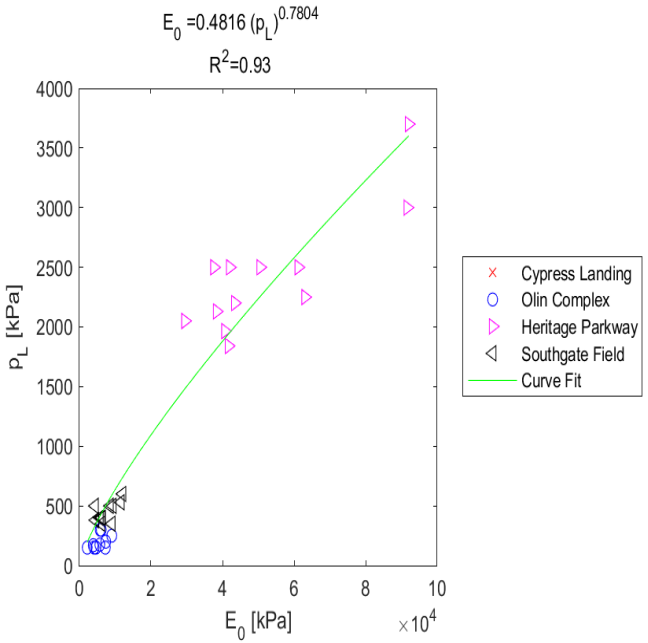
6-in Incremental



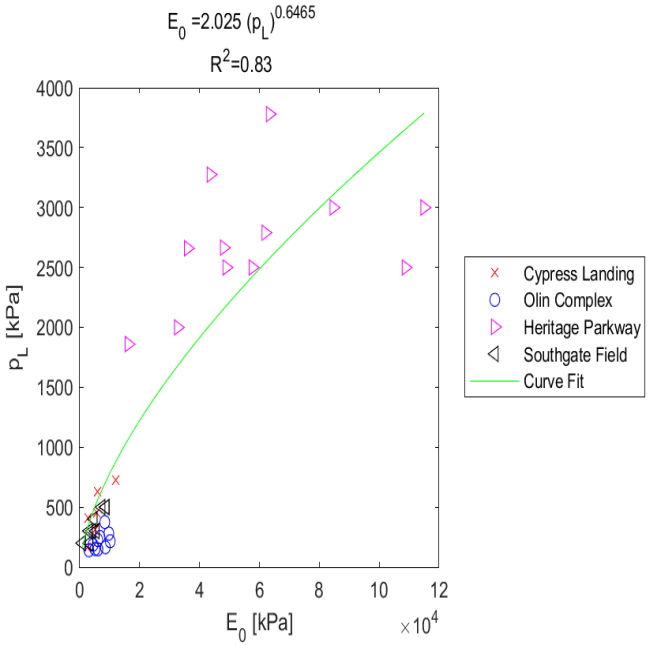
12-in Incremental



6-in Continuous

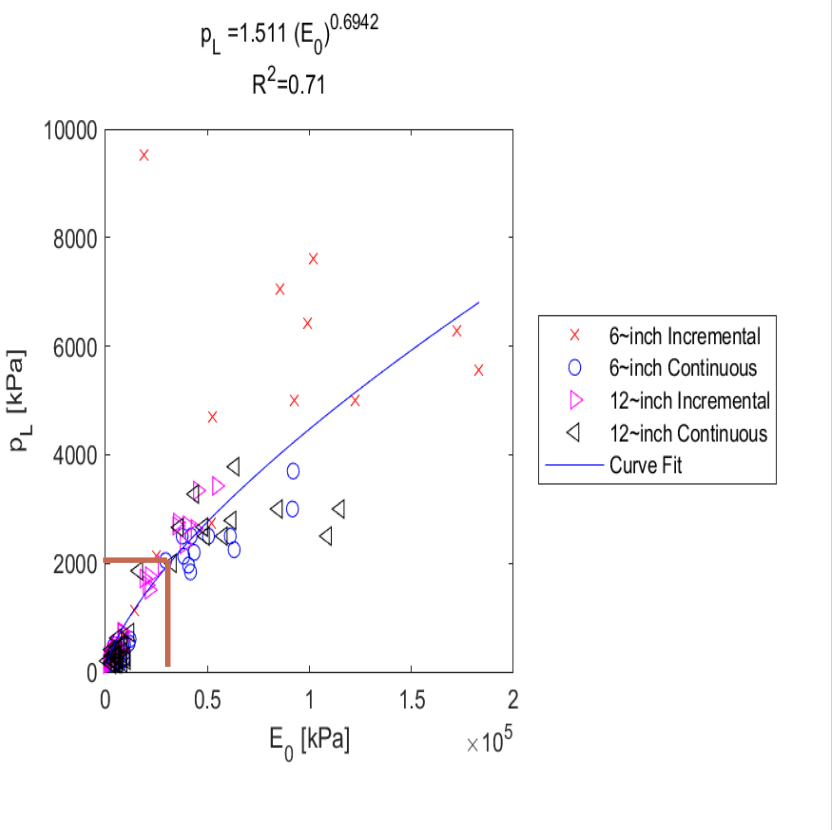


12-in Continuous

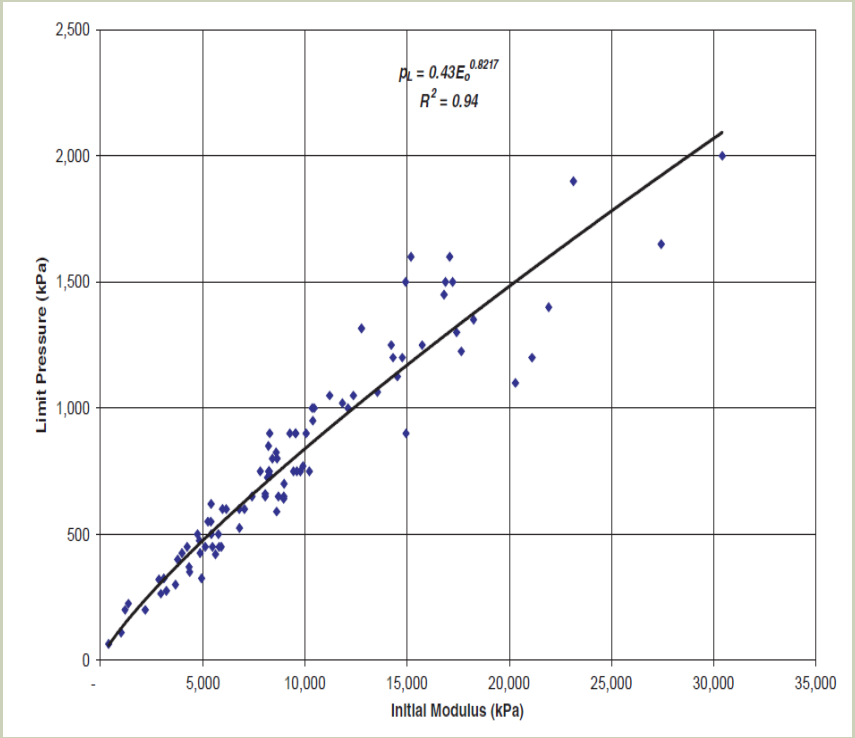


COMPARISON TO EXISTING CORRELATION

Project



Previous -- Silty Sands



Cosentino, Paul J, Kalajian, Edward, Messaoud, Farid, Sundaram, Sunil, Misilo, Thaddeus J, and Horhota, David J. "Correlations between PENCEL pressuremeter, cone penetrometer, and dilatometer parameters." Transportation Research Record: Journal of the Transportation Research Board 2053 (2008).1: 65-71.

CONCLUSIONS FOR P_L VERSES E_0

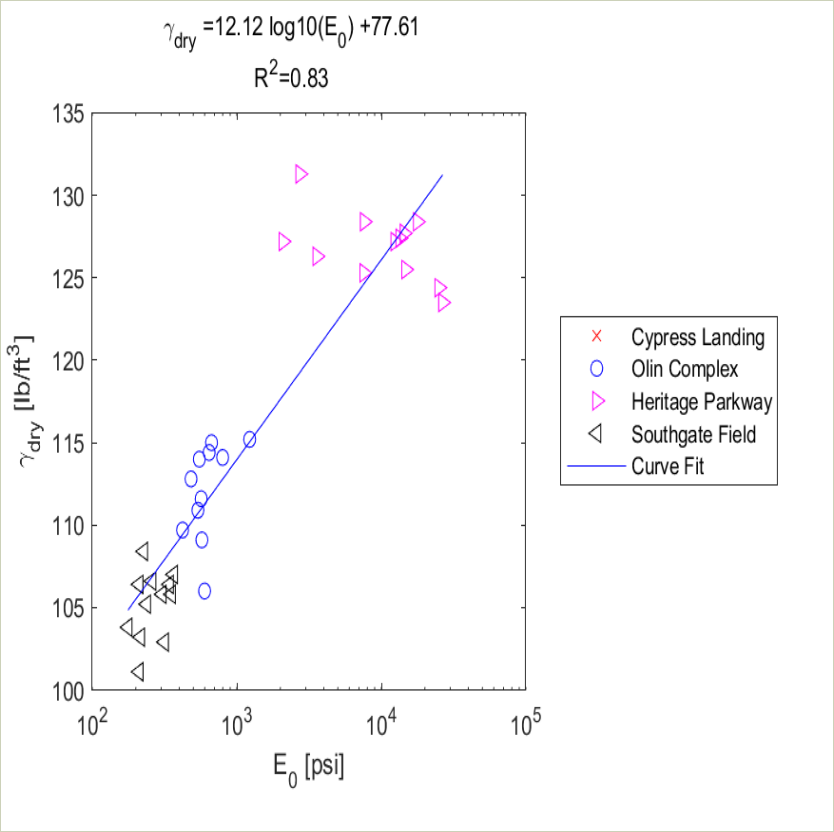
- Data collected during this research shows an excellent correlation between p_L and E_0.
- An exponential relationship exists between p_L and E_0.
- SDPMT test data shows similar results to work by Cosentino et al. for the relationship between p_L and E_0

DRY UNIT WEIGHT COMPARISONS

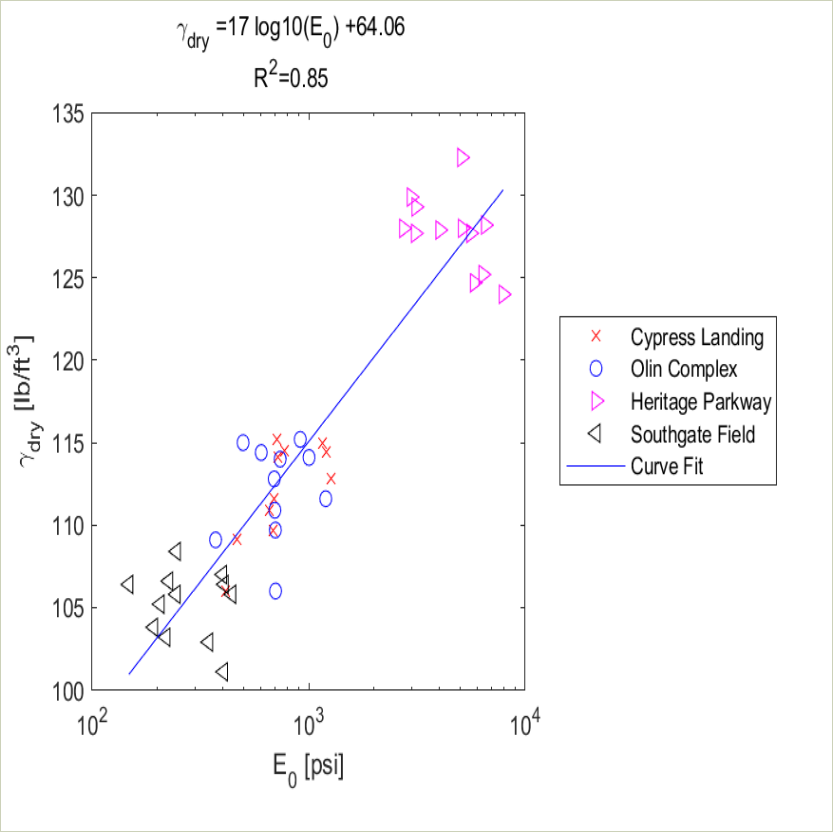
		linear	Linear-Log	log-linear	log-log	Exponential
γ_{dry} vs. E_0	6I	0.46	0.46	0.83	0.83	0.81
	6C	0.64	0.63	0.72	0.74	0.73
	12I	0.69	0.68	0.85	0.85	0.85
	12C	0.54	0.54	0.74	0.74	0.75
γ_{dry} vs. p_0	6I	0.11	0.11	0.14	0.14	0.14
	6C	0.38	0.37	0.46	0.45	0.46
	12I	0.47	0.46	0.40	0.40	0.41
	12C	0.22	0.22	0.33	0.33	0.33
γ_{dry} vs. p_L	6I	0.69	0.67	0.87	0.86	0.86
	6C	0.73	0.71	0.61	0.59	0.63
	12I	0.74	0.73	0.86	0.85	0.86
	12C	0.78	0.76	0.71	0.70	0.73

LOG-LINEAR MODELS OF γ_{DRY} VERSES E_0

SDPMT-6 Incremental

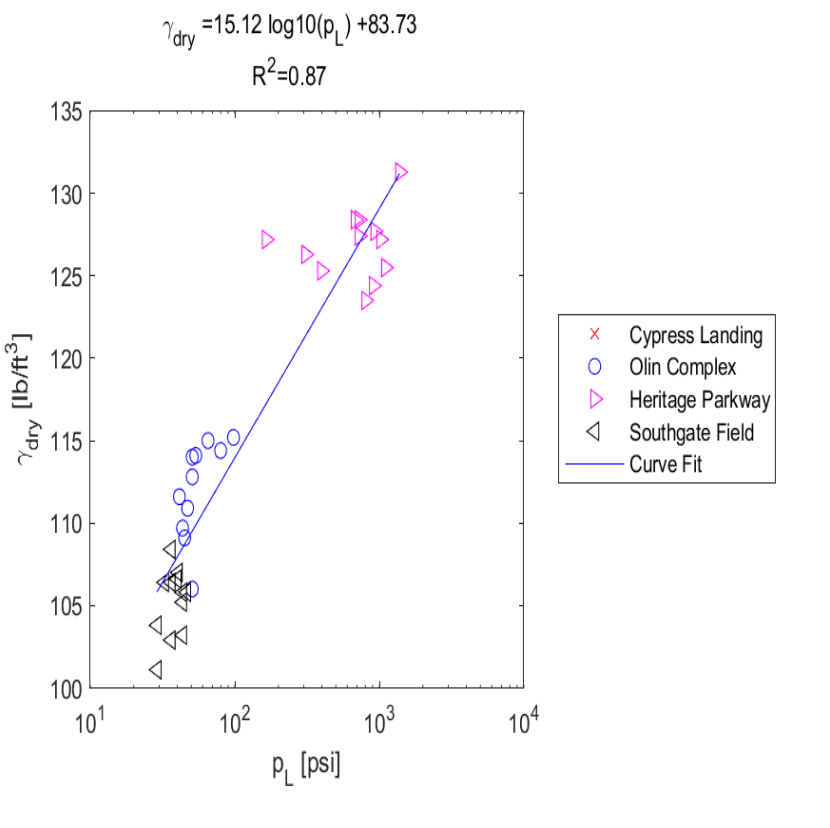


SDPMT-12 Incremental

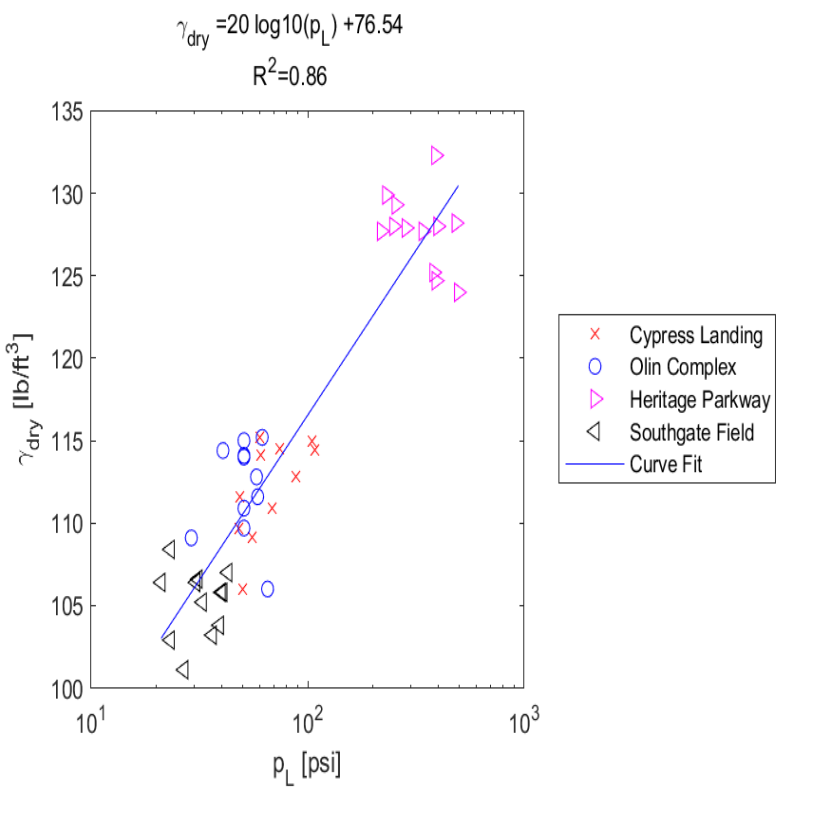


LOG-LINEAR MODELS OF γ_{DRY} VERSES P_L

SDPMT-6 Incremental



SDPMT-12 Incremental



CORRELATIONS WITH γ_{DRY}

- Conclusions for γ_{dry} and γ_{wet} verses E_0
  - Data collected during this research shows an excellent correlation with γ_{wet}, γ_{dry} and E_0 for all test configurations.
  - An logarithmic relationship exists between γ and E_0 for the incremental and continuous SDPMT test with both 6 and 12 inch probes.

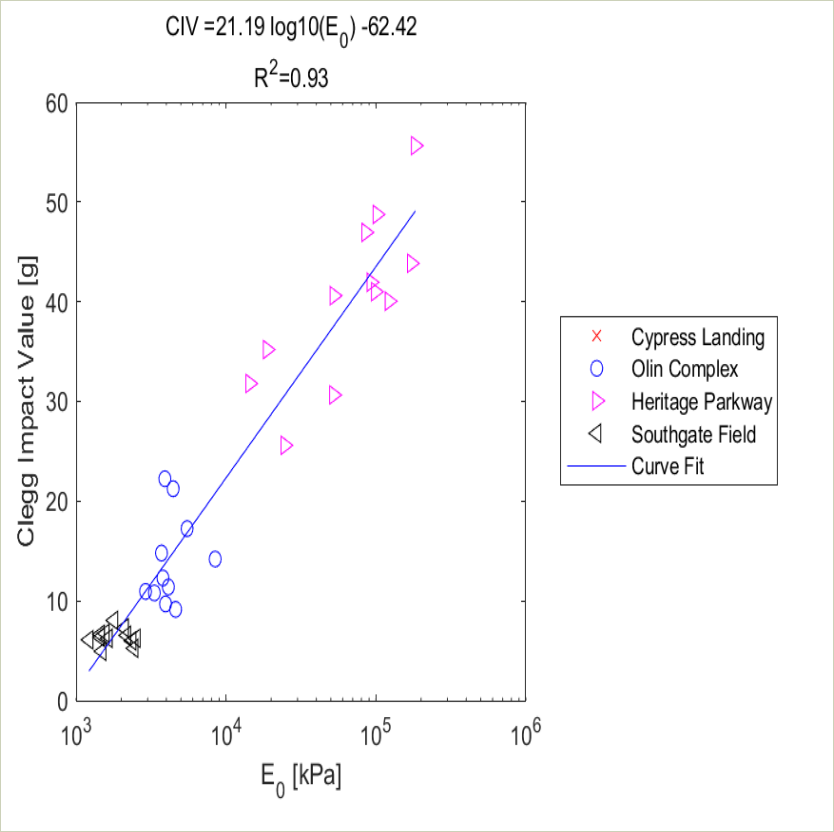
- Conclusions for γ_{dry} and γ_{wet} verses p_L
  - Data collected during this research shows an excellent correlation with γ_{wet}, γ_{dry} and p_L for all test configurations.
  - An logarithmic relationship exists between γ and p_L for the incremental and continuous SDPMT test with both 6 and 12 inch probes.

CLEGG IMPACT TEST COMPARISONS

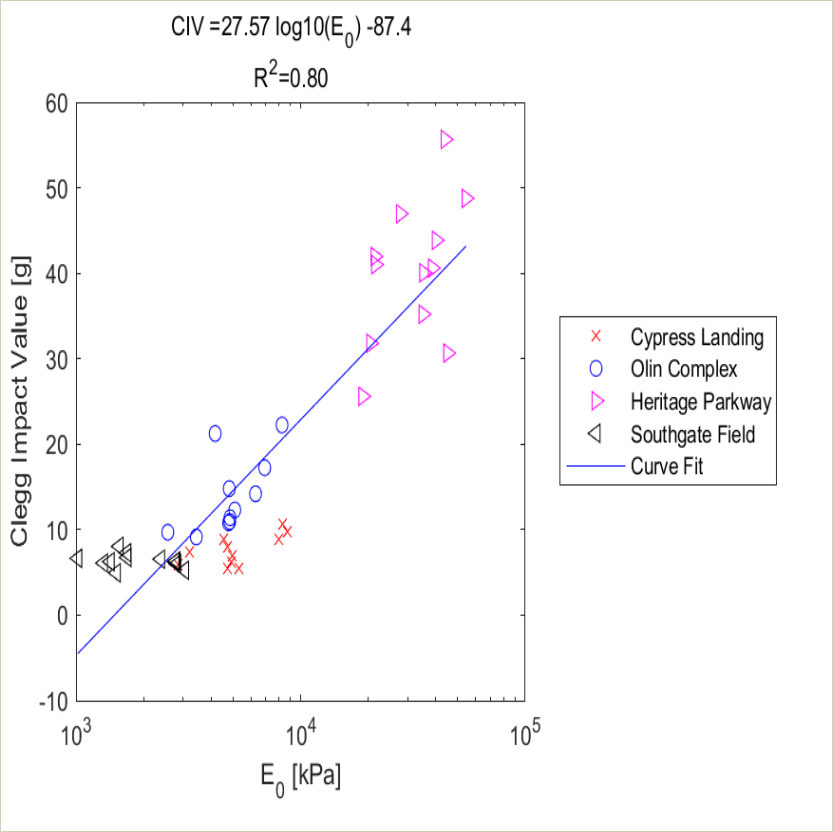
		Log-Linear	Linear-Log	log-linear	log-log	Exponential
CIV vs. E_0	6I	0.76	0.59	0.93	0.88	0.90
	6C	0.70	0.63	0.73	0.65	0.75
	12I	0.83	0.75	0.80	0.81	0.86
	12C	0.72	0.64	0.79	0.78	0.80
CIV vs. p_0	6I	0.12	0.08	0.15	0.12	0.14
	6C	0.28	0.26	0.39	0.34	0.37
	12I	0.49	0.45	0.44	0.37	0.51
	12C	0.04	0.09	0.17	0.24	0.15
CIV vs. p_L	6I	0.78	0.67	0.90	0.83	0.87
	6C	0.79	0.69	0.65	0.52	0.77
	12I	0.79	0.69	0.65	0.52	0.77
	12C	0.79	0.71	0.68	0.58	0.78

LOG-LINEAR MODELS OF CIV VERSES E_0

SDPMT-6 Incremental

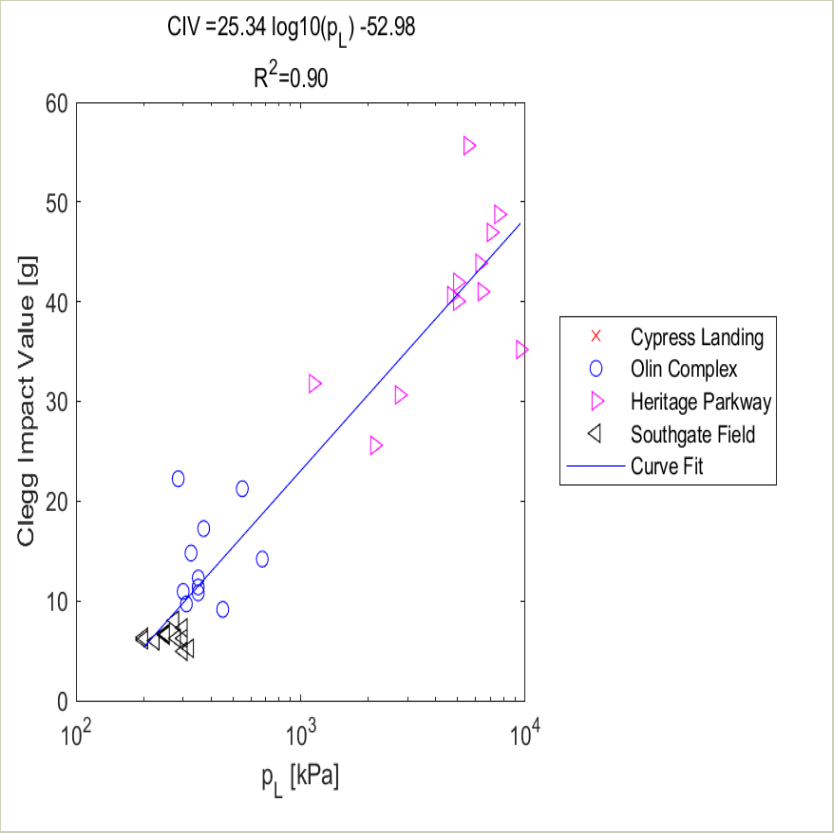


SDPMT-12 Incremental



LOG-LINEAR MODELS OF CIV VERSES P_L

SDPMT-6 Incremental



CIV CONCLUSIONS

- CIV verses SDPMT E_0
  - Data shows a good logarithmic correlation ($0.80 < R^2 > 0.93$) with the Clegg impact test value (CIV) and the SDPMT initial moduli (E_0) for 6 inch and 12 inch incremental tests.

- CIV verses SDPMT p_L
  - Data excellent logarithmic correlation ($R^2 = 0.90$) with the Clegg impact test value (CIV) and the SDPMT initial moduli (p_L) for 6 and 12 inch incremental tests.

LWD – DYNATEST COMPARISONS

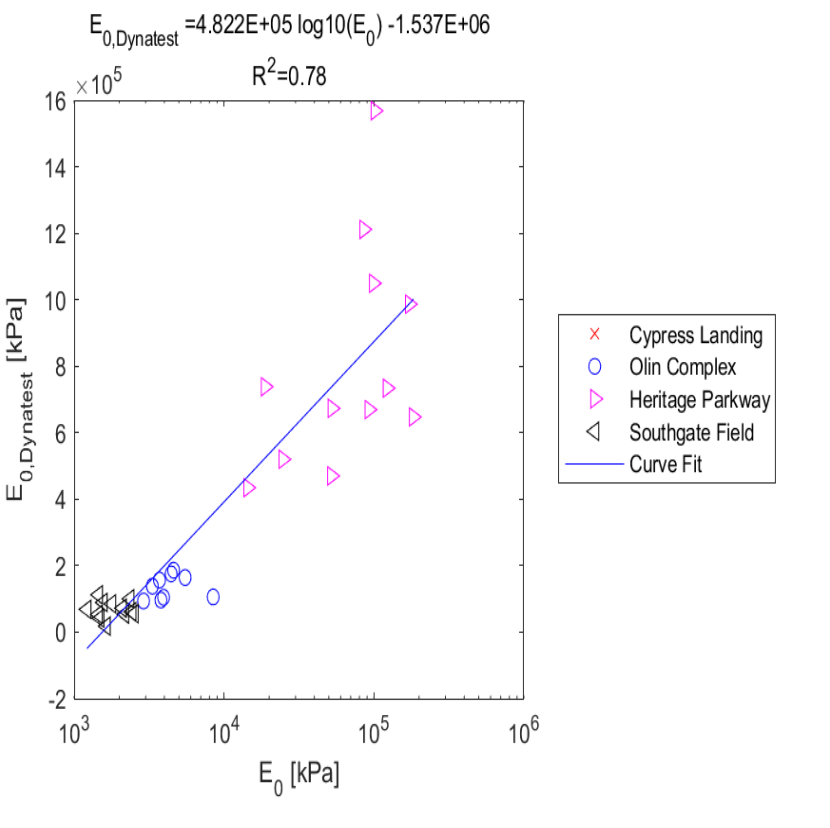
		Log-Linear	Linear-Log	log-linear	log-log	Exponential
$E_{d,zorn}$ vs. E_0	6I	0.63	0.55	0.89	0.86	0.82
	6C	0.83	0.69	0.85	0.72	0.87
	12I	0.81	0.70	0.83	0.83	0.86
	12C	0.78	0.63	0.82	0.73	0.86
$E_{d,zorn}$ vs. p_L	6I	0.79	0.69	0.93	0.86	0.88
	6C	0.88	0.75	0.76	0.61	0.88
	12I	0.83	0.71	0.86	0.80	0.86
	12C	0.88	0.74	0.79	0.64	0.88

LWD – ZORN COMPARISONS

		Log-Linear	Linear-Log	log-linear	log-log	Exponential
$E_{0,dyn}$ vs. E_0	6I	0.62	0.58	0.78	0.86	0.75
	6C	0.82	0.72	0.74	0.72	0.82
	12I	0.77	0.74	0.68	0.78	0.77
	12C	0.84	0.70	0.75	0.77	0.85
$E_{0,dyn}$ vs. p_L	6I	0.84	0.75	0.84	0.86	0.86
	6C	0.82	0.78	0.68	0.65	0.83
	12I	0.76	0.74	0.70	0.74	0.76
	12C	0.74	0.76	0.67	0.67	0.74

LOG-LINEAR CORRELATIONS, $E_{0,DYNATEST}$ VERSES E_0

SDPMT-6 Incremental



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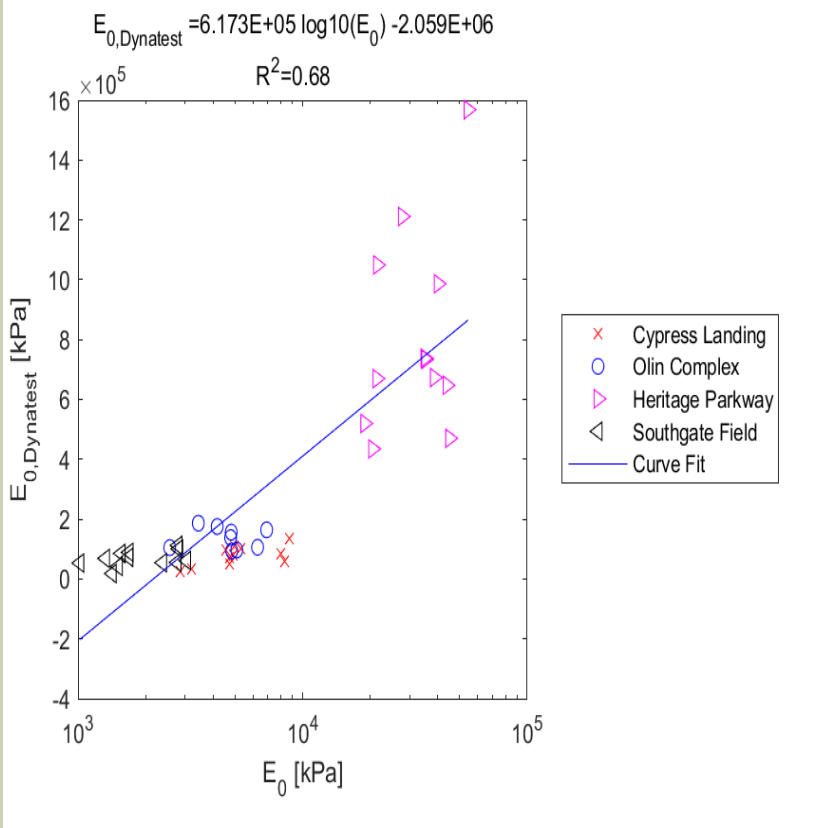
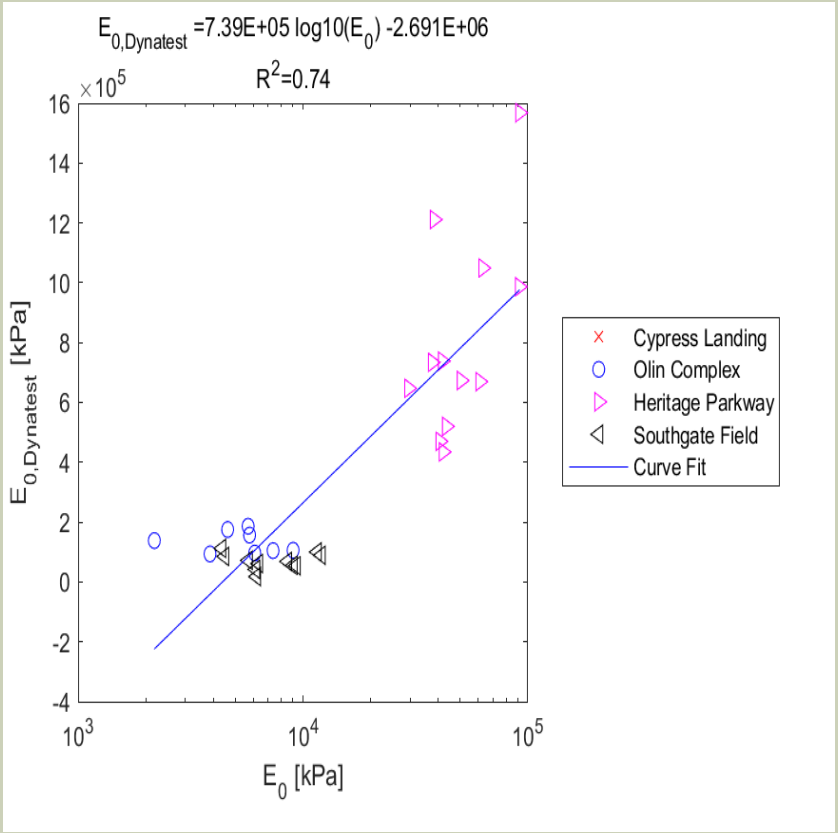
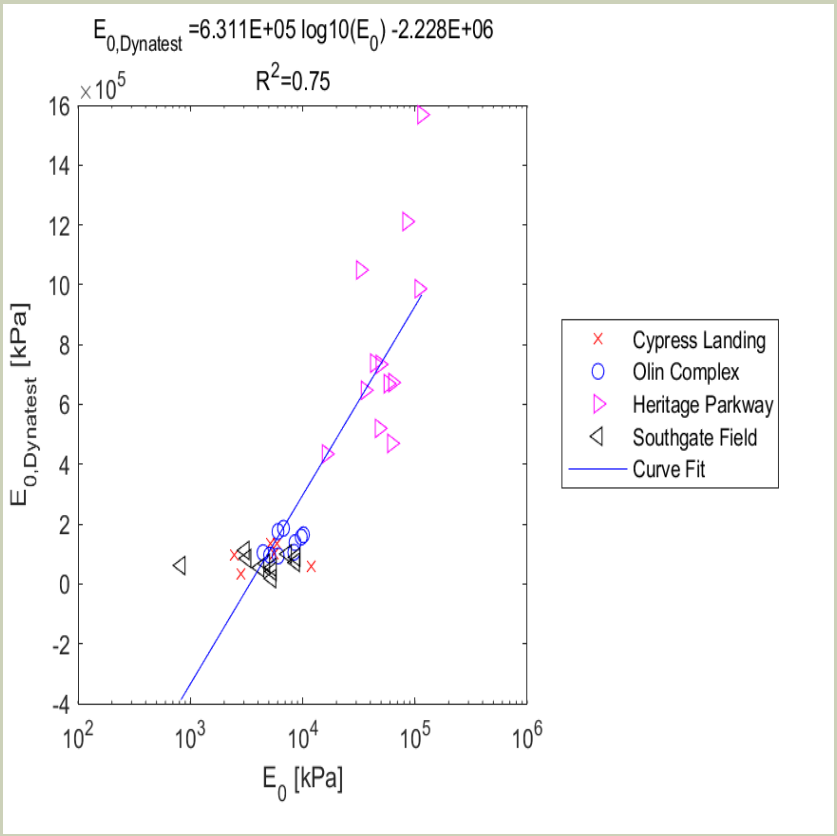


LOG-LINEAR CORRELATIONS, $E_{0,DYNATEST}$ VERSES E_0

SDPMT-6 Continuous

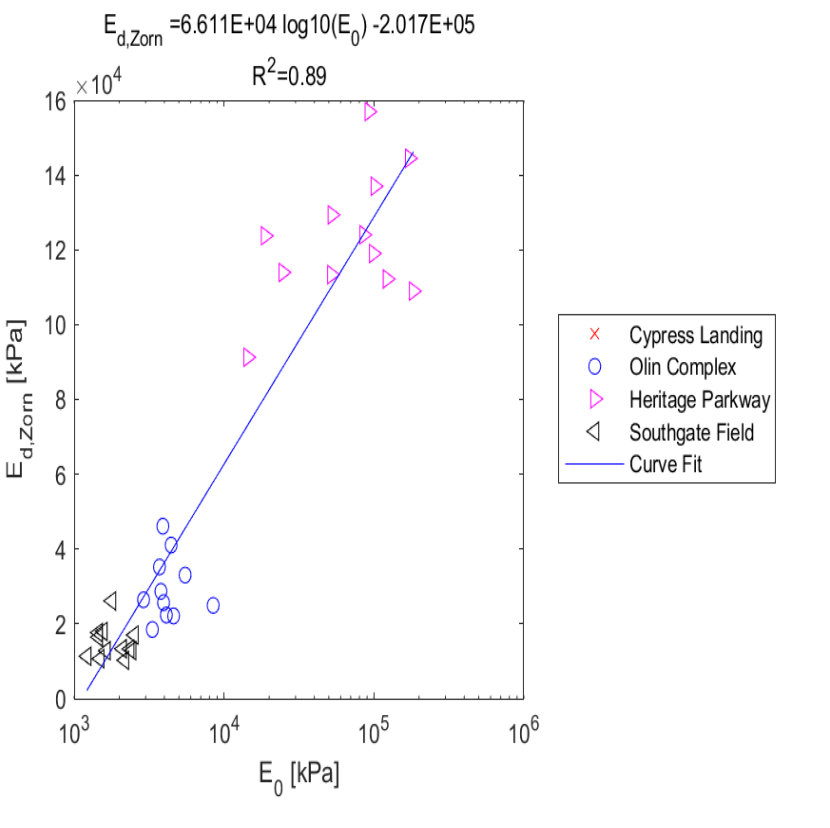


SDPMT-12 Continuous

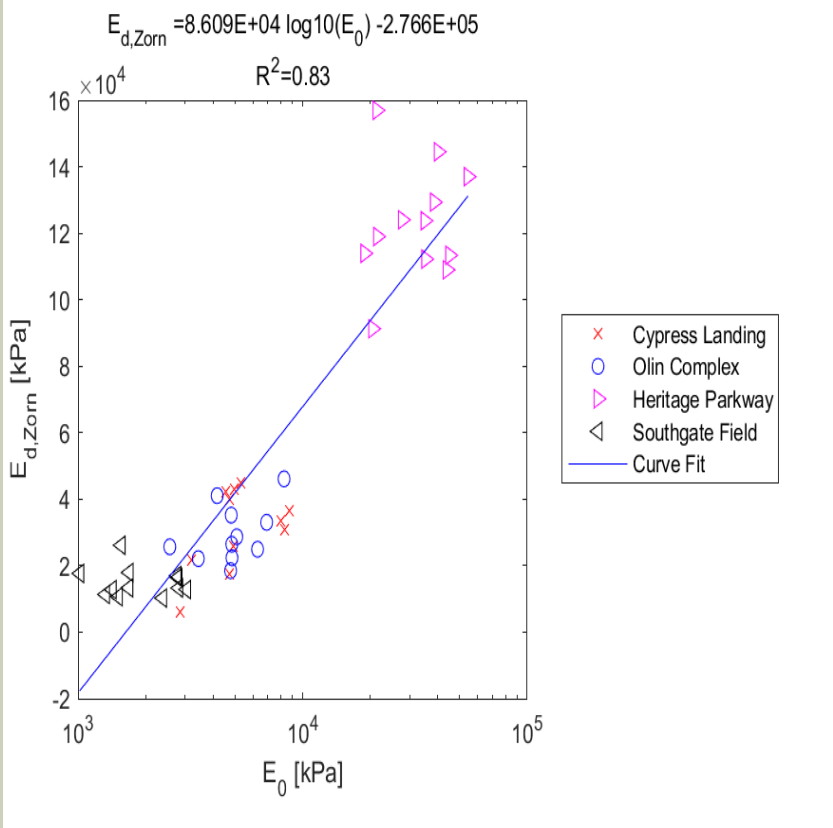


LOG-LINEAR CORRELATIONS, $E_{D,ZORN}$ VERSES E_0

SDPMT-6 Incremental

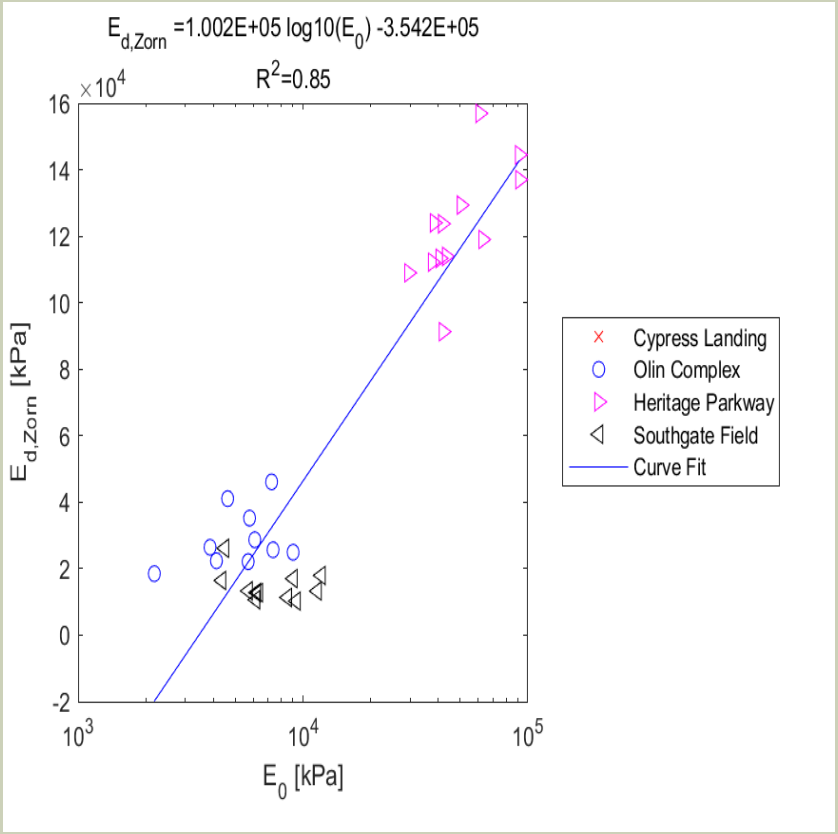


SDPMT-12 Incremental

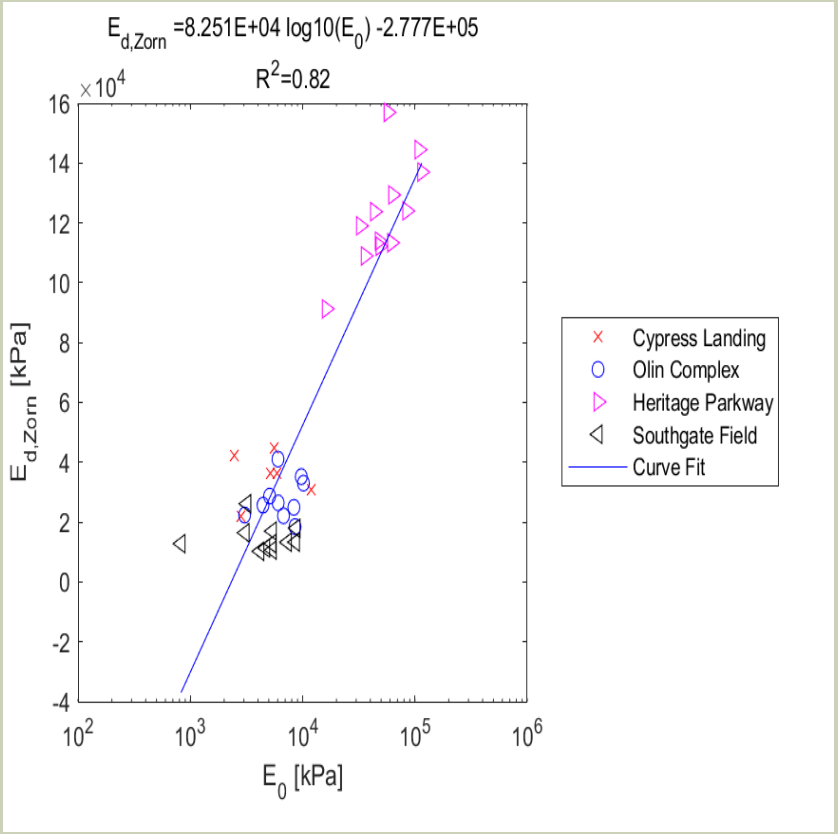


LOG-LINEAR CORRELATIONS, $E_{D,ZORN}$ VERSES E_0

SDPMT-6 Continuous

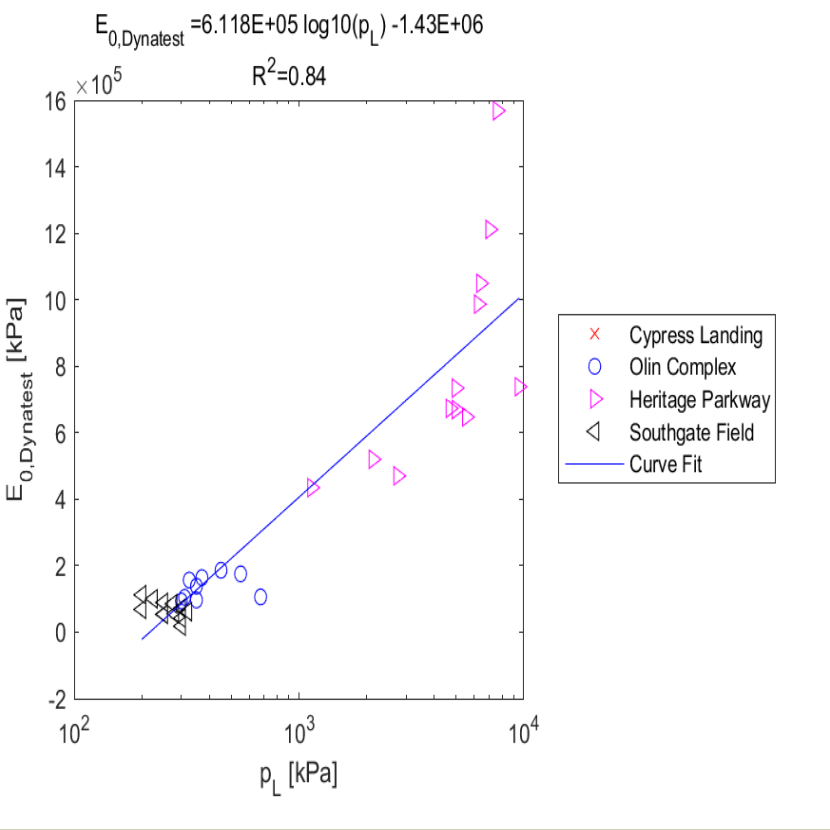


SDPMT-12 Continuous

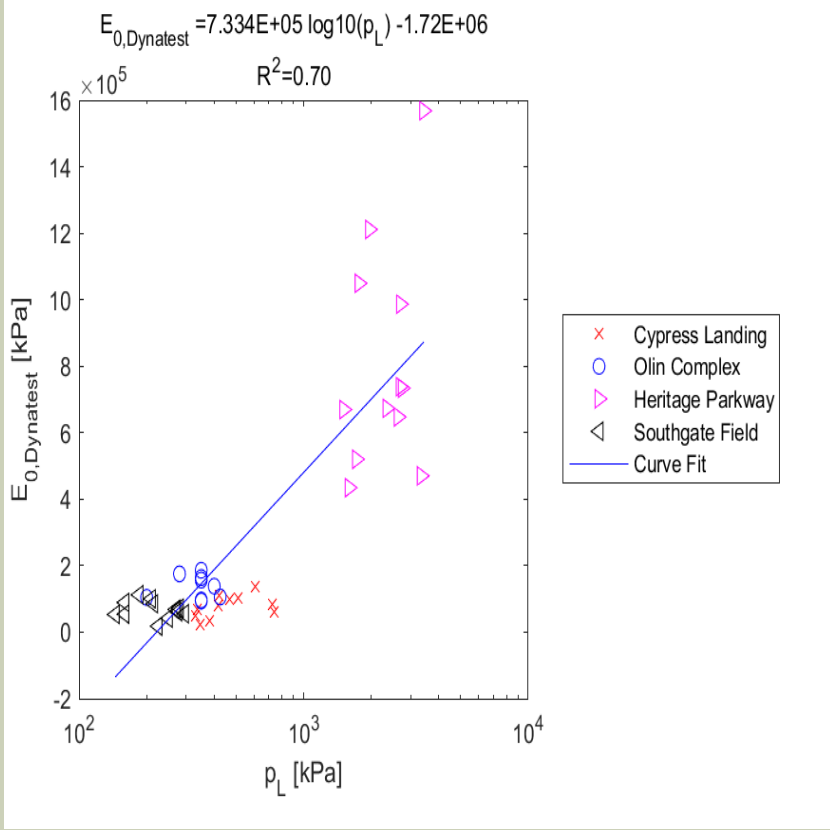


LOG-LINEAR CORRELATIONS, $E_{0,DYNATEST}$ VERSES P_L

SDPMT-6 Incremental

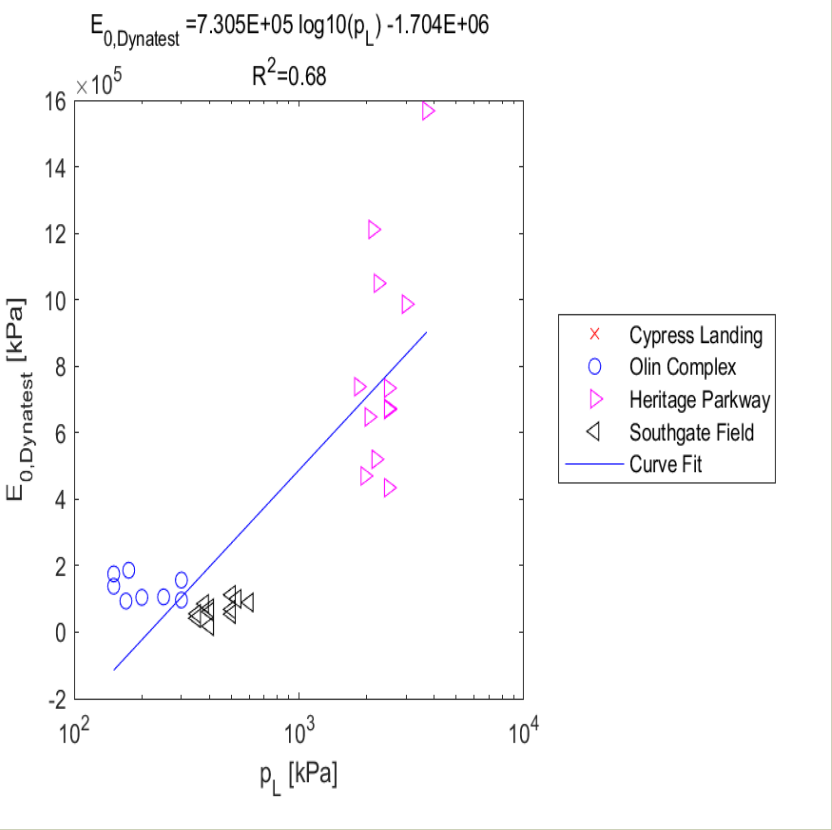


SDPMT-12 Incremental

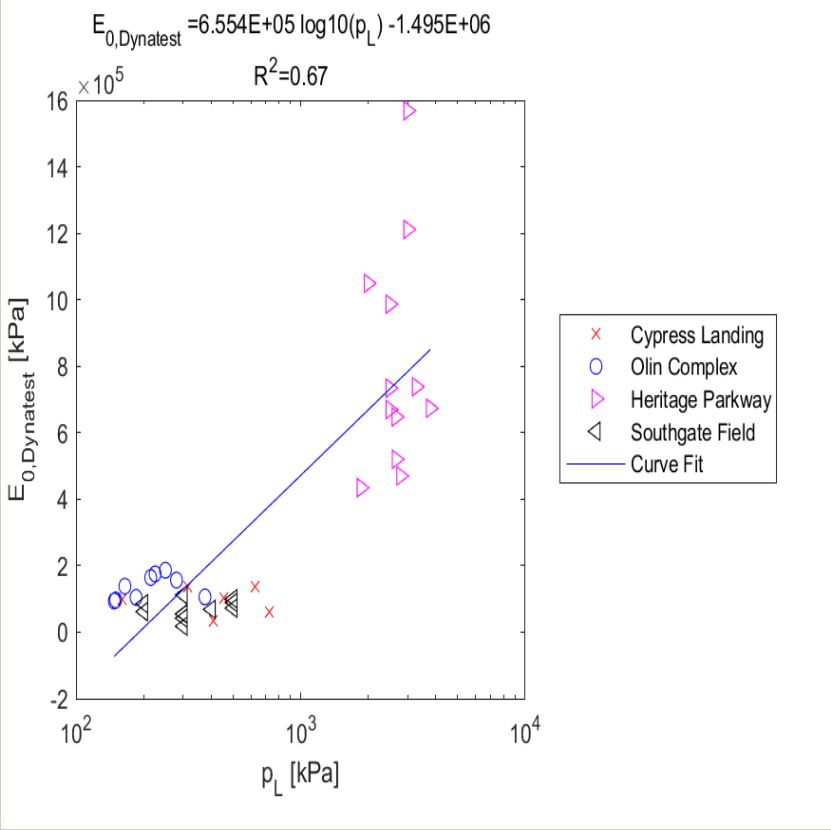


LOG-LINEAR CORRELATIONS, $E_{0,DYNATEST}$ VERSES P_L

SDPMT-6 Continuous



SDPMT-12 Continuous



LWD CONCLUSIONS

- Dynatest LWD E_0 verses SDPMT E_0
  - Data shows a good logarithmic correlation ($0.68 < R^2 > 0.75$) with the Dynatest LWD moduli (E_0) and initial moduli (E_0) for all SDPMT test configurations.

- Zorn LWD E_d verses E_0
  - Data shows an excellent logarithmic correlation with the Zorn LWD deformation moduli (E_d) and E_0 for all SDPMT test configurations.

SDPMT TO DCP COMPARISONS

		Log-Linear	Linear-Log	log-linear	log-log	Exponential
DCP vs. E_0	6I	0.57	0.58	0.68	0.69	0.65
	6C	0.16	0.13	0.16	0.13	0.16
	12I	0.38	0.34	0.47	0.38	0.48
	12C	0.14	0.15	0.13	0.13	0.12
DCP vs. p_0	6I	0.06	0.03	0.00	0.00	0.01
	6C	0.10	0.12	0.11	0.15	0.11
	12I	0.04	0.08	0.13	0.15	0.11
	12C	0.13	0.05	0.33	0.18	0.33
DCP vs. p_L	6I	0.34	0.34	0.39	0.40	0.39
	6C	0.64	0.62	0.67	0.65	0.64
	12I	0.19	0.10	0.29	0.17	0.36
	12C	0.13	0.28	0.20	0.26	0.17

DCP INDEX CONCLUSIONS

- Based on the data collected no correlation between the DCP Index and the SDPMT p_0, p_L or E_0 exists.

RECOMMENDATIONS

- Continued Development / Evaluation of Continuous Test Procedure
- Evaluation of the Use of Surcharge Weights to Evaluate Surface Cracking
- Evaluate Drill / Drive Method of Hole Construction

QUESTIONS ?